Part 5 Ship types

Chapter 7 Liquefied gas tankers
FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

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CHANGES – CURRENT

This is a new document.
The rules enter into force 1 January 2016.
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SECTION 1  GENERAL REQUIREMENTS

1 Introduction

1.1 Introduction

1.1.1 This chapter provides rules for safe carriage of the liquefied gases.

1.2 Scope

1.2.1 The scope of this chapter includes requirements applicable to tankers for liquefied gas, regardless of size.

1.3 Application

1.3.1 The requirements in 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.370(93).

**Guidance note:**
In the period before International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, IGC Code, Res. MSC.370(93) comes into force, the previous code International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, IGC Code, Res. MSC.5(48) with amendments should be applied. This will be handled on case by case basis.

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

1.3.2 The requirements in this chapter 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.

1.3.3 Machinery installations and their auxiliary systems that support cargo handling shall meet the same rule requirements as if they were considered to support a main function, see Pt.1 Ch.1 Sec.1.

1.3.4 List of products
The list of products in Sec.19 gives a summary of minimum requirements for each individual product. This list will be supplemented and adjusted by the Society as found necessary.

1.4 Class notations

1.4.1 Ship type notation

Table 1 Ship type notations

<table>
<thead>
<tr>
<th>Class notation</th>
<th>Description</th>
<th>Applications</th>
<th>Design requirements, rule reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tanker for liquefied gas</strong></td>
<td>ships designed for transportation of liquefied gas</td>
<td>mandatory for ships that shall transport products given in Sec.19</td>
<td>complete rule set</td>
</tr>
</tbody>
</table>
### 1.4.2 Additional notations

The following additional notations, as specified in Table 2, may be applicable. The following notations are particularly connected to liquefied gas cargo.

**Table 2 Additional class notations**

<table>
<thead>
<tr>
<th>Class notations</th>
<th>Description</th>
<th>Applications</th>
<th>Design requirements, rule reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGAS</td>
<td>ships designed for regasification operations.</td>
<td>all ships with regasification plant installed</td>
<td>Pt.6 Ch.4 Sec.8</td>
</tr>
<tr>
<td>Plus</td>
<td>extended fatigue analysis of ship details</td>
<td>all ships</td>
<td>Pt.6 Ch.1 Sec.6</td>
</tr>
<tr>
<td>CSA</td>
<td>direct analysis of ship structures</td>
<td>all ships</td>
<td>Pt.6 Ch.1 Sec.7</td>
</tr>
</tbody>
</table>

For full definition of all additional class notations, see Pt.1 Ch.2

### 1.4.3 Register information

Special features notations provide information regarding special features of the ship and will be stated in the register of vessels classed with the Society.

**Table 3 Register information**

<table>
<thead>
<tr>
<th>Technical features</th>
<th>Register information</th>
<th>Description</th>
<th>Design requirements, rule reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>ship type</td>
<td>ship type 1G</td>
<td>the damage stability standard in accordance with IMO’s international gas carrier code</td>
<td>Sec.2 [1]</td>
</tr>
<tr>
<td></td>
<td>ship type 2G</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ship type 2PG</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ship type 3G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>design parameters</td>
<td>temperature °C</td>
<td>the minimum and/or maximum acceptable temperature in the tank in °C</td>
<td></td>
</tr>
<tr>
<td>(specified in brackets)</td>
<td>density kg/m³</td>
<td>the maximum acceptable cargo density in kg/m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pressure MPa</td>
<td>maximum allowable relief valve setting, MARVS in MPa</td>
<td></td>
</tr>
<tr>
<td>fuel type</td>
<td>GF</td>
<td>gas fuelled after the requirements given this rule chapter</td>
<td>Sec.16</td>
</tr>
</tbody>
</table>
Guidance note:
A ship with class notation **Tanker for liquefied gas** and the following data may be recorded in the Register of vessels classed with the Society: **Ship type 2G (-163°C, 500 kg/m$^3$, 0.5 MPa) GF** which means that the ship is a type 2G ship according to IMO's International Gas Carrier Code, the lowest acceptable tank temperature is -163°C, maximum acceptable density of the cargo is 500 kg/m$^3$, MARVS is 0.5 MPa and Gas Fuelled

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

2 General

2.1 General

2.1.1 When cargo tanks contain products for which the chapter requires a type 1G ship, neither flammable liquids having a flashpoint of 60°C (closed cup test) or less, nor flammable products listed in Sec.19, shall be carried in tanks located within the protective zones described in Sec.2 [4.1.1].

2.1.2 Similarly, when cargo tanks contain products for which the chapter requires a type 2G/2PG ship, the flammable liquids as described in [2.1.1], shall not be carried in tanks located within the protective zones described in Sec.2 [4.1.2].

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

2.1.4 The flammable liquids and products described in [2.1.1] may be carried within these protective zones when the quantity of products retained in the cargo tanks, for which the chapter requires a type 1G or 2G/2PG ship is solely used for cooling, circulation or fuelling purposes.

2.1.5 When a ship is intended to operate for periods at a fixed location in a re-gasification and gas discharge mode or a gas receiving, processing, liquefaction and storage mode, the flag Administration and port Administrations involved in the operation shall take appropriate steps to ensure implementation of the provisions of this chapter as are applicable to the proposed arrangements. Furthermore, additional requirements shall be established based on the principles of this chapter as well as recognized standards that address specific risks not envisaged by it. Such risks may include, but not be limited to:

1) fire and explosion
2) evacuation
3) extension of hazardous areas
4) pressurized gas discharge to shore
5) high-pressure gas venting
6) process upset conditions
7) storage and handling of flammable refrigerants
8) continuous presence of liquid and vapour cargo outside the cargo containment system
9) tank over-pressure and under-pressure
10) ship-to-ship transfer of liquid cargo, and
11) collision risk during berthing manoeuvres.

Guidance note:
Note that ships intended for regasification operations are covered in the rules given in Pt.6 Ch.4 Sec.8 with notation **REGAS** as given in [2.1.2].

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

2.1.6 Where a risk assessment or study of similar intent is utilized within these rules, the results shall also include, but not be limited to, the following as evidence of effectiveness:
1) description of methodology and standards applied
2) potential variation in scenario interpretation or sources of error in the study
3) validation of the risk assessment process by an independent and suitable third party
4) quality system under which the risk assessment was developed
5) the source, suitability and validity of data used within the assessment
6) the knowledge base of persons involved within the assessment
7) system of distribution of results to relevant parties, and
8) validation of results by an independent and suitable third party.

2.2 Tank types

2.2.1 Design basis together with reference to the respective rule parts are given in Table 4.

Table 4 Tank type characteristics

<table>
<thead>
<tr>
<th>Tank type</th>
<th>Characteristics</th>
<th>Design requirements, rule reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>integral tanks</td>
<td>Integral tanks form a part of the ship's hull and are influenced by the hull load.</td>
<td>Sec.24 [1] (integral tanks)</td>
</tr>
<tr>
<td>membrane tanks</td>
<td>Membrane tanks consist of a thin membrane(s) supported through insulation by the adjacent hull structure. Thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.</td>
<td>Sec.23 (membrane tanks)</td>
</tr>
<tr>
<td>semi-membrane tanks</td>
<td>Semi-membrane tanks consist of a layer, partly supported through insulation by the adjacent hull structure, whereas rounded parts of the layer connecting the supported parts are designed to accommodate thermal and other expansion or contraction.</td>
<td>Sec.24 [2] (semi-membrane tanks)</td>
</tr>
<tr>
<td>independent tanks</td>
<td>Do not form part of the ship hull and is designed to minimise interaction forces on the tanks from hull deflection.</td>
<td>Sec.20 (prismatic tanks)</td>
</tr>
<tr>
<td>type A</td>
<td>Primarily designed using classical ship-structural analysis procedures in accordance with recognized standards.</td>
<td>Sec.20 (prismatic tanks)</td>
</tr>
<tr>
<td>type B</td>
<td>Designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics.</td>
<td>Sec.20 (prismatic tanks) or Sec.21 (spherical tanks)</td>
</tr>
<tr>
<td>type C</td>
<td>Pressure vessel design with a minimum design pressure $P_0$ is defined to ensure that stresses are predominantly of membrane type, and dynamic stresses are sufficiently low.</td>
<td>Sec.22 (cylindrical tanks)</td>
</tr>
</tbody>
</table>
## 3 Definitions

### 3.1 Terms

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>accommodation spaces</td>
<td><em>accommodation spaces</em> are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobby rooms, barber shops, pantries without cooking appliances and similar spaces</td>
</tr>
<tr>
<td>&quot;A&quot; class divisions</td>
<td>&quot;A&quot; class divisions are divisions as defined in regulation II-2/3.2 of the SOLAS Convention</td>
</tr>
<tr>
<td>air Lock</td>
<td>an air lock is an enclosed space for entrance between a hazardous area on open deck and a non-hazardous space, arranged to prevent ingress of gas to the non-hazardous space.</td>
</tr>
<tr>
<td>anniversary date</td>
<td><em>anniversary date</em> means the day and the month of each year that will correspond to the date of expiry of the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk</td>
</tr>
<tr>
<td>boiling point</td>
<td><em>boiling point</em> is the temperature at which a product exhibits a vapour pressure equal to the atmospheric pressure</td>
</tr>
<tr>
<td>breadth, B</td>
<td><em>breadth, B</em> means the maximum breadth of the ship, measured amidships to the moulded line of the frame in a hull with a metal shell, and to the outer surface of the hull in a ship with a shell of any other material. The breadth, B, shall be measured in metres, see also Pt.3 Ch.1 Sec.4 [2]</td>
</tr>
<tr>
<td>cargo area</td>
<td><em>cargo area</em> is that part of the ship which contains the cargo containment system and cargo pump and compressor rooms and includes the deck areas over the full length and breadth of the part of the ship over these 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 foremost hold space are excluded from the cargo area</td>
</tr>
<tr>
<td>cargo containment system</td>
<td><em>cargo containment system</em> 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</td>
</tr>
<tr>
<td>cargo control room</td>
<td><em>cargo control room</em> is a space used in the control of cargo handling operations and complying with the requirements of Sec.3 [4.1]</td>
</tr>
<tr>
<td>cargo machinery spaces</td>
<td><em>cargo machinery spaces</em> are the spaces where cargo compressors or pumps, cargo processing units, are located, including those supplying gas fuel to the engine-room</td>
</tr>
<tr>
<td>cargo process pressure vessels</td>
<td><em>cargo process pressure vessels</em> are process pressure vessels in the cargo handling plant, which during normal operations will contain cargo in the liquid and or gaseous phase. See Sec.5 [1.1.3] and Sec.5 [13.6]</td>
</tr>
<tr>
<td>cargo pumps</td>
<td><em>cargo pumps</em> are pumps used for the transfer of liquid cargo including main pumps, booster pumps, spray pumps, etc.</td>
</tr>
<tr>
<td>cargoes</td>
<td><em>cargoes</em> are products listed in Sec.19 that are carried in bulk by ships subject to this chapter</td>
</tr>
<tr>
<td>cargo service spaces</td>
<td><em>cargo service spaces</em> are spaces within the cargo area, used for workshops, lockers and store-rooms that are of more than 2 m$^2$ in area</td>
</tr>
<tr>
<td>Terms</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>cargo tank</td>
<td>cargo tank is the liquid-tight shell designed to be the primary container of the cargo and includes all such containment systems whether or not they are associated with the insulation or/and the secondary barriers</td>
</tr>
<tr>
<td>closed loop sampling</td>
<td>closed loop sampling is a cargo sampling system that minimizes the escape of cargo vapour to the atmosphere by returning product to the cargo tank during sampling</td>
</tr>
<tr>
<td>cofferdam</td>
<td>cofferdam is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.</td>
</tr>
<tr>
<td>control station</td>
<td>control stations are those spaces in which ship's radio, 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.</td>
</tr>
<tr>
<td>design temperature for cargo tanks</td>
<td>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.</td>
</tr>
<tr>
<td>design temperature for cargo piping</td>
<td>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</td>
</tr>
<tr>
<td>design temperature for secondary barrier</td>
<td>design temperature for a complete or partial secondary barrier is equal to the boiling point of the most volatile cargo</td>
</tr>
<tr>
<td>design vapour pressure (P)</td>
<td>design vapour pressure (P_0) for cargo tank is the maximum gauge pressure at the top of the tank which has been used in the design of the tank. See Sec.4 for the definition for each containment type.</td>
</tr>
<tr>
<td>design pressure (P_0)</td>
<td>design pressure (P_0) for cargo piping used to determine minimum scantlings of piping and piping system components. See Sec.5.</td>
</tr>
<tr>
<td>flammable products</td>
<td>flammable products are those identified by an “F” in column “f” in the table of Sec.19</td>
</tr>
<tr>
<td>flammability limits</td>
<td>flammability limits are the conditions defining the state of fuel-oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus</td>
</tr>
<tr>
<td>gas carrier</td>
<td>gas carrier is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in the table of Sec.19</td>
</tr>
<tr>
<td>gas combustion unit (GCU)</td>
<td>gas combustion unit (GCU) is a means of disposing excess cargo vapour by thermal oxidation</td>
</tr>
<tr>
<td>gas consumer</td>
<td>gas consumer is any unit within the ship using cargo vapour as a fuel.</td>
</tr>
<tr>
<td>gauging device</td>
<td>gauging device is meant an arrangement for determining the amount of cargo in tanks. See Sec.13 [2.1].</td>
</tr>
</tbody>
</table>
Terms | Definition
---|---
hazardous area | is an area in which an explosive gas atmosphere is, or may be expected to be present, in quantities that require special precautions for the construction, installation and use of electrical equipment. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity, reactivity and low temperature. These hazards shall also be taken into account and additional precautions for the ventilation of spaces and protection of the crew will need to be considered. Examples of hazardous areas include, but are not limited to, the following with detailed requirements given in section 10:
.1 the interiors of cargo containment systems and any pipework of pressure-relief or other venting systems for cargo tanks, pipes and equipment containing the cargo
.2 interbarrier spaces
.3 hold spaces where the cargo containment system requires a secondary barrier
.4 hold spaces where the cargo containment system does not require a secondary barrier
.5 a space separated from a hold space by a single gastight steel boundary where the cargo containment system requires a secondary barrier
.6 cargo machinery spaces
.7 areas on open deck, or semi-enclosed spaces on open deck, within 3 m of possible sources of gas release, such as cargo valve, cargo pipe flange, cargo machinery space ventilation outlet, etc.
.8 areas on open deck or semi-enclosed spaces on open deck within 1.5 m of cargo machinery space entrances, cargo machinery space ventilation inlets
.9 areas on open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck up to a height of 2.4 m above the weather deck
.10 an area within 2.4 m of the outer surface of a cargo containment system where such surface is exposed to the weather
.11 enclosed or semi-enclosed spaces in which pipes containing cargoes are located, except those where pipes containing cargo products for boil-off gas fuel burning systems are located
.12 an enclosed or semi-enclosed space having a direct opening into any hazardous area
.13 void spaces, cofferdams, trunks, passageways and enclosed or semi-enclosed spaces, adjacent to, or immediately above or below, the cargo containment system areas on open deck or semi-enclosed spaces on open deck above and in the vicinity of any vent riser outlet, 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, and
.14 areas on open deck within spillage containment surrounding cargo manifold valves and 3 m beyond these up to a height of 2.4 m above deck

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---

Non-hazardous area | non-hazardous area is an area other than a hazardous area, i.e. gas safe

hold space | is the space enclosed by the ship’s structure in which a cargo containment system is situated

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>independent</td>
<td><em>independent</em> means that a piping or venting system, for example, is in no way connected to another system and that there are no provisions available for the potential connection to other systems</td>
</tr>
<tr>
<td>insulation space</td>
<td><em>insulation space</em> is the space, which may or may not be an interbarrier space, occupied wholly or in part by insulation</td>
</tr>
<tr>
<td>length, $L_{LL}$</td>
<td>$length, L_{LL}$ is the freeboard length as defined in the International Convention on Load Lines in force, see also Pt.3 Ch.1 Sec.4 [2]</td>
</tr>
<tr>
<td>liquefied gas</td>
<td><em>liquefied gas</em> is a cargo with a vapour pressure equal to or above 0.28 MPa absolute at 37.8°C.</td>
</tr>
<tr>
<td>machinery spaces of category A</td>
<td><em>machinery spaces of category A</em> are those spaces, and trunks to those spaces, which contain either:</td>
</tr>
<tr>
<td></td>
<td>.1  internal combustion machinery used for main propulsion, or</td>
</tr>
<tr>
<td></td>
<td>.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</td>
</tr>
<tr>
<td></td>
<td>.3  any oil-fired boiler or oil fuel unit or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.</td>
</tr>
<tr>
<td>machinery space</td>
<td><em>machinery spaces</em> are machinery spaces of category A and other spaces containing propelling machinery, boilers, oil fuel units, steam and internal-combustion generators, engines, and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces and the trunks to such spaces</td>
</tr>
<tr>
<td>MARVS</td>
<td>MARVS is the maximum allowable relief valve setting of a cargo tank (gauge pressure)</td>
</tr>
<tr>
<td>nominated surveyor</td>
<td>nominated surveyor is a surveyor nominated/appointed by an Administration to enforce the provisions of the SOLAS convention regulations with regard to inspections and surveys and the granting of exemptions therefrom</td>
</tr>
<tr>
<td>non-cargo process pressure vessels</td>
<td><em>non-cargo process pressure vessels</em> 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.</td>
</tr>
<tr>
<td>oil fuel unit</td>
<td><em>oil fuel unit</em> 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 0.18 MPa gauge</td>
</tr>
<tr>
<td>organization</td>
<td><em>organization</em> is the International Maritime Organization (IMO)</td>
</tr>
<tr>
<td>permeability of a space</td>
<td><em>permeability of a space</em> means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space</td>
</tr>
<tr>
<td>port administration</td>
<td><em>port administration</em> means the appropriate authority of the country for the port where the ship is loading or unloading</td>
</tr>
<tr>
<td>pressure relief valves PRV</td>
<td><em>pressure relief valve PRV</em> denotes a safety valve which opens at a given internal pressure above atmospheric pressure. See Sec.8</td>
</tr>
<tr>
<td>primary barrier</td>
<td><em>primary barrier</em> is the inner element designed to contain the cargo when the cargo containment system includes two boundaries.</td>
</tr>
<tr>
<td>Terms</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>products</strong></td>
<td><em>products</em> are the collective term used to cover the list of gases indicated in Sec.19 of this chapter</td>
</tr>
<tr>
<td><strong>public spaces</strong></td>
<td><em>public spaces</em> are those portions of the accommodation that are used for halls, dining rooms, lounges and similar permanently enclosed spaces</td>
</tr>
<tr>
<td><strong>recognized organization</strong></td>
<td><em>recognized organization</em> is an organization authorized by an Administration in accordance with SOLAS regulation XI-1/1 to act on its behalf</td>
</tr>
<tr>
<td><strong>recognized standards</strong></td>
<td><em>recognized standards</em> are applicable international or national standards acceptable to the Administration, or standards laid down and maintained by the recognized organization</td>
</tr>
<tr>
<td><strong>relative density</strong></td>
<td><em>relative density</em> is the ratio of the mass of a volume of a product to the mass of an equal volume of fresh water.</td>
</tr>
<tr>
<td><strong>secondary barrier</strong></td>
<td><em>secondary barrier</em> 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. Types of secondary barrier are more fully defined in Sec.4.</td>
</tr>
<tr>
<td><strong>separate systems</strong></td>
<td><em>separate systems</em> are those cargo piping and vent systems that are not permanently connected to each other</td>
</tr>
<tr>
<td><strong>service spaces</strong></td>
<td><em>service spaces</em> are those 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</td>
</tr>
<tr>
<td><strong>SOLAS convention</strong></td>
<td><em>SOLAS convention</em> means the International Convention for the Safety of Life at Sea, 1974, as amended</td>
</tr>
<tr>
<td><strong>spaces not normally entered</strong></td>
<td><em>spaces not normally entered</em> are cofferdams, double bottoms, duct keels, pipe tunnels, stool tanks, spaces containing cargo tanks and other spaces where cargo may accumulate. See Sec.12 [2].</td>
</tr>
<tr>
<td><strong>steel significant temperature</strong></td>
<td><em>steel significant temperature</em> is the calculated temperature in the hull structures, tank fundaments and tank supports 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.4 [5.1.1] and Sec.4 [5.1.2].</td>
</tr>
<tr>
<td><strong>tank cover</strong></td>
<td><em>tank cover</em> is the protective structure intended to either 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</td>
</tr>
</tbody>
</table>
Part 5 Chapter 7 Section 1

### Terms

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>tank dome</td>
<td>tank dome is the upward extension of a portion of a cargo tank. In the case of below-deck cargo containment systems, the tank dome protrudes through the weather deck or through a tank cover</td>
</tr>
<tr>
<td>thermal oxidation</td>
<td>thermal oxidation method means a system where the boil-off vapours are utilized as fuel for shipboard use or as a waste heat system subject to the provisions of Sec.16 or a system not using the gas as fuel complying with this chapter</td>
</tr>
<tr>
<td>toxic products</td>
<td>toxic products are those defined by a &quot;T&quot; in column &quot;F&quot; in the table of Sec.19</td>
</tr>
<tr>
<td>turret compartments</td>
<td>turret compartments are those spaces and trunks that contain equipment and machinery for retrieval and release of the disconnectable turret mooring system, high-pressure hydraulic operating systems, fire protection arrangements and cargo transfer valves</td>
</tr>
<tr>
<td>vacuum relief valve</td>
<td>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. See Sec.8.</td>
</tr>
<tr>
<td>vapour pressure</td>
<td>vapour pressure is the equilibrium pressure of the saturated vapour above the liquid, expressed in Pascal (Pa) absolute at a specified temperature</td>
</tr>
<tr>
<td>void space</td>
<td>void space is an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, oil fuel tank, cargo pumps or compressor room, or any space in normal use by personnel</td>
</tr>
</tbody>
</table>

### 3.2 Symbols

For symbols not defined in this chapter, refer to Pt.3 Ch.1 Sec.4.

- $T_{\text{MIN}} = \text{min. relevant seagoing draught in m}$
- $T_{\text{DAM}} = \text{damaged draught from damage stability calculation in m}$
- $h = \text{usage factor}$
- $R_m = \text{the specified minimum tensile strength at room temperature in N/mm}^2$. For welded connections in aluminium alloys the tensile strength in annealed condition shall be used, see also Sec.4 [4.3.2].
- $R_{\text{elH}} = \text{the specified minimum upper yield stress at room temperature in N/mm}^2$. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies, see also Sec.4 [4.3.2].
- $R_{\text{elH,0.2}} = \text{the specified minimum 0.2% proof stress at room temperature in N/mm}^2$. For welded connections in aluminium alloys the 0.2% proof stress in annealed condition shall be used, see also Sec.4 [4.3.2].
- $LT = \text{material grade intended for low temperature service.}$
- $UDW = \text{Ultimate Design Wave determined by direct hydrodynamic wave load analysis. The UDW returns the same long term load level as spectral analysis and corresponds to a probability level } 10^{-8} \text{ in North Atlantic wave environment.}$
- $FDW = \text{Fatigue Design Wave determined by direct hydrodynamic wave load analysis. The FDW returns the same long term load level as spectral analysis and corresponds to a probability level } 10^{-2} \text{ in North Atlantic wave environment.}$
## 4 Documentation

### 4.1 Documentation requirements

Documentation shall be submitted as required by **Table 6**.

**Table 6 Documentation requirements - Liquefied gas tankers**

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>damage stability</td>
<td>I200 - Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>B070 – Preliminary damage stability calculation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>B130 – Final damage stability calculation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>fuel gas system</td>
<td>I200 - Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S010 – Piping diagram (PD)</td>
<td>from master gas valve in cargo area to consumer, including vent arrangement</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>details of installation for preparations of gas before combustion</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z060 – Functional description</td>
<td>applicable for novel gas fuel designs or for ships with gas only installation</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z030 – Arrangement plan</td>
<td>gas piping, gastight boiler casing with funnel, ventilation, gas valve train and other items necessary for the fuel gas handling</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>G130 – Cause and effect diagram</td>
<td>including all items that gives alarm and automatic shutdown</td>
<td>AP</td>
</tr>
<tr>
<td>bilge water control and monitoring system</td>
<td>Z030 – Arrangement plan</td>
<td>sensors in hold spaces and secondary insulation spaces</td>
<td>AP</td>
</tr>
<tr>
<td>hazardous areas classification</td>
<td>G080 – Hazardous area classification drawing</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>explosion (Ex) protection</td>
<td>E170 – Electrical schematic drawing</td>
<td>single line diagrams for all intrinsically safe circuits, for each circuit including data for verification of the compatibility between the barrier and the field components</td>
<td>AP</td>
</tr>
<tr>
<td>Object</td>
<td>Documentation type</td>
<td>Additional description</td>
<td>Info</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------</td>
<td>------------------------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>Z030 – Arrangement plan</td>
<td>electrical equipment in hazardous areas. Where relevant, based on an approved 'Hazardous area classification drawing' where location of electric equipment in hazardous area is added (except battery room, paint stores and gas bottle store)</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z250 – Explosion protected equipment maintenance manual</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>inert gas system</td>
<td>Z030 – Arrangement plan</td>
<td>shows all details including — inert gas plant — cooling and cleaning devices — non-return devices — pressure vacuum devices — inert gas distribution piping</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>I200 – Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S010 – Piping diagram (PD)</td>
<td>including drying and backflow prevention arrangements</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z161 – Operational manual</td>
<td>can be part of operation manual required by Sec.18 [1]. See also Sec.9 [2.1]</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>S010 – Piping diagram (PD)</td>
<td>inerting, purging and gas freeing of cargo tanks and hold spaces</td>
<td>AP</td>
</tr>
<tr>
<td>emergency shut down system</td>
<td>I200 – Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>G130 – Cause and effect diagram</td>
<td>including all items that gives alarm and automatic shutdown. Can include both cargo handling and fuel.</td>
<td>AP</td>
</tr>
<tr>
<td>hydrocarbon gas detection and alarm system, fixed</td>
<td>I200 – Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z030 – Arrangement plan</td>
<td>detectors, call points and alarm devices</td>
<td>AP</td>
</tr>
<tr>
<td>fire water system</td>
<td>S010 – Piping diagram (PD)</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S030 – Capacity analysis</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z030 – Arrangement plan</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>cargo tank deck fire extinguishing system</td>
<td>G200 – Fixed fire extinguishing system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>cargo handling spaces fire extinguishing system</td>
<td>G200 – Fixed fire extinguishing system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>external surface protection water-spray system</td>
<td>G200 – Fixed fire extinguishing system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>Object</td>
<td>Documentation type</td>
<td>Additional description</td>
<td>Info</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>--------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>ventilation systems for cargo handling spaces</td>
<td>Z030 – Arrangement plan</td>
<td>including gas safe spaces and air locks in cargo area</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>fans</td>
<td>FI</td>
</tr>
<tr>
<td>cargo handling spaces</td>
<td>C030 – Detailed drawing</td>
<td>gas tight bulkhead shaft penetrations</td>
<td>AP</td>
</tr>
<tr>
<td>cargo handling arrangement</td>
<td>Z254 – Commissioning procedure</td>
<td>gas trial program for complete cargo system including tank</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z161 – Operational manual</td>
<td>covers items given in Sec.18</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>filling limits of cargo tanks</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S030 – Capacity analysis</td>
<td>BOG handling</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S010 - Piping diagram (PD)</td>
<td>P&amp;ID auxiliary systems like glycol, steam, lube oil, etc.</td>
<td>AP</td>
</tr>
<tr>
<td>cargo piping system</td>
<td>S010 – Piping diagram (PD)</td>
<td>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</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S070 – Pipe stress analysis</td>
<td>when design temperature is below – 110° C</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>S090 – Specification of pipes, valve, flanges and fittings</td>
<td>including non-destructive testing specification. In addition also flame screen, if fitted</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z030 – Arrangement plan</td>
<td>protection of hull against cryogenic leakage in way of loading manifolds</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>liquid relief valves</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>insulation including arrangement, if fitted</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z254 – Commissioning procedure</td>
<td>gas trial program for complete cargo system including cargo tanks preferable done at yard.</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z254 – Commissioning procedure</td>
<td>function tests and capacity tests of the cargo system</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z161 – Operational manual</td>
<td>covers items given in Sec.18 including filling limit</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S030 – Capacity analysis</td>
<td>boil of gas handling</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S010 - Piping diagram (PD)</td>
<td>auxiliary systems like glycol, steam, lubrication oil, etc.</td>
<td>AP</td>
</tr>
<tr>
<td>vapour handling system (boil-off handling)</td>
<td>I200 – Control and monitoring system documentation</td>
<td>gas combustion unit</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S010 - Piping diagram (PD)</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>Object</td>
<td>Documentation type</td>
<td>Additional description</td>
<td>Info</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------</td>
<td>------------------------</td>
<td>------</td>
</tr>
<tr>
<td>cargo valves control and monitoring system</td>
<td>I200 – Control and monitoring system documentation</td>
<td>shows all tank details including — complete tank with internal structure and bulkheads — secondary barrier, if fitted — access for inspection — support arrangement with anti-float/roll — tank insulation — dome arrangement including tank connections — pump tower arrangement</td>
<td>AP</td>
</tr>
<tr>
<td>cargo compartments (general requirements for all tanks)</td>
<td>Z030 – Arrangement plan</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>H131 – Non-destructive testing (NDT) plan</td>
<td>welds</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>M010 – Material specification, metals</td>
<td>including internal structures and piping</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>M060 – Welding procedures (WPS)</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>P030 - Temperature calculations</td>
<td>hull steel temperature when cargo temperature is below -10°C</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z265 – Calculation report</td>
<td>boil-off calculation</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z265 – Calculation report</td>
<td>vibration analysis, if relevant</td>
<td>FI</td>
</tr>
<tr>
<td>cargo independent tank arrangements type A</td>
<td>H050 – Structural drawing</td>
<td>support and anti-flotation arrangement</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>H080 – Strength analysis</td>
<td>including: — interaction between hull and tanks — partial filling, if applicable — cooling-down condition, when cargo temperature is below -55°C</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>S010 – Piping diagram (PD)</td>
<td>hold spaces drainage arrangement</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z161 – Operation manual</td>
<td>cooling-down procedure for tanks with design temperature below -55°C</td>
<td>AP</td>
</tr>
<tr>
<td>cargo independent tank arrangements type B</td>
<td>H050 – Structural drawing</td>
<td>support and anti-flotation arrangement</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>H080 – Strength analysis</td>
<td>including: — interaction between hull and tanks — partial filling, if applicable — cooling-down condition, when cargo temperature is below -55°C</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z161 – Operation manual</td>
<td>cooling-down procedure</td>
<td>AP</td>
</tr>
<tr>
<td>Object</td>
<td>Documentation type</td>
<td>Additional description</td>
<td>Info</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------</td>
<td>------------------------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>Z100 – Specification</td>
<td>small leak protection system, including arrangement</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>S010 – Piping diagram (PD)</td>
<td>nitrogen purging system for insulation spaces</td>
<td>AP</td>
</tr>
<tr>
<td>cargo independent tank arrangements type C</td>
<td>H050 – Structural drawing</td>
<td>support and anti-flotation arrangement</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>H080 – Strength analysis</td>
<td>prescriptive stress analysis</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z252 – Test procedure at manufacture</td>
<td>stress relieving procedures, thermal or mechanical</td>
<td>AP</td>
</tr>
</tbody>
</table>
|        | H080 – Strength analysis | including:  
| | | — finite element analysis of highly stressed tank areas, for e.g. multi-lobe and vacuum insulated tanks  
| | | — interaction between hull and tanks  
| | | — partial filling, if applicable  
| | | — cooling-down condition, when cargo temperature is below -55° C | FI |
| cargo membrane tanks | H050 – Structural drawing | pump tower and its supports | AP |
|        | H080 – Strength analysis | including:  
| | | — strength and fatigue assessment of pump towers and bottom supports  
| | | — partial filling, if applicable  
<p>| | | — cooling-down condition, when cargo temperature is below -55° C | FI |
|        | S010 – Piping diagram (PD) | nitrogen purging system for insulation spaces | AP |
|        | S010 – Piping diagram (PD) | water drainage arrangement for secondary insulation space | AP |
|        | Z030 – Arrangement plan | building principle including location of insulation boxes of different strength rating | AP |
|        | Z100 – Specification | insulation including load bearing capacities | AP |
|        | Z100 – Specification | load bearing components | AP |
|        | Z100 – Specification | materials for membranes and insulation | AP |
|        | Z251 – Test procedure | tightness test of primary and secondary membranes | AP |</p>
<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z251 – Test procedure</td>
<td>strength and tightness test of adjacent ballast tanks</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>Z250 – Procedure</td>
<td>bonding handbook, if secondary barrier is bonded</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>Z250 – Procedure</td>
<td>repair</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>Z250 – Procedure</td>
<td>erection handbook</td>
<td>FI</td>
<td></td>
</tr>
<tr>
<td>Z100 – Specification</td>
<td>reference list of generic approved documents, if applicable</td>
<td>FI</td>
<td></td>
</tr>
<tr>
<td>Z265 – Calculation report</td>
<td>vibration analysis</td>
<td>FI</td>
<td></td>
</tr>
<tr>
<td>cargo compartments over- and under-pressure prevention arrangements</td>
<td>Z100 – Specification</td>
<td>relief valves for hold spaces and interbarrier spaces</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z265 – Calculation report</td>
<td>required cargo tank relief valve capacity</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z250 – Procedure</td>
<td>changing of set pressures of cargo tank safety relief valves, if applicable</td>
<td>FI</td>
</tr>
<tr>
<td>cargo tanks level monitoring system</td>
<td>I200 – Control and monitoring system documentation</td>
<td>testing procedure including intervals between recalibration</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>I260 – Plan for periodic test of field instruments</td>
<td>testing procedure including intervals between recalibration</td>
<td>FI</td>
</tr>
<tr>
<td>cargo tanks overflow protection system</td>
<td>I200 – Control and monitoring system documentation</td>
<td>testing procedure including intervals between recalibration</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>I260 – Plan for periodic test of field instruments</td>
<td>testing procedure including intervals between recalibration</td>
<td>FI</td>
</tr>
<tr>
<td>cargo temperature monitoring system</td>
<td>I200 – Control and monitoring system documentation</td>
<td>testing procedure including intervals between recalibration</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>I260 – Plan for periodic test of field instruments</td>
<td>testing procedure including intervals between recalibration</td>
<td>FI</td>
</tr>
<tr>
<td>cargo pumps control and monitoring system</td>
<td>I200 - Control and monitoring system documentation</td>
<td>testing procedure including intervals between recalibration</td>
<td>AP</td>
</tr>
<tr>
<td>temperature indication system in insulation spaces and cofferdams</td>
<td>I200 – Control and monitoring system documentation</td>
<td>for membrane tank systems</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z030 – Arrangement plan</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>I260 – Plan for periodic test of field instruments</td>
<td>including intervals between recalibration</td>
<td>FI</td>
</tr>
<tr>
<td>cargo pressure alarm system</td>
<td>I200 – Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>I260 – Plan for periodic test of field instruments</td>
<td>including intervals between recalibration</td>
<td>FI</td>
</tr>
<tr>
<td>reliquefaction system</td>
<td>I200 – Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
</tbody>
</table>
5 Certification requirements

5.1 General

5.1.1 For general certification requirements, see Pt.1 Ch.3 Sec.4. For a definition of the certification types, see Pt.1 Ch.3 Sec.5.

5.2 Certification of components

Products shall be certified as required in Table 7.

Table 7 Certification of components

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard</th>
<th>Additional description</th>
<th>Rule reference</th>
</tr>
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<tr>
<td>valves</td>
<td>PC</td>
<td>Society</td>
<td>DN ≥ 100</td>
<td></td>
<td>Sec.5 [13.1]</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>manufacturer</td>
<td>DN &lt; 100</td>
<td></td>
<td>Sec.5 [13.1]</td>
</tr>
<tr>
<td>cargo tank pressure relief valves</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Sec.8 [2.2] and Sec.8 [5]</td>
</tr>
<tr>
<td>pressure relief valves for cargo system, except for cargo tanks</td>
<td>PC</td>
<td>Society</td>
<td>DN ≥ 75</td>
<td>given in Sec.5 [13.5]</td>
<td>Sec.8 [2.2] and Sec.8 [5]</td>
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<tr>
<td></td>
<td>PC</td>
<td>manufacturer</td>
<td>DN &lt; 75</td>
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<td>Sec.8 [2.2] and Sec.8 [5]</td>
</tr>
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<td>cargo process pressure vessels</td>
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<td>Society</td>
<td></td>
<td></td>
<td>Sec.5 [13.6]</td>
</tr>
<tr>
<td>cargo, fuel and Booster pumps pumps</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td>given in Sec.5 [13.5]</td>
<td>Sec.5 [13.5]</td>
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<td>cargo and fuel compressors</td>
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<td>Society</td>
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<td>Society</td>
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<td></td>
<td>Pt.4 Ch.7</td>
</tr>
<tr>
<td>pumps for glycol, ethanol, lube oil</td>
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<td>manufacturer</td>
<td></td>
<td></td>
<td>Pt.4 Ch.6</td>
</tr>
<tr>
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<td>PC</td>
<td>Society</td>
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<td>Sec.5 [11.6]</td>
</tr>
<tr>
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<td>Issued by</td>
<td>Certification standard*</td>
<td>Additional description Parameter: Size [mm] or PV [-](^{1}) or other</td>
<td>Rule reference</td>
</tr>
<tr>
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<td>------------------</td>
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<td>ventilation fans and portable ventilators for hazardous spaces</td>
<td>PC</td>
<td>Society</td>
<td></td>
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<td>Sec.12 [3.2]</td>
</tr>
<tr>
<td>inert gas generator</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>inert gas generator, air blower</td>
<td>PC</td>
<td>manufacturer</td>
<td></td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>inert gas, scrubber</td>
<td>PC</td>
<td>manufacturer</td>
<td></td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>inert gas, cooling water pumps for scrubber</td>
<td>PC</td>
<td>manufacturer</td>
<td></td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>inert gas, refrigerant type drier</td>
<td>PC</td>
<td>Society</td>
<td>PV ≥ 1.5</td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>manufacturer</td>
<td>PV &lt; 1.5</td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>inert gas, absorption drier</td>
<td>PC</td>
<td>Society</td>
<td>PV ≥ 1.5</td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>manufacturer</td>
<td>PV &lt; 1.5</td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>inert gas, control and monitoring system</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>nitrogen system, membrane separation vessels</td>
<td>PC</td>
<td>Society</td>
<td>PV ≥ 1.5</td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>manufacturer</td>
<td>PV &lt; 1.5</td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>nitrogen system, air compressors for nitrogen plant</td>
<td>PC</td>
<td>Society</td>
<td>&gt; 100 kW</td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>manufacturer</td>
<td>≤ 100 kW</td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>nitrogen system, control and monitoring system</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Sec.9</td>
</tr>
<tr>
<td>Associated electrical equipment (motors, frequency converters,</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Pt.4 Ch.8 Sec.1 [2.3.1]</td>
</tr>
<tr>
<td>switchgear and controlgear) serving an item that is required to be</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>delivered with a Society product certificate</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gas combustion unit</td>
<td>PC</td>
<td>manufacturer</td>
<td></td>
<td></td>
<td>Sec.7 [4] and Sec.13 [11]</td>
</tr>
<tr>
<td>cargo valves control and monitoring system</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Sec.13 and Pt.4 Ch.9</td>
</tr>
<tr>
<td>cargo pumps control and monitoring system</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Sec.13 and Pt.4 Ch.9</td>
</tr>
<tr>
<td>cargo tanks level monitoring system</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Sec.13 and Pt.4 Ch.9</td>
</tr>
<tr>
<td>cargo tanks overflow protection system</td>
<td>PC</td>
<td>Society</td>
<td></td>
<td></td>
<td>Sec.13 and Pt.4 Ch.9</td>
</tr>
</tbody>
</table>
### 5.3 Material certification of cargo pipe systems and cargo components

#### 5.3.1 The materials used in cargo piping systems shall be furnished with documentation according to Table 8. For definition of material documentation, see Pt.1 Ch.1 Sec.4.

**Table 8 Certification of material quality and testing**

<table>
<thead>
<tr>
<th>Object</th>
<th>Certificate type</th>
<th>Issued by</th>
<th>Certification standard*</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pipes</td>
<td>MC</td>
<td>Society</td>
<td></td>
<td>pressure</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td>pressure</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td>open ended</td>
</tr>
<tr>
<td>elbows, t-pieces etc., fabricated by welding</td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td>steel</td>
</tr>
<tr>
<td></td>
<td>TR</td>
<td>manufacturer</td>
<td></td>
<td>open ended</td>
</tr>
<tr>
<td>flanges</td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td>pressure</td>
</tr>
<tr>
<td></td>
<td>TR</td>
<td>Manufacturer</td>
<td></td>
<td>open ended</td>
</tr>
<tr>
<td>bodies of valves and fittings, pump housings, source materials of steel expansion bellows, other pressure containing components not considered as pressure vessels</td>
<td>MC</td>
<td>Society</td>
<td></td>
<td>steel</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td>pressure</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td>pressure</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td>pressure</td>
</tr>
<tr>
<td></td>
<td>TR</td>
<td>manufacturer</td>
<td></td>
<td>open ended</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td>copper alloys</td>
</tr>
<tr>
<td></td>
<td>TR</td>
<td>manufacturer</td>
<td></td>
<td>pressure</td>
</tr>
<tr>
<td>Object</td>
<td>Certificate type</td>
<td>Issued by</td>
<td>Certification standard*</td>
<td>Additional description</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------</td>
<td>---------------</td>
<td>-------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>nuts and bolts</td>
<td>TR</td>
<td>manufacturer</td>
<td></td>
<td>open ended</td>
</tr>
<tr>
<td>wooden block</td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>resin</td>
<td>MC</td>
<td>manufacturer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Unless otherwise specified the certification standard is the rules.
PC = product certificate, MC = material certificate, TR = test report

6 Testing

6.1 Testing during newbuilding

6.1.1 Function tests and capacity tests shall be carried out according to a test programme set up by the builder and approved by the Society.

6.1.2 Testing requirements for class notation **Tanker for liquefied gas** are given in Sec.4 [5.2.3] and Sec.4 [5.2.4] in general and Sec.20 [1.5], Sec.20 [2.6], Sec.21 [6], Sec.22 [7], Sec.23 [6] and Sec.24 [1.3] for each gas carrier ship type and other relevant parts of the rule set in addition to the ones listed below.

6.1.3 All systems covered by this chapter including containment system shall be tested in operation according to approved programme. As far as practicable, these tests shall be performed at the building yard.

6.1.4 Function tests and capacity tests, which cannot be carried out without cargo on board, may be carried at the first cargo loading or transport with a representative cargo.

Guidance note 1:
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".

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

Guidance note 2:
If the LNG Carrier has completed gas trial, the test required in above guidance note can be taken at later stage than first loading and discharging.

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---
6.1.5 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 should be performed during a loaded voyage, e.g. by stopping the reliquefaction plant and record cargo temperature and pressure over given period. Then start up the reliquefaction plant and run full capacity without the stand by compressor, and record temperature and pressure decrease of cargo. Together with recording of ambient working conditions, air and seawater temperature, during this test verification of sufficient capacity can be shown when these parameters are calculated up to design conditions.

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

6.1.6 Heating arrangements, if fitted in accordance with Sec.4 [5.1.1].6, shall be tested to show heating of applicable space as required.

6.1.7 The cargo containment system shall be inspected for cold spots. See Sec.4 [1.1.1] and Sec.4 [5.2.3].7.

6.1.8 Cargo containment system shall be tested. See Sec.4 [5.2.3] and Sec.4 [5.2.4]

7 Signboards

7.1 References

7.1.1 Signboards are required by the rules in:
1) Sec.3 [2.1.9]. Regarding plates bolted to boundaries facing the cargo area which can be opened for removal of machinery.
2) Sec.6 [9.1.4]. Regarding marking plates for independent tanks, pipes and valves.
3) Sec.12 [3.1.7]. Regarding ventilation system for pump and compressor rooms.
4) Sec.10 [4.1]. Regarding electrical installations.
5) Sec.16 [6.3.10]. Regarding gas operation of propulsion machinery.
SECTION 2 SHIP SURVIVAL CAPABILITY AND LOCATION OF CARGO TANKS

1 General

1.1 Requirements and definitions

1.1.1 Ships shall survive the hydrostatic effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the ship and the environment, the cargo tanks shall be protected from penetration in the case of minor damage to the ship resulting, for example, from contact with a jetty or tug, and also given a measure of protection from damage in the case of collision or grounding, by locating them at specified minimum distances inboard from the ship's shell plating. Both the damage to be assumed and the proximity of the tanks to the ship's shell shall be dependent upon the degree of hazard presented by the product to be carried. In addition, the proximity of the cargo tanks to the ship's shell shall be dependent upon the volume of the cargo tank.

1.1.2 Ships subject to this chapter shall be designed to one of the following standards:

.1 A type 1G ship is a gas carrier intended to transport the products indicated in Sec.19 that require maximum preventive measures to preclude their escape.

.2 A type 2G ship is a gas carrier intended to transport the products indicated in Sec.19, that require significant preventive measures to preclude their escape.

.3 A type 2PG ship is a gas carrier of 150 m in length or less intended to transport the products indicated in Sec.19 that require significant preventive measures to preclude their escape, and where the products are carried in type C independent tanks designed (see Sec.4 and Sec.22) for a MARVS of at least 0.7 MPa gauge and a cargo containment system design temperature of -55°C or above. A ship of this description that is over 150 m in length is to be considered a type 2G ship.

.4 A type 3G ship is a gas carrier intended to carry the products indicated in Sec.19 that require moderate preventive measures to preclude their escape.

Therefore, a type 1G ship is a gas carrier intended for the transportation of products considered to present the greatest overall hazard and types 2G/2PG and type 3G for products of progressively lesser hazards. Accordingly, a type 1G ship shall survive the most severe standard of damage and its cargo tanks shall be located at the maximum prescribed distance inboard from the ship's shell plating.

1.1.3 The ship type required for individual products is indicated in column 'c' in the table of Sec.19.

1.1.4 If a ship is intended to carry more than one of the products listed in Sec.19, the standard of damage shall correspond to the product having the most stringent ship type requirements. The requirements for the location of individual cargo tanks, however, are those for ship types related to the respective products intended to be carried.

1.1.5 The position of the moulded line for different containment systems is shown in [4.1].

2 Freeboard and stability

2.1 General requirements

2.1.1 Ships may be assigned the minimum freeboard permitted by the International Convention on Load Lines in force. However, the draught associated with the assignment shall not be greater than the maximum draught otherwise permitted by the rules.
2.1.2 The stability of the ship, in all seagoing conditions and during loading and unloading cargo, shall comply with the requirements of the International Code on Intact Stability. This includes partial filling and loading and unloading at sea, when applicable. Stability during ballast water operations shall fulfil stability criteria.

2.1.3 When calculating the effect of free surfaces of consumable liquids for loading conditions, it shall be assumed that, for each type of liquid, at least one transverse pair or a single centre tank has a free surface. The tank or combination of tanks to be taken into account shall be those where the effect of free surfaces is the greatest. The free surface effect in undamaged compartments shall be calculated by a method according to the International Code on Intact Stability.

2.1.4 Solid ballast shall not normally 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, its disposition shall be governed by the need to enable access for inspection and to ensure that the impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.

2.1.5 The master of the ship shall be supplied with a loading and stability information booklet. This booklet shall contain details of typical service conditions, loading, unloading and ballasting operations, provisions for evaluating other conditions of loading and a summary of the ship’s survival capabilities. The booklet shall also contain sufficient information to enable the master to load and operate the ship in a safe and seaworthy manner.

2.1.6 All ships, subject to this chapter shall be fitted with a stability instrument, capable of verifying compliance with intact and damage stability requirements, approved by the Society (see guidance note):

.1 ships constructed before 1 July 2016 shall comply with this paragraph at the first scheduled renewal survey of the ship after (date of entry into force) but not later than (five years after date of entry into force)
.2 notwithstanding the requirements of paragraph .1 a stability instrument installed on a ship constructed before 1 July 2016 need not be replaced provided it is capable of verifying compliance with intact and damage stability, to the satisfaction of the Society, and
.3 for the purposes of control under SOLAS regulation XI-1/4, the Society shall issue a document of approval for the stability instrument.

Guidance note:
Refer to part B, chapter 4, of the International Code on Intact Stability, 2008 (2008 IS Code), as amended; the Guidelines for the Approval of Stability Instruments (MSC.1/Circ.1229), annex, section 4, as amended; and the technical standards defined in part 1 of the guidelines for verification of damage stability requirements for tankers (MSC.1/Circ.1461).

2.1.7 The Society may give special dispensation to the following ships from the requirements of [2.1.6], provided the procedures employed for intact and damage stability verification maintain the same degree of safety as being loaded in accordance with the approved conditions (see below guidance note). Any such dispensation shall be duly noted on the International Certificate of Fitness:

.1 ships which are on a dedicated service, with a limited number of permutations of loading such that all anticipated conditions have been approved in the stability information provided to the master in accordance with the requirements of paragraph [2.1.5]
.2 ships where stability verification is made remotely by a means approved by the Society
.3 ships which are loaded within an approved range of loading conditions, or
.4 ships constructed before 1 July 2016 provided with approved limiting KG/GM curves covering all applicable intact and damage stability requirements.

Guidance note:
Refer to operational guidance provided in part 2 of the Guidelines for verification of damage stability requirements for tankers (MSC.1/ Circ.1461).
2.1.8 Conditions of loading

Damage survival capability shall be investigated on the basis of loading information for all anticipated conditions of loading and variations in draught and trim. This shall include ballast and, where applicable, cargo heel.

3 Damage assumptions

3.1 Maximum extent of damage

3.1.1 The assumed maximum extent of damage shall be as given in Table 1:

Table 1 Assumed maximum extent of damage

<table>
<thead>
<tr>
<th>.1</th>
<th>Side damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>.1.1</td>
<td>longitudinal extent</td>
</tr>
<tr>
<td>.1.2</td>
<td>transverse extent measured inboard from the moulded line of the outer shell at right angles to the centreline at the level of the summer waterline</td>
</tr>
<tr>
<td>.1.3</td>
<td>vertical extent from the moulded line of the outer shell at right angles to the centreline</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>.2</th>
<th>bottom damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>.2.1</td>
<td>longitudinal extent for $0.3 L_{LL}$ from the forward perpendicular of the ship</td>
</tr>
<tr>
<td>.2.2</td>
<td>transverse extent</td>
</tr>
<tr>
<td>.2.3</td>
<td>vertical extent</td>
</tr>
</tbody>
</table>

3.1.2 Other damage

1. If any damage of a lesser extent than the maximum damage specified in [3.1.1] would result in a more severe condition, such damage shall be assumed.

2. Local damage anywhere in the cargo area extending inboard distance “d” as defined in [4.1.1], measured normal to the moulded line of the outer shell shall be considered. Bulkheads shall be assumed damaged when the relevant sub-paragraphs of [6.1.1] apply. If a damage of a lesser extent than “d” would result in a more severe condition, such damage shall be assumed.
4 Location of cargo tanks

4.1 General requirements

4.1.1 Cargo tanks shall be located at the following distances inboard:

.1 Type 1G ships: from the moulded line of the outer shell, not less than the transverse extent of damage specified in [3.1.1].1.2 and, from the moulded line of the bottom shell at centreline, not less than the vertical extent of damage specified in [3.1.1].2.3, and nowhere less than "d" where "d" is as follows:

.1 for $V_c$ below or equal 1000 m$^3$, $d = 0.8$ m
.2 for 1000 m$^3 < V_c < 5000$ m$^3$, $d = 0.75 + V_c \times 0.2/4000$ m
.3 for 5000 m$^3 \leq V_c < 30 000$ m$^3$, $d = 0.8 + V_c/25 000$ m, and
.4 for $V_c \geq 30 000$ m$^3$, $d = 2$ m.

where:

$V_c$ corresponds to 100 % of the gross design volume of the individual cargo tank at 20°C, including domes and appendages (see Figure 1 and Figure 2. For the purpose of cargo tank protective distances, the cargo tank volume is the aggregate volume of all the parts of tank that have a common bulkhead(s), and "d" is measured at any cross section at a right angle from the moulded line of outer shell.

Tank size limitations may apply to type 1G ship cargoes in accordance with Sec.17.

.2 Types 2G/2PG: from the moulded line of the bottom shell at centreline not less than the vertical extent of damage specified in [3.1.1].2.3 and nowhere less than "d" as indicated in [4.1.1].1 (see Figure 1 and Figure 3).

.3 Type 3G ships: from the moulded line of the bottom shell at centreline not less than the vertical extent of damage specified in [3.1.1].2.3 and nowhere less than "d", where "d" = 0.8 m from the moulded line of outer shell (see Figure 1 and Figure 4).

4.1.2 For the purpose of tank location, the vertical extent of bottom damage shall be measured to the inner bottom when membrane or semi-membrane tanks are used, otherwise to the bottom of the cargo tanks. The transverse extent of side damage shall be measured to the longitudinal bulkhead when membrane or semi-membrane tanks are used, otherwise to the side of the cargo tanks. The distances indicated in [3.1] and [4.1] shall be applied as in Figure 5 to Figure 9. These distances shall be measured plate to plate, from the moulded line to the moulded line, excluding insulation.
Figure 1 Cargo tank locations centreline profile – Type 1G, 2G, 2PG and 3G ships

Figure 2 Transverse sections- type 1G ship
Figure 3 Transverse sections- type 2G and 2PG ship
Figure 4 Transverse sections – type 3G ship

Figure 5 Protective distance independent prismatic tank
Figure 6 Protective distance semi-membrane tank
Figure 7 Protective distance membrane tank
Figure 8 Protective distance spherical tank
4.1.3 Except for type 1G ships, suction wells installed in cargo tanks may protrude into the vertical extent of bottom damage specified in [3.1.1].2.3 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. Where there is no double bottom, the protrusion below the upper limit of bottom damage shall not exceed 350 mm. Suction wells installed in accordance with this paragraph may be ignored when determining the compartments affected by damage.

4.1.4 Cargo tanks shall not be located forward of the collision bulkhead.
5 Flood assumptions

5.1 General requirements

5.1.1 The requirements of [7.1] shall be confirmed by calculations that take into consideration the design characteristics of the ship, the arrangements, configuration and contents of the damaged compartments, the distribution, relative densities and the free surface effects of liquids and the draught and trim for all conditions of loading.

5.1.2 The permeabilities of spaces assumed to be damaged shall be as given in Table 2:

Table 2 Permeability of damaged spaces

<table>
<thead>
<tr>
<th>Spaces</th>
<th>Permeabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>stores</td>
<td>0.6</td>
</tr>
<tr>
<td>accommodation</td>
<td>0.95</td>
</tr>
<tr>
<td>machinery</td>
<td>0.85</td>
</tr>
<tr>
<td>voids</td>
<td>0.95</td>
</tr>
<tr>
<td>hold spaces</td>
<td>0.95(1)</td>
</tr>
<tr>
<td>consumable liquids</td>
<td>0 to 0.95(2)</td>
</tr>
<tr>
<td>other liquids</td>
<td>0 to 0.95(2)</td>
</tr>
</tbody>
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notes
1) Other values of permeability can be considered based on the detailed calculations. Interpretations of regulation of part B-1 of SOLAS chapter II-1 (MSC/Circ.651) are referred.
2) The permeability of partially filled compartments shall be consistent with the amount of liquid carried in the compartment.

5.1.3 Wherever damage penetrates a tank containing liquids, it shall be assumed that the contents are completely lost from that compartment and replaced by salt water up to the level of the final plane of equilibrium.

5.1.4 Where damage between transverse watertight bulkheads is envisaged, as specified in [6.1.1].4, [6.1.1].5, and [6.1.1].6, transverse bulkheads shall be spaced at least at a distance equal to the longitudinal extent of damage specified in[3.1.1].1.1 in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads within such extent of damage shall be assumed as non-existent for the purpose of determining flooded compartments. Further, any portion of a transverse bulkhead bounding side compartments or double bottom compartments shall be assumed damaged if the watertight bulkhead boundaries are within the extent of vertical or horizontal penetration required by [3.1]. Also, any transverse bulkhead shall be assumed damaged if it contains a step or recess of more than 3 m in length located within the extent of penetration of assumed damage. The step formed by the after peak bulkhead and the after peak tank top shall not be regarded as a step for the purpose of this paragraph.

5.1.5 The ship shall be designed to keep unsymmetrical flooding to the minimum consistent with efficient arrangements.

5.1.6 Equalization arrangements requiring mechanical aids such as valves or cross-levelling pipes, if fitted, shall not be considered for the purpose of reducing an angle of heel or attaining the minimum range of
residual stability to meet the requirements of [7.1.1], and sufficient residual stability shall be maintained during all stages where equalization is used. Spaces linked by ducts of large cross-sectional area may be considered to be common.

5.1.7 If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in [3.1], arrangements shall be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.

5.1.8 The buoyancy of any superstructure directly above the side damage shall be disregarded. However, the unflooded parts of superstructures beyond the extent of damage may be taken into consideration, provided that:

.1 they are separated from the damaged space by watertight divisions and the requirements of [7.1.1].1 in respect of these intact spaces are complied with, and
.2 openings in such divisions are capable of being closed by remotely operated sliding watertight doors and unprotected openings are not immersed within the minimum range of residual stability required in [7.1.2].1. However, the immersion of any other openings capable of being closed weather tight may be permitted.

6 Standard of damage

6.1 Damage related to ship types

6.1.1 Ships shall be capable of surviving the damage indicated in [3.1] with the flood assumptions in [5.1], to the extent determined by the ship's type, according to the following standards:

.1 a type 1G ship shall be assumed to sustain damage anywhere in its length, \( L_{LL} \)
.2 a type 2G ship of more than 150 m in length shall be assumed to sustain damage anywhere in its length
.3 a type 2G ship of 150 m in length or less shall be assumed to sustain damage anywhere in its length, except involving either of the bulkheads bounding a machinery space located aft
.4 a type 2PG ship shall be assumed to sustain damage anywhere in its length except involving transverse bulkheads spaced further apart than the longitudinal extent of damage as specified in [3.1.1].1
.5 a type 3G ship of 80 m in length or more shall be assumed to sustain damage anywhere in its length, except involving transverse bulkheads spaced further apart than the longitudinal extent of damage specified [3.1.1].1, and
.6 a type 3G ship less than 80 m in length shall be assumed to sustain damage anywhere in its length, except involving transverse bulkheads spaced further apart than the longitudinal extent of damage specified in [3.1.1].1 and except damage involving the machinery space when located after.

6.1.2 In the case of small type 2G/2PG and 3G ships that do not comply in all respects with the appropriate requirements of [6.1.1].3, [6.1.1].4 and [6.1.1].6, special dispensations may only be considered if alternative measures can be taken which maintain the same degree of safety. The nature of the alternative measures shall be approved and clearly stated and be available to the port administration. Any such dispensation shall be duly noted on the international certificate of fitness for the carriage of liquefied gases in bulk.
7 Survival of ship

7.1 General requirements

Ships subject to the rules shall be capable of surviving the assumed damage specified in [3.1], to the standard provided in [6.1], in a condition of stable equilibrium and shall satisfy the following criteria.

7.1.1 In any stage of flooding:

1. the waterline, taking into account sinkage, heel and trim, shall be below the lower edge of any opening through which progressive flooding or downflooding may take place. Such openings shall include air pipes and openings that are closed by means of weather tight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and watertight flush scuttles, small watertight cargo tank hatch covers that maintain the high integrity of the deck, remotely operated watertight sliding doors and side scuttles of the non-opening type.

2. the maximum angle of heel due to unsymmetrical flooding shall not exceed 30°, and

3. the residual stability during intermediate stages of flooding shall not be less than that required by [7.1.2].1.

7.1.2 At final equilibrium after flooding:

1. the righting lever curve shall have a minimum range of 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 0.1 m within the 20° range; the area under the curve within this range shall not be less than 0.0175 m-radians. The 20° range may be measured from any angle commencing between the position of equilibrium and the angle of 25° (or 30° if no deck immersion occurs). Unprotected openings shall not be immersed within this range unless the space concerned is assumed to be flooded. Within this range, the immersion of any of the openings listed in [7.1.1].1 and other openings capable of being closed weather tight may be permitted, and

2. the emergency source of power shall be capable of operating.
SECTION 3 SHIP ARRANGEMENTS

1 Segregation of the cargo area

1.1 General requirements

1.1.1 Hold spaces shall be segregated from machinery and boiler spaces, accommodation spaces, service spaces, control stations, chain lockers, domestic water tanks and from stores. Hold spaces shall be located forward of machinery spaces of category A. Alternative arrangements, including locating machinery spaces of category A forward, may be accepted, based on SOLAS regulation II-2/17, after further consideration of involved risks, including that of cargo release and the means of mitigation.

1.1.2 Where cargo is carried in a cargo containment system not requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in [1.1.1] or spaces either below or outboard of the hold spaces may be effected by cofferdams, oil fuel tanks or a single gastight bulkhead of all-welded construction forming an "A-60" class division. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

1.1.3 Where cargo is carried in a cargo containment system requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in [1.1.1], or spaces either below or outboard of the hold spaces that contain a source of ignition or fire hazard, shall be effected by cofferdams or oil fuel tanks. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

1.1.4 Turret compartments segregation from spaces referred to in [1.1.1], or spaces either below or outboard of the turret compartment that contain a source of ignition or fire hazard, shall be effected by cofferdams or an A-60 class division. A gastight "A-0" class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

1.1.5 In addition, the risk of fire propagation from turret compartments to adjacent spaces shall be evaluated by a risk analysis Sec.1 [2.1.5] and further preventive measures, such as the arrangement of a cofferdam around the turret compartment, shall be provided if needed.

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

1. at temperatures below -10°C, hold spaces shall be segregated from the sea by a double bottom, and
2. at temperatures below -55°C, the ship shall also have a longitudinal bulkhead forming side tanks.

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

2 Accommodation, service and machinery spaces and control station

2.1 General requirements

2.1.1 No accommodation space, service space or control station shall be located within the cargo area. The bulkhead of accommodation spaces, service spaces or control stations that 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.

2.1.2 To guard against the danger of hazardous vapours, due consideration shall be given to the location of air intakes/outlets and openings into accommodation, service and machinery spaces and control stations in relation to cargo piping, cargo vent systems and machinery space exhausts from gas burning arrangements.

2.1.3 Access through doors, gastight or otherwise, shall not be permitted from a non-hazardous area to a hazardous area except for access to service spaces forward of the cargo area through airlocks, as permitted by [6.1.1], when accommodation spaces are aft.

2.1.4
   .1 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 2 % of the length (L) of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m. Air outlets are subject to the same requirements as air inlets/intakes.

   Guidance note:
   Compliance with other relevant paragraphs of this chapter and in particular with this requirement [2.1.4] other requirements given in Sec.8 [2.2.8], Sec.8 [2.2.9], Sec.10 [2] and Sec.12 where applicable will ensure compliance with this requirement.

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

   .2 Windows and sidescuttles facing the cargo area and on the sides of the superstructures or deckhouses 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 designed in a manner that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured.

   .3 For ships dedicated to the carriage of cargoes that have neither flammable nor toxic hazards, the Society may approve relaxations from the above requirements.

   .4 Accesses to forecastle spaces containing sources of ignition may be permitted through a single door facing the cargo area, provided the doors are located outside hazardous areas as defined in Sec.10.

2.1.5 Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in [2.1.4], except wheelhouse windows, shall be constructed to “A-60” class. Wheelhouse windows shall be constructed to not less than “A-0” class (for external fire load). Sidescuttles in the shell below the uppermost continuous deck and in the first tier of the superstructure or deckhouse shall be of fixed (non-opening) type.

2.1.6 All air intakes, outlets and other openings into the accommodation spaces, service spaces and control stations shall be fitted with closing devices. When carrying toxic products, they shall be capable of being operated from inside the space. The requirement for fitting air intakes and openings with closing devices operated from inside the space for toxic products need not apply to spaces not normally manned, such as deck stores, forecastle stores, workshops. In addition, the requirement does not apply to cargo control rooms located within the cargo area.

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.

2.1.7 Control rooms and machinery spaces of turret systems may be located in the cargo area forward or aft of cargo tanks in ships with such installations. Access to such spaces containing sources of ignition may be permitted through doors facing the cargo area, provided the doors are located outside hazardous areas or access is through airlocks.

2.1.8 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.
2.1.9 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.

3 Cargo machinery spaces and turret compartments

3.1 General requirements

3.1.1 Cargo machinery spaces shall be situated above the weather deck and located within the cargo area. Cargo machinery spaces and turret compartments shall be treated as cargo pump-rooms for the purpose of fire protection according to SOLAS regulation II-2/9.2.4, and for the purpose of prevention of potential explosion according to SOLAS regulation II-2/4.5.10.

   Guidance note:
   Measures for preventing explosion protection required by SOLAS is gas detection.

3.1.2 When cargo machinery spaces are located at the after end of the aftermost hold space or at the forward end of the foremost hold space, the limits of the cargo area, as defined in Sec.1 [3.1], shall be extended to include the cargo machinery spaces for the full breadth and depth of the ship and the deck areas above those spaces.

3.1.3 Where the limits of the cargo area are extended by [3.1.2], the bulkhead that separates the cargo machinery spaces from accommodation and service spaces, control stations and machinery spaces of category A shall be located so as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.

3.1.4 Cargo compressors and cargo pumps may be driven by electric motors in an adjacent non-hazardous space separated by a bulkhead or deck, if the seal around the bulkhead penetration ensures effective gastight segregation of the two spaces. Alternatively, such equipment may be driven by certified safe electric motors adjacent to them if the electrical installation complies with the requirements of Sec.10.

3.1.5 Arrangements of cargo machinery spaces and turret compartments shall ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. At least two widely separated escape routes and doors shall be provided in cargo machinery spaces, except that a single escape route may be accepted where the maximum travel distance to the door is 5 m or less.

   Guidance note:
   Two escape routes and doors are required for the cargo machinery space. For the electrical motor room one access door and one escape hatch is acceptable

3.1.6 All valves necessary for cargo handling shall be readily accessible to personnel wearing protective clothing. Suitable arrangements shall be made to deal with drainage of pump and compressor rooms.

3.1.7 Turret compartments shall be designed to retain their structural integrity in case of explosion or uncontrolled high-pressure gas release (overpressure and/or brittle fracture), the characteristics of which shall be substantiated on the basis of a risk analysis with due consideration of the capabilities of the pressure relieving devices. Turret compartment should be provided with explosion pressure relief arrangements unless structure analysis show that the turret compartment can contain the explosion pressure.
4 Cargo control rooms

4.1 General requirements

4.1.1 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:

1. the cargo control room is a non-hazardous area
2. if the entrance complies with [2.1.4] .1, the control room may have access to the spaces described above, and
3. if the entrance does not comply with [2.1.4] .1, the cargo control room shall have no access to the spaces described above and the boundaries for such spaces shall be insulated to "A-60" class.

4.1.2 If the cargo control room is designed to be a non-hazardous area, instrumentation shall, as far as possible, be by indirect reading systems and shall, in any case, be designed to prevent any escape of gas into the atmosphere of that space. Location of the gas detection system within the cargo control room will not cause the room to be classified as a hazardous area, if installed in accordance with Sec.13 [6.1.11].

4.1.3 If the cargo control room for ships carrying flammable cargoes is classified as a hazardous area, sources of ignition shall be excluded and any electrical equipment shall be installed in accordance with Sec.10.

5 Access to spaces in the cargo area

5.1 General requirements

5.1.1 Visual inspection of at least one side of the inner hull structure shall be possible without the removal of any fixed structure or fitting. If such a visual inspection, whether combined with those inspections required in [5.1.2], Sec.4 [2.4.2] .4 or Sec.4 [5.2.3] .7 or not, is only possible at the outer face of the inner hull, the inner hull shall not be a fuel-oil tank boundary wall.

5.1.2 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.

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

1. Access shall be provided as follows:

   1. access to all cargo tanks. Access shall be direct from the weather deck
   2. access through horizontal openings, hatches or manholes. The dimensions shall be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction, and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening shall be not less than 600 mm x 600 mm
   3. access through vertical openings or manholes providing passage through the length and breadth of the space. The minimum clear opening shall be not less than 600 mm x 800 mm at a height of
.4  circular access openings to type C tanks shall have a diameter of not less than 600 mm.

.2  The dimensions referred to in .1.2 and .1.3 may be decreased, if the requirements of [5.1.3] can be met.

.3  Where cargo is carried in a containment system requiring a secondary barrier, the requirements of .1.2 and .1.3 do not apply to spaces separated from a hold space by a single gastight steel boundary. Such spaces shall be provided only with direct or indirect access from the weather deck, not including any enclosed non-hazardous area.

.4  Access required for inspection shall be a designated access through structures below and above cargo tanks, which shall have at least the cross-sections as required by .1.3.

**Guidance note 1:**
The term minimum clear opening of not less than 600 × 600 mm means that such openings may have corner radii up to 100 mm maximum.
Due regard should be given to avoid high stress concentrations. Thus for areas with high stresses the radius can be increased to \( r = 0.2 \times b \) (min. 600 mm), i.e. 120 mm where \( b \) = “breadth of opening”.

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

**Guidance note 2:**
For type C tanks the term minimum clear opening of not less than 600 × 800 mm includes also an opening of the size given in Figure 1.

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

.5  For the purpose of [5.1.1] or [5.1.2], the following shall apply:

.1  where it is required to pass between the surface to be inspected, flat or curved, and structures such as deck beams, stiffeners, frames, girders, etc., the distance between that surface and the free edge of the structural elements shall be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g. deck, bulkhead or shell, shall be at least 450 mm for a curved tank surface, e.g. for a type C tank, or 600 mm for a flat tank surface, e.g. for a type A tank, see Figure 2.
Figure 2 Minimum passage requirements involving structural elements

where it is not required to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected shall be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger, see Figure 3

Figure 3 Minimum visibility requirements

if for inspection of a curved surface where it is required to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces shall be at least 380 mm, see Figure 4. Where it is not required to pass between that curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface.
4. If for inspection of an approximately flat surface where it is required to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces shall be at least 600 mm. Where fixed access ladders are fitted, a clearance of at least 450 mm shall be provided for access, see Figure 5.

5. The minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction well shall not be less than those shown in Figure 6. This figure shows that the distance between the plane surfaces of the sump and the well is a minimum of 150 mm and that the clearance between the well and the knuckle point between the spherical or circular surface and sump of the tank is at least 380 mm. If there is no suction well, the distance between the cargo tank sump and the inner bottom shall not be less than 50 mm.
Figure 6 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 Figure 7

Figure 7 Minimum distance requirement between cargo tank dome and deck structures

.7 fixed or portable staging shall be installed as necessary for inspection of cargo tanks, cargo tank supports and restraints, e.g. anti-pitching, anti-rolling and anti-flotation chocks, cargo tank insulation etc. This staging shall not impair the clearances specified in .5.1 to .5.4, and

.8 if fixed or portable ventilation ducting shall be fitted in compliance with Sec.12 [1.1.2], such ducting shall not impair the distances required under .5.1 to .5.4.
6 Airlocks

6.1 General requirements

6.1.1 Access between hazardous area on the open weather deck and non-hazardous spaces shall be by means of an airlock. This shall consist of two self-closing, substantially gastight, steel doors without any holding back arrangements, capable of maintaining the overpressure, at least 1.5 m but no more than 2.5 m apart. The airlock space shall be artificially ventilated from a non-hazardous area and maintained at an overpressure to the hazardous area on the weather deck.

6.1.2 Where spaces are protected by pressurization, the ventilation shall be designed and installed in accordance with Sec.12.

6.1.3 An audible and visible alarm system to give a warning on both sides of the airlock shall be provided. The visible alarm shall indicate if one door is open. The audible alarm shall sound if doors on both sides of the airlock are moved from the closed positions.

6.1.4 In ships carrying flammable products, electrical equipment that is located in spaces protected by airlocks and not of the certified safe type, shall be de-energized in case of loss of overpressure in the space. Electrical equipment which is not of the certified safe type for maneuvering, anchoring and mooring equipment as well as the emergency fire pumps shall not be located in spaces to be protected by air-locks.

6.1.5 Electrical equipment for manoeuvring, anchoring and mooring, as well as emergency fire pumps that are located in spaces protected by airlocks, shall be of a certified safe type.

6.1.6 The airlock space shall be monitored for cargo vapours, see Sec.13 [6].

6.1.7 Subject to the requirements of the International Convention on Load Lines in force, the door sill shall not be less than 300 mm in height.

6.1.8 Air locks shall have a simple geometrical form. Air locks shall not be used for other purposes, for instance as store rooms.

7 Bilge, ballast and oil fuel arrangements

7.1 General requirements

7.1.1 Where cargo is carried in a cargo containment system not requiring a secondary barrier, suitable drainage arrangements for the hold spaces that are not connected with the machinery space shall be provided. Means of detecting any leakage shall be provided.

7.1.2 Where there is a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure shall be provided. The suction shall not lead to pumps inside the machinery space. Means of detecting such leakage shall be provided.

7.1.3 The hold or interbarrier 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 shall provide for the return of any cargo leakage to the liquid cargo piping.

7.1.4 Arrangements referred to in [7.1.3] shall be provided with a removable spool piece.
7.1.5 Ballast spaces, including wet duct keels used as ballast piping, oil fuel tanks and non-hazardous spaces, may be connected to pumps in the machinery spaces. Dry duct keels with ballast piping passing through may be connected to pumps in the machinery spaces, provided the connections are led directly to the pumps, and the discharge from the pumps is led directly overboard with no valves or manifolds in either line that could connect the line from the duct keel to lines serving non-hazardous spaces. Pump vents shall not be open to machinery spaces.

**Guidance note:**

Pump vents should not be open to machinery spaces and this applies only to pumps serving the dry duct keel.

---end---of---guidance---note---

7.1.6 For ships with integral tanks such connection given in [7.1.5] between cargo area and machinery spaces is not acceptable.

8 Bow and stern loading and unloading arrangements

8.1 General requirements

8.1.1 Subject to the requirements of this paragraph [8.1] and Sec.5, cargo piping may be arranged to permit bow or stern loading and unloading.

8.1.2 Bow or stern loading and unloading lines that 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.

8.1.3 Portable arrangements shall not be permitted.

8.1.4 Entrances, air inlets and openings

1. Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and controls 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 need not exceed 5 m. Air outlets are subject to the same requirements as air inlets and air intakes.

2. Windows and 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.

3. 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.

4. Where, in the case of small ships, compliance with [2.1.4].1 to .4 and [8.1.4] .1 to .3 is not possible, the Society may approve relaxations from the above requirements.

8.1.5 Deck openings and air inlets and outlets 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.

8.1.6 Fire-fighting arrangements for the bow or stern loading and unloading areas shall be in accordance with Sec.11 [3.1.1] .4 and Sec.11 [4.1.6].

8.1.7 Means of communication between the cargo control station and the shore connection location shall be provided and, where applicable, certified for use in hazardous areas.
9 Cofferdams and pipe tunnels

9.1 General requirements

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

9.1.2 Ballast tanks will be accepted as cofferdams.

9.1.3 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.

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

10 Guard rails and bulwarks

10.1 Arrangement

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.

11 Diesel engines driving emergency fire pumps or similar equipment forward of cargo area

11.1 General requirements

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

11.1.2 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.

12 Chain locker and windlass

12.1 General requirements

12.1.1 The chain locker shall be arranged as a non-hazardous space. Windlass and chain pipes shall be situated in a non-hazardous area.
13 Anodes and other fittings in tanks and cofferdams

13.1 General requirements

13.1.1 Anodes 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.

14 Emergency towing

14.1 General requirements

14.1.1 Emergency towing arrangement for gas carriers of 20 000 tonnes deadweight and above shall comply with requirements in Ch.5 Sec.2 [2.3].
SECTION 4 CARGO CONTAINMENT

1 General

1.1 Definitions

1.1.1 A cold spot is a part of the inner hull or thermal insulation surface where a localized temperature decrease occurs with respect to the allowable minimum temperature of the hull or of its adjacent hull structure, or to design capabilities of cargo pressure/temperature control systems required in Sec.7.

1.1.2 Design vapour pressure “P₀” is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

1.1.3 Design temperature for selection of materials is the minimum temperature at which cargo may be loaded or transported in the cargo tanks.

1.1.4 Independent tanks are self-supporting tanks. They do not form part of the ship’s hull and are not essential to the hull strength. There are three categories of independent tank, which are referred to in Sec.20, Sec.21 and Sec.22.

1.1.5 Membrane tanks are non-self-supporting tanks that consist of a thin liquid and gastight layer (membrane) supported through insulation by the adjacent hull structure. Membrane tanks are covered in Sec.23.

1.1.6 Integral tanks are tanks that form a structural part of the hull and are influenced in the same manner by the loads that stress the adjacent hull structure. Integral tanks are covered in Sec.24 [1].

1.1.7 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. Semi-membrane tanks are covered in Sec.24 [2].

1.2 Application

1.2.1 Unless otherwise specified in Sec.20, Sec.21, Sec.22 and Sec.23, the requirements of this section shall apply to all types of tanks, including those covered in Sec.24.

2 Cargo containment

2.1 Functional requirements

2.1.1 The design life of the cargo containment system shall not be less than the design life of the ship or 25 years whichever is the larger.

2.1.2 Cargo containment systems shall be designed for North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. Lesser environmental conditions, consistent with the expected usage, may be accepted by the Society for cargo containment systems used exclusively for restricted navigation. Greater environmental conditions may be required for cargo containment systems operated in conditions more severe than the North Atlantic environment.
2.1.3 Cargo containment systems shall be designed with suitable safety margins:

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

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

2.1.4 The cargo containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling, and fatigue. The specific design conditions which shall be considered for the design of each cargo containment system are given in Sec.20 to Sec.24. There are three main categories of design conditions:

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

.1 internal pressure
.2 external pressure
.3 dynamic loads due to the motion of the ship
.4 thermal loads
.5 sloshing loads
.6 loads corresponding to ship deflections
.7 tank and cargo weight with the corresponding reaction in way of supports
.8 insulation weight
.9 loads in way of towers and other attachments, and
.10 test loads.

.2 Fatigue design conditions – The cargo containment system structure and its structural components shall not fail under accumulated cyclic loading.

.3 The cargo containment system shall meet the following criteria:

.1 Collision – The cargo containment system shall be protectively located in accordance with Sec.2[4.1.1] and withstand the collision loads specified in [3.5.2] without deformation of the supports, or the tank structure in way of the supports, likely to endanger the tank structure.

.2 Fire – The cargo containment systems shall sustain without rupture the rise in internal pressure specified in Sec.8[4.1.1] under the fire scenarios envisaged therein.

.3 Flooded compartment causing buoyancy on tank – The anti-flotation arrangements shall sustain the upward force, specified in [3.5.3], and there shall be no endangering plastic deformation to the hull.

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

2.1.6 An inspection/survey plan for the cargo containment system shall be developed and approved by the Society. The inspection/survey plan shall identify areas that need inspection during surveys throughout the cargo containment system’s life and, in particular, all necessary in-service survey and maintenance that was assumed when selecting cargo containment system design parameters. Cargo containment systems shall be designed, constructed and equipped to provide adequate means of access to areas that need inspection as specified in the inspection/survey plan. Cargo containment systems, including all associated internal
equipment, shall be designed and built to ensure safety during operations, inspection and maintenance, see Sec.3 [5].

2.2 Cargo containment safety principles

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

2.2.2 However, the size and configuration or arrangement of the secondary barrier may be reduced where an equivalent level of safety is demonstrated in accordance with the requirements of [2.2.3] to [2.2.5], as applicable.

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

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

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

2.2.5 No secondary barrier is required where the cargo temperature at atmospheric pressure is at or above -10°C.

2.2.6 Leak before failure
For type B-tanks it shall be document if failure development can be safely detected by leakage detection. If the following conditions have been fulfilled, leak-before-failure (LBF) has been proven:

.1 A crack in the tank shell must be shown by fracture mechanics to exhibit stable growth through the shell thickness until the crack is sufficiently large to cause a leakage likely to be detected by the gas detection system, and
.2 continue to grow in a stable manner for a period of at least 15 days in specified environmental conditions.
.3 The small leak protection system must be designed to safely contain and dispose of the expected leakage rate during the 15 day period.
2.3 Secondary barriers in relation to tank types

2.3.1 Secondary barriers in relation to the tank types defined in Sec.20 to Sec.24 shall be provided in accordance with the following table.

Table 1 Secondary barriers in relation to tank types

<table>
<thead>
<tr>
<th>Cargo temperature at atmospheric pressure</th>
<th>-10°C and above</th>
<th>Below -10°C down to -55°C</th>
<th>Below -55°C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic tank type</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>integral</td>
<td>No secondary barrier required</td>
<td>Hull may act as secondary barrier</td>
<td>Separate secondary barrier where required</td>
</tr>
<tr>
<td>membrane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>semi-membrane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>independent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— type A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— type B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— type C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1) A complete secondary barrier shall normally be required if cargoes with a temperature at atmospheric pressure below -10°C are permitted in accordance with Sec.24 [1.1].
2) In the case of semi-membrane tanks that comply in all respects with the requirements applicable to type B independent tanks, except for the manner of support, the Society may, after special consideration, accept a partial secondary barrier.

2.4 Design of secondary barriers

2.4.1 Where the cargo temperature at atmospheric pressure is not below -55°C, the hull structure may act as a secondary barrier based on the following:

.1 the hull material shall be suitable for the cargo temperature at atmospheric pressure as required by [5.1.1] .4, and
.2 the design shall be such that this temperature will not result in unacceptable hull stresses.

2.4.2 The design of the secondary barrier shall be such that:

.1 it is capable of containing any envisaged leakage of liquid cargo for a period of 15 days, unless different criteria apply for particular voyages, taking into account the load spectrum referred to in [4.3.3] .5
.2 physical, mechanical, or operational events within the cargo tank that could cause failure of the primary barrier shall not impair the due function of the secondary barrier, or vice versa
.3 failure of a support or an attachment to the hull structure will not lead to loss of liquid tightness of both the primary and secondary barriers
.4 it is capable of being periodically checked for its effectiveness by means acceptable to the Society. This may be by means of a visual inspection or a pressure/vacuum test or other suitable means carried out according to a documented procedure agreed with the Society
the methods required in .4 above shall be approved by the Society and shall include, where applicable to the test procedure:

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

.2 accuracy and range of values of the proposed method for detecting defects in 1 above

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

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

.6 the secondary barrier shall fulfil its functional requirements at a static angle of heel of 30°

.7 Requirements with respect to pressure and leak testing of secondary barriers will be decided in each separate case.

Guidance note:
See IACS UI GC12 and testing requirements given in [5.2.4]

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

2.5 Partial secondary barriers and primary barrier small leak protection system

2.5.1 Partial secondary barriers as permitted in [2.2.3] shall be used with a small leak protection system and meet all the requirements in [2.4.2]. The small leak protection system shall include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquid cargo down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.

2.5.2 The capacity of the partial secondary barrier shall be determined, based on the cargo leakage corresponding to the extent of failure resulting from the load spectrum referred to in [4.3.3] .5, after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors.

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

2.6 Supporting arrangements

2.6.1 The cargo tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in [3.2] to [3.5], where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

2.6.2 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 β may be determined as shown in Figure 1. The half axes of the “acceleration ellipse” are determined according to [6.1.2] for all tanks except type B-tanks where accelerations from direct hydrodynamic analysis shall be applied, see Sec.20 and Sec.21.

2.6.3 For independent tanks and, where appropriate, for membrane tanks and semi-membrane tanks, provisions shall be made to key the tanks against the rotational effects referred to in [2.6.2] for all tanks except type B tanks where accelerations from direct hydrodynamics analysis shall apply. See Sec.20 and Sec.21.

2.6.4 Anti flotation arrangements shall be provided for independent tanks and capable of withstanding the loads defined in [3.5.3] without plastic deformation likely to endanger the hull structure.
2.6.5 Supports and supporting arrangements shall withstand the loads defined in [3.3.9] and [3.5], but these loads need not be combined with each other or with wave-induced loads.

2.7 Associated structure and equipment

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

2.8 Thermal insulation

2.8.1 Thermal insulation shall be provided as required to protect the hull from temperatures below those allowable, see [5.1.1], and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in Sec.7.

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

3 Design loads

3.1 General

3.1.1 This section defines the design loads to be considered with regard to the requirements in [4.1], [4.2] and [4.3]. This includes:

1. load categories (permanent, functional, environmental and accidental) and the description of the loads
2. the extent to which these loads shall be considered depending on the type of tank, and is more fully detailed in the following paragraphs, and
3. tanks, together with their supporting structure and other fixtures, that shall be designed taking into account relevant combinations of the loads described below.

3.2 Permanent loads

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

3.2.2 Permanent external loads
Gravity loads of structures and equipment acting externally on the tank shall be considered.

3.3 Functional loads

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

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

3.3.2 Internal pressure
In all cases, including .2 below, \( P_0 \) shall not be less than MARVS.

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

1. lower values of ambient temperature may be accepted by the Society in restricted areas. Conversely, higher values of ambient temperature may be required, and
2. for ships on voyages of restricted duration, \( P_0 \) may be calculated based on the actual pressure rise during the voyage, and account may be taken of any thermal insulation of the tank.
3. Subject to special consideration by the Society and to the limitations given in Sec.20 to Sec.24, for the various tank types, a vapour pressure \( P_h \) higher than \( P_0 \) may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced. Any relief valve setting resulting from this paragraph shall be recorded in the Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.
4. The internal pressure \( P_{eq} \) results from the vapour pressure \( P_0 \) or \( P_h \) plus the maximum associated dynamic liquid pressure \( P_{gd} \), but not including the effects of liquid sloshing loads. Unless other values are justified by independent direct calculations, guidance formulae for associated dynamic liquid pressure \( P_{gd} \) are given in the guidance note in [6.1.1]. For FE analyses, see the cargo containment specific Sec.20 to Sec.24.

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

3.3.4 Thermally induced loads
Transient thermally induced loads during cooling down periods shall be considered for tanks intended for cargo temperatures below -55°C.
Stationary thermally induced loads shall be considered for cargo containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses, see Sec.7 [2].

3.3.5 Vibration
The potentially damaging effects of vibration on the cargo containment system shall be considered.
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, 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.

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

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

3.3.8 Test loads
Account shall be taken of the loads corresponding to the testing of the cargo containment system referred to in Sec.20 to Sec.24.

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

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

3.4 Environmental loads

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

3.4.2 Loads due to ship motion
.1 The determination of dynamic loads shall take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading.
.2 The ship's motion shall include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks shall be estimated at their centre of gravity and include the following components:
   .1 vertical acceleration: motion accelerations of heave, pitch and, possibly roll normal to the ship base
   .2 transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll, and
   .3 longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.
.3 Methods to predict accelerations due to ship motion shall be proposed and approved by the Society.
.4 Guidance formulæ for acceleration components are given in [6.1.2].
.5 Ships for restricted service may be given special consideration.

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

3.4.4 Sloshing loads
.1 The sloshing loads on a cargo containment system and internal components shall be evaluated based on allowable filling levels.
.2 When significant sloshing-induced loads are expected to be present, special tests and calculations shall be required covering the full range of intended filling levels.

3.4.5 Snow and ice loads
Snow and icing shall be considered, if relevant.

3.4.6 Loads due to navigation in ice
Loads due to navigation in ice shall be considered for vessels intended for such service.

Guidance note:
See Pt.6 Ch.6 Sec.4 for requirements for operation in ice.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
3.5 Accidental loads

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

3.5.2 Collision loads
The collision load shall be determined based on the cargo containment system under fully loaded condition with an inertial force corresponding to $0.5g$ in the forward direction and $0.25g$ in the aft direction, where $g$ is gravitational acceleration.

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

4 Structural integrity

4.1 General

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

4.1.2 The structural integrity of cargo containment systems shall be demonstrated by compliance with Sec.20 to Sec.24, as appropriate for the cargo containment system type.

4.1.3 The structural integrity of cargo containment system types that are of novel design and differ significantly from those covered by Sec.20 to Sec.24 shall be demonstrated by compliance with Sec.24 [3] to ensure that the overall level of safety provided for in this chapter is maintained.

4.1.4 When determining the design stresses 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°C. However, material strength data at ambient temperature shall be applied at ambient temperature conditions, e.g. pressure testing

4.2 Structural analyses

4.2.1 Analysis

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

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

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

4.2.2 Load scenarios

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

.2 The most unfavourable scenarios for all relevant phases during construction, handling, testing and in service and conditions shall be considered.
4.2.3 When the static and dynamic stresses are calculated separately, and unless other methods of calculation are justified, the total stresses shall be calculated according to:

\[
\sigma_x = \sigma_{x, st} \pm \sqrt{\sum (\sigma_{x, dyn})^2}
\]

\[
\sigma_y = \sigma_{y, st} \pm \sqrt{\sum (\sigma_{y, dyn})^2}
\]

\[
\sigma_z = \sigma_{z, st} \pm \sqrt{\sum (\sigma_{z, dyn})^2}
\]

\[
\tau_{xy} = \tau_{xy, st} \pm \sqrt{\sum (\tau_{xy, dyn})^2}
\]
\[
\tau_{xz} = \tau_{xz, st} \pm \sqrt{\sum (\tau_{xz, dyn})^2}
\]

\[
\tau_{yz} = \tau_{yz, st} \pm \sqrt{\sum (\tau_{yz, dyn})^2}
\]

where:

\(\sigma_{x, st}, \sigma_{y, st}, \sigma_{z, st}, \tau_{xy, st}, \tau_{xz, st}\) and \(\tau_{yz, st}\) are static stresses, and

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

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

### 4.3 Design conditions

#### 4.3.1 General

All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in the earlier part of this section, and the load scenarios are covered by [4.2.2].

#### 4.3.2 Ultimate design condition

Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by this chapter.

1. Plastic deformation and buckling shall be considered.
2. Analysis shall be based on characteristic load values as follows:

<table>
<thead>
<tr>
<th>Type of Load</th>
<th>Load Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>permanent loads</td>
<td>expected values</td>
</tr>
<tr>
<td>functional loads</td>
<td>specified values</td>
</tr>
<tr>
<td>environmental loads</td>
<td>for wave loads: most probable largest load encountered during (10^8) wave encounters, or 25 years whichever is the stricter, in North Atlantic environment</td>
</tr>
</tbody>
</table>

3. For the purpose of ultimate strength assessment, the following material parameters apply:

   1. \(R_{eh}\) = specified minimum yield stress at room temperature in N/mm². If the stress-strain curve does not show a defined yield stress, the 0.2 % proof stress applies.
   2. \(R_m\) = specified minimum tensile strength at room temperature in N/mm².

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

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

.4 The equivalent stress von Mises $\sigma_{vm}$ shall be determined by:

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

where:

- $\sigma_x =$ total normal stress in x-direction
- $\sigma_y =$ total normal stress in y-direction
- $\sigma_z =$ total normal stress in z-direction
- $\tau_{xy} =$ total shear stress in x-y plane
- $\tau_{xz} =$ total shear stress in x-z plane, and
- $\tau_{yz} =$ total shear stress in y-z plane.

The above values shall be calculated as described in [4.2.3].

.5 Allowable stresses for materials other than those covered by Sec.6 shall be subject to approval by the Society in each case.

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

### 4.3.3 Fatigue design condition

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

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

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

where:

- $n_i =$ number of stress cycles at each stress level during the life of the tank
- $N_i =$ number of cycles to fracture for the respective stress level according to the high cycle design S-N curve
- $n_{\text{loading}} =$ number of loading and unloading cycles during the life of the tank, not to be less than 1000. Loading and unloading cycles include a complete pressure and thermal cycle
- $N_{\text{loading}} =$ number of loading cycles to fracture due to low cycle fatigue from loading and unloading, and
\[ C_w = \text{maximum allowable cumulative fatigue damage ratio} \]

The fatigue damage shall be based on the design life of the tank but not less than \(10^8\) wave encounters, or 25 years whichever is the stricter.

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

.4 .1 Design S-N curves used in the analysis shall be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned.

.2 The S-N curves shall be based on a 97.6% probability of survival corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different way requires adjustments to the acceptable \(C_w\) values specified in .7 to .9.

.5 Analysis shall be based on characteristic load values as follows:

- **Permanent loads**: expected values
- **Functional loads**: specified values or specified history
- **Environmental loads**: expected load history, but not less than \(10^8\) cycles or 25 years whichever is the stricter, in North Atlantic environment

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

.6 .1 Where the size of the secondary barrier is reduced, as is provided for in [2.2.3], fracture mechanics analyses of fatigue crack growth shall be carried out to determine:

- .1 crack propagate on paths in the structure;
- .2 crack growth rate;
- .3 the time required for a crack to propagate to cause a leakage from the tank;
- .4 the size and shape of through thickness cracks; and
- .5 the time required for detectable cracks to reach a critical state. The fracture mechanics are, in general, based on crack growth data taken as a mean value plus two standard deviations of the test data.

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

.3 Crack propagation analysis under the condition specified in .7: the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in Figure.4. Load distribution and sequence for longer periods, such as in .8 and .9 shall be approved by the Society.

.4 The arrangements shall comply with .7 to .9, as applicable.

.5 The analysis shall establish the size and shape of possible fatigue cracks at penetration of the tank wall and during subsequent propagation as through-thickness cracks as relevant, taking into account the stress distribution in the tank wall.

.6 If necessary, the requirements for establishing crack sizes and crack 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 crack sizes for important parts of the tanks. The determination of crack sizes shall be performed using recognized calculation procedures which have to be approved in each case.

.7 The fracture toughness properties shall be expressed using recognized standards or practice e.g., BS 7910 “Guide on the Methods for Assessing the Acceptability of Flaws in Metallic Structures”.
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 recognized 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 shall be taken into account when establishing the choice of fatigue crack propagation rate parameters.

Fracture mechanics analysis procedures are given in the rule sections for the Independent tanks of type B, Sec.20 for prismatic tanks and Sec.21 for spherical tanks.

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

$$C_w \leq 0.5$$

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

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

$$C_w \leq 0.5$$

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

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

$$C_w \leq 0.1$$

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

**4.3.4 Accident design condition**

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

Analysis shall be based on the characteristic values as follows:

- permanent loads | expected values
- functional loads | specified values
- environmental loads | specified values
- accidental loads | specified values or expected values

Loads mentioned in [3.3.9] and [3.5] need not be combined with each other or with wave induced loads.

**5 Materials and construction**

**5.1 Materials**

**5.1.1 Materials forming ship structure**

To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types when the cargo temperature is below -10°C. The following assumptions shall be made in this calculation:

- the primary barrier of all tanks shall be assumed to be at the cargo temperature
.2 in addition to .1.1, where a complete or partial secondary barrier is required, it shall be assumed to be at the cargo temperature at atmospheric pressure for any one tank only.

.3 for worldwide service, ambient temperatures shall be taken as 5°C for air and 0°C for seawater. Higher values may be accepted for ships operating in restricted areas and conversely, lower values may be fixed by the Society for ships trading to areas where lower temperatures are expected during the winter months.

.4 still air and sea water conditions shall be assumed, i.e. no adjustment for forced convection.

.5 degradation of the thermal insulation properties over the life of the ship due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations, as defined in [5.1.3].6 and .7, shall be assumed.

.6 the cooling effect of the rising boil-off vapour from the leaked cargo shall be taken into account, where applicable.

.7 credit for hull heating may be taken in accordance with .5, provided the heating arrangements are in compliance with .6.

.8 no credit shall be given for any means of heating, except as described in .5, and

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

The ambient temperatures used in the design, described in this paragraph, shall be shown in appendix to class certificate and on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

.2 The shell and deck plating of the ship and all stiffeners attached thereto shall be in accordance with Sec.6. If the calculated temperature of the material in the design condition is below -5°C due to the influence of the cargo temperature, the material shall be in accordance with Sec.6 Table 5.

.3 The materials of all other hull structures for which the calculated temperature in the design condition is below 0°C, due to the influence of cargo temperature and that do not form the secondary barrier, shall also be in accordance with Sec.6 Table 5. This includes hull structure supporting the cargo tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

.4 The hull material forming the secondary barrier shall be in accordance with Sec.6 Table 2. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by Sec.6 Table 2 shall be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

.5 Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in Sec.6 Table 5. In the calculations required in .1, credit for such heating may be taken in accordance with the following:

.1 for any transverse hull structure

.2 for longitudinal hull structure referred to in .2 and .3 where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of +5°C for air and 0°C for seawater with no credit taken in the calculations for heating, and

.3 as an alternative to .2, for longitudinal bulkhead between cargo tanks, credit may be taken for heating provided the material remain suitable for a minimum design temperature of -30°C, or a temperature 30°C lower than that determined by .1 with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with SOLAS regulation II-1/3-1 for both when those bulkhead(s) are considered effective and not. An additional risk assessment may be required by the Society.

.6 The means of heating referred to in .5 shall comply with the following requirements:

.1 the heating system shall be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to not less than 100% of the theoretical heat requirement

.2 the heating system shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with .5.1 shall be supplied from the emergency source of electrical power, and
the design and construction of the heating system shall be included in the approval of the containment system by the Society.

5.1.2 Materials of primary and secondary barriers

1. Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with, Sec.6 Table 1, Sec.6 Table 2 or Sec.6 Table 3.

2. Materials, either non-metallic or metallic but not covered by Sec.6 Table 1, Sec.6 Table 2 or Sec.6 Table 3, used in the primary and secondary barriers may be approved by the Society, considering the design loads that they may be subjected to, their properties and their intended use.

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

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

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

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

Guidance on the use of non-metallic materials in the construction of primary and secondary barriers is provided in App.A.

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

5.1.3 Thermal insulation and other materials used in cargo containment systems

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

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

   1. compatibility with the cargoes
   2. solubility in the cargo
   3. absorption of the cargo
   4. shrinkage
   5. ageing
   6. closed cell content
   7. density
   8. mechanical properties, to the extent that they are subjected to cargo and other loading effects, thermal expansion and contraction
   9. abrasion
   10. cohesion
   11. thermal conductivity
   12. resistance to vibrations
   13. resistance to fire and flame spread, and
   14. resistance to fatigue failure and crack propagation.
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3 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than -196°C.

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

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

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

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

5.2 Construction processes

5.2.1 Weld joint design

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

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

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

2 The bevel preparation of the joints between the tank body and domes and between domes and relevant fittings shall be designed according to the Society's requirements for welding, e.g. Pt.4 Ch.8. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds.

3 Where applicable, all the construction processes and testing, except that specified in [5.2.3], shall be done in accordance with the applicable provisions of Sec.6.

5.2.2 Design for gluing and other joining processes

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

5.2.3 Testing

1 All cargo tanks and process pressure vessels shall be subjected to hydrostatic or hydropneumatic pressure testing in accordance with Sec.20 to Sec.24, as applicable for the tank type.

2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in .1.

3 Requirements with respect to inspection of secondary barriers shall be decided by the Society in each case, taking into account the accessibility of the barrier. See also [2.4.2].

4 The Society may require that for ships fitted with novel type B independent tanks, or tanks designed according to Sec.24 [3] at least one prototype tank and its supporting structures shall be instrumented with strain gauges or other suitable equipment to confirm stress levels. Similar instrumentation may be required for type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.
The overall performance of the cargo containment system shall be verified for compliance with the design parameters during the first full loading and discharging of the cargo, in accordance with the survey procedure of the Society. Records of the performance of the components and equipment essential to verify the design parameters, shall be maintained and be available to the Society.

.6 Heating arrangements, if fitted in accordance with [5.1.1] .5 and .6, shall be tested for required heat output and heat distribution.

.7 The cargo containment system shall be inspected for cold spots during, or immediately following, the first loaded voyage. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked shall be carried out in accordance with recognized standards.

5.2.4 Membrane containment testing requirements
Following testing apply:

.1 For membrane and semi-membrane tanks systems, inspection and testing are to be carried out in accordance with programmes specially prepared in accordance with an approved method for the actual tank system.

.2 For membrane containment systems a tightness test of the primary and secondary barrier shall be carried out in accordance with the system designers’ procedures and acceptance criteria as approved. Low differential pressure tests may be used for monitoring the cargo containment system performance, but are not considered an acceptable test for the tightness of the secondary barrier.

.3 For membrane containment systems with glued secondary barriers if the designer's threshold values are exceeded, an investigation is to be carried out and additional testing such as thermographic or acoustic emissions testing should be carried out.

.4 The values recorded should be used as reference for future assessment of secondary barrier tightness.

.5 For containment systems with welded metallic secondary barriers, a tightness test after initial cool down is not required.

Guidance note:
With reference to IACS UI GC12.

5.3 Welding procedure tests

5.3.1 Cargo tanks and cargo process pressure vessels
The requirements for welding procedure tests for cargo tanks and cargo process pressure vessels are given in Pt.2 Ch.4 Sec.5.

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

5.4 Welding production tests

5.4.1 General

.1 Weld production tests shall be carried out to the extent given in [5.4.2] for the different types of tanks. The test requirements are given in [5.4.4].

.2 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.

.3 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.

.4 Tests other than those specified in [5.4.2], may be required for cargo tanks or secondary barriers at the discretion of the Society.
5.4.2 Extent of testing
.1 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.
.2 For independent tanks type C and cargo process pressure vessels, transverse weld tensile tests are required in addition to those tests listed in .1.
.3 Production tests for integral and membrane tanks will be dealt with in each separate case.

5.4.3 Preparation of production weld test
.1 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.
.2 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.
.3 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.
.4 The production weld test shall be heat-treated as the product.
.5 The weld reinforcement shall be machined flush with the plate surface on both sides of the test assembly.

5.4.4 Test requirements
.1 The dimensions of test pieces shall be as required for the welding procedure test detailed in Pt.2 Ch.4 Sec.5.
.2 Test requirements are given in Pt.2 Ch.4 Sec.5.

5.5 Requirements for weld types and non-destructive testing (NDT)

5.5.1 General
Non-destructive testing, NDT, shall be performed in accordance with approved procedures. All test procedures shall be in accordance with recognised standards.
Basic requirements are given in Pt.2 Ch.4 Sec.7.

5.5.2 Extent of testing
.1 The requirements to weld type and extent of non-destructive testing are given in Table 2.
.2 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.
.3 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.

5.5.3 Acceptance criteria
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 2 Requirements for tank welds and non-destructive testing

<table>
<thead>
<tr>
<th>Tank type</th>
<th>Weld type requirement</th>
<th>Non-destructive testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Radiography</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>integral</td>
<td>full penetration</td>
<td>special weld inspection procedures and acceptable standards shall be submitted by the designers for approval</td>
</tr>
<tr>
<td>membrane</td>
<td>subject to special consideration</td>
<td></td>
</tr>
<tr>
<td>semi-membrane</td>
<td>as for independent tanks or for membrane tanks as appropriate</td>
<td></td>
</tr>
</tbody>
</table>

|                          |                                                            | radiography:                                                                          |                                                                 |
|                          |                                                            | 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 |                                                                 |
| 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. For tank type C, see also Sec.22 [8.1.2] |                                                                 |
| independent, type B     |                                                                                                           |                                                                                       |
| independent, type C     |                                                                                                           |                                                                                       |
| secondary barriers      |                                                                                                           |                                                                                       |

|                          |                                                            | ultrasonic testing:                                                                    |                                                                 |
|                          |                                                            | a) reinforcement rings around holes 100%                                                |                                                                 |
|                          |                                                            | b) reinforcement rings around holes, nozzles etc. 100%                                   |                                                                 |
|                          |                                                            |                                                                                       |
|                          |                                                            | surface crack detection:                                                                |                                                                 |
|                          |                                                            | a) all butt welds in shell 10%                                                        |                                                                 |
|                          |                                                            | b) butt welds of face plates and web plates of girders                                 |                                                                 |
|                          |                                                            | stiffening rings etc. shall be radiographed as considered necessary                    |                                                                 |
|                          |                                                            |                                                                                       |                                                                 |
|                          |                                                            | 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. |                                                                 |

### 6 Guidance

#### 6.1 Guidance notes for section 4
6.1.1 Guidance to detailed calculation of internal pressure for quasi-static design purpose

.1 This section provides guidance for the calculation of the associated dynamic liquid pressure for the purpose of quasi-static design calculations. This pressure may be used for determining the internal pressure referred to in [3.3.2] .4, where:

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

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

.3 \(P_{eq}\) should be the greater of \(P_{eq1}\) and \(P_{eq2}\) calculated as follows:

\[
P_{eq1} = P_o + (P_{gd})_{max},
\]

\[
P_{eq2} = P_h + (P_{gd\ sites})_{max}.
\]

.2 The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the cargo due to the motions of the ship referred to in [3.4.2]. The value of internal liquid pressure \(P_{gd}\), in MPa, resulting from combined effects of gravity and dynamic accelerations should be calculated as follows:

\[
P_{gd} = \alpha_{\beta} Z^2_{\beta} \left( \frac{\rho}{1.02 \cdot 10^5} \right)
\]

where:

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

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

\(\rho\) = maximum cargo density in kg/m\(^3\) at the design temperature

\(Z_{\beta}\) = largest liquid height in m above the point where the pressure is to be determined measured from the tank shell in the \(\beta\) direction, see Figure 2. Tank domes considered to be part of the accepted total tank volume shall be taken into account when determining \(Z_{\beta}\), unless the total volume of tank domes \(V_d\) does not exceed the following value:

\[
V_d = V_t \left( \frac{100 - FL}{FL} \right)
\]

with

\(V_t\) = tank volume without any domes, and

\(FL\) = filling limit according to Sec.15.

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

6.1.2 Guidance formulae for acceleration components

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

- Vertical acceleration as defined in [3.4.2]:

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DNV GL AS
— Transverse acceleration as defined in [3.4.2]:

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

— Longitudinal acceleration as defined in [3.4.2]:

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

where:

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

\[ L \] = rule length in m of the ship for determination of scantlings as defined in Pt.3 Ch.1 Sec.4

\[ C_B \] = block coefficient as defined in Pt.3 Ch.1 Sec.4

\[ B \] = greatest moulded breadth in m of the ship as defined in Pt.3 Ch.1 Sec.4

\[ x \] = longitudinal distance in m from amidships to the centre of gravity of the tank with contents. \( x \) is positive forward of amidships, negative aft of amidships.

\[ y \] = transverse distance in m from centreline to the centre of gravity of the tank with contents, and

\[ z \] = vertical distance in m from the ship's actual waterline to the centre gravity of tank with contents; \( z \) is positive above and negative below the waterline.

\[ K \] = 1 in general. For particular loading conditions and hull forms, determination of \( K \) according to the formula below may be necessary

\[ K = \max(13 \frac{GM}{B}; 1.0) \] where \( GM \) = metacentric height in m

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

\[ V \] = service speed in knots

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

6.1.3 Stress categories

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

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

.3 Membrane stress is the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

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

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

.6 Primary stress is a stress produced by the imposed loading, which is necessary to balance the external forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or at least in gross deformations.

.7 Primary general membrane stress is a primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding.

.8 Primary local membrane stress arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress, although it has some characteristics of a secondary stress. A stress region may be considered as local, if:

\[
S_1 \leq 0.5 \sqrt{Rt} \quad \text{and} \quad S_2 \geq 2.5 \sqrt{Rt}
\]

where:

- \(S_1\) = distance, in mm, in the meridional direction over which the equivalent stress exceeds \(1.1f\)
- \(S_2\) = distance, in mm, in the meridional direction to another region where the limits for primary general membrane stress are exceeded
- \(R\) = mean radius of the vessel in mm
- \(t\) = net wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded, in mm, and
- \(f\) = allowable primary general membrane stress in N/mm².

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

.10 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.

.11 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.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Figure 1 Acceleration ellipsoid
Figure 2 Determination of internal pressure heads

Figure 3 Determination of liquid height $Z_b$ for points 1, 2 and 3
\( \sigma_0 \) = most probable maximum stress over the life of the ship

Response cycle scale is logarithmic; the value of \( 2.10^5 \) is given as an example of estimate.

**Figure 4 Simplified load distribution**
SECTION 5 PROCESS PRESSURE VESSELS AND LIQUIDS, VAPOUR AND PRESSURE PIPING SYSTEMS

1 General

1.1 General requirements

1.1.1 The requirements of this section shall apply to products and process piping, including vapour piping, gas fuel piping and vent lines of safety valves or similar piping. Auxiliary piping systems not containing cargo are exempt from the general requirements of this section.

Guidance note:
Requirements for auxiliary piping systems not containing cargo is given in Pt.4 Ch.6

1.1.2 The requirements for type C independent tanks provided in Sec.4 may also apply to process pressure vessels. If so required, the term 'pressure vessels' as used in Sec.4, covers both type C independent tanks and process pressure vessels.

1.1.3 Process pressure vessels include surge tanks, heat exchanges and accumulators that store or treat liquid or vapour cargo [13.6]

1.1.4 The temperature in a steam pipe and any other hot pipeline shall not exceed 220°C, or be at least 40°C lower than the auto ignition temperature for the products intended to be carried, in hazardous space or area, or in any non-hazardous area protected by mechanical ventilation.

1.1.5 Pipes to engine or boiler rooms shall not pass through hold spaces serving as secondary barriers.

1.1.6 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.

2 System requirements

2.1 General requirements

2.1.1 The cargo handling and cargo control systems shall be designed taking into account the following:

.1 prevention of an abnormal condition escalating to a release of liquid or vapour cargo
.2 the safe collection and disposal of cargo fluids released
.3 prevention of the formation of flammable mixtures
.4 prevention of ignition of flammable liquids or gases and vapours released, and
.5 limiting the exposure of personnel to fire and other hazards.

2.2 General arrangements

2.2.1 Any piping system that may contain cargo liquid or vapour shall:

.1 be segregated from other piping systems, except where interconnections are required for cargo related operations such as purging, gas-freeing or inerting. The requirements of Sec.9 [1.4.4] shall be taken into account with regard to preventing back-flow of cargo. In such cases, precautions shall be taken to ensure that cargo or cargo vapour cannot enter other piping systems through the interconnections
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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 machinery space

be connected to the cargo containment system directly from the weather decks except where pipes installed in a vertical trunkway or equivalent are used to traverse void spaces above a cargo containment system and except where pipes for drainage, venting or purging traverse cofferdams

be located in the cargo area above the weather deck except for bow or stern loading and unloading arrangements in accordance with Sec.3 [8], emergency cargo jettisoning piping systems in accordance with [3.1], turret compartment systems in accordance with [3.3] and except in accordance with Sec.16, and

be located inboard of the transverse tank location requirements of Sec.2 [4.1], except for athwartship shore connection piping not subject to internal pressure at sea or emergency cargo jettisoning piping systems.

2.2.2 Suitable means shall be provided to relieve the pressure and remove liquid cargo from loading and discharging crossover headers; likewise, any piping between the outermost manifold valves and loading arms or cargo hoses to the cargo tanks, or other suitable location, prior to disconnection.

2.2.3 Piping systems carrying fluids for direct heating or cooling of cargo shall not be led outside the cargo area unless a suitable means is provided to prevent or detect the migration of cargo vapour outside the cargo area, see also Sec.13 [6.1.2] .6.

2.2.4 Relief valves discharging liquid cargo from the piping system shall discharge into the cargo tanks. Alternatively, they may discharge to the cargo vent mast if means are provided to detect and dispose of any liquid cargo that may flow into the vent system. Where required to prevent overpressure in downstream piping, relief valves on cargo pumps shall discharge to the pump suction.

2.2.5 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.

2.2.6 Means for effective drainage and gas-freeing of the cargo piping systems shall be provided. Any connections shall be by spool pieces.

3 Arrangements for cargo piping outside the cargo area

3.1 Emergency cargo jettisoning

3.1.1 If fitted, an emergency cargo jettisoning piping system shall comply with [2.2], as appropriate, and may be led aft, external to accommodation spaces, service spaces or control stations or machinery spaces, but shall not pass through them. If an emergency cargo jettisoning piping system is permanently installed, a suitable means of isolating the piping system from the cargo piping shall be provided within the cargo area.

3.2 Bow and stern loading arrangements

3.2.1 Subject to approval of Society and by the requirements of Sec.3 [8], this section and [10.1] cargo piping may be arranged to permit bow or stern loading and unloading.

3.2.2 Arrangements shall be made to allow such piping to be purged and gas-freed after use. When not in use, the spool pieces shall be removed and the pipe ends blank-flanged. The vent pipes connected with the purge shall be located in the cargo area.
3.3 Turret compartment transfer systems

3.3.1 For the transfer of liquid or vapour cargo through an internal turret arrangement located outside the cargo area, the piping serving this purpose shall comply with [2.2], as applicable, [10.2] and the following:

.1 piping shall be located above the weather deck except for the connection to the turret
.2 portable arrangements shall not be permitted, and
.3 arrangements shall be made to allow such piping to be purged and gas-freed after use. When not in use, the spool pieces for isolation from the cargo piping shall be removed and the pipe ends blank-flanged. The vent pipes connected with the purge shall be located in the cargo area.

3.4 Gas fuel piping systems

3.4.1 Gas fuel piping in machinery spaces shall comply with all applicable parts of this section in addition to the requirements of Sec.16.

4 Design pressure

4.1

4.1.1 The design pressure \( P_0 \), used to determine minimum scantlings of piping and piping system components, shall be not less than the maximum gauge pressure to which the system may be subjected in service. The minimum design pressure used shall not be less than 1 MPa, except for: open-ended lines or pressure relief valve discharge lines, where it shall be not less than the lower of 0.5 MPa, or 10 times the relief valve set pressure.

4.1.2 The greater of the following design conditions shall be used for piping, piping systems and components, based on the cargoes being carried:

.1 for vapour piping systems or components that may be separated from their relief valves and which may contain some liquid: the saturated vapour pressure at a design temperature of 45°C. Higher or lower values may be used if agreed upon by the society, see Sec.4 [3.3.2] .2, or
.2 for systems or components that may be separated from their relief valves and which contain only vapour at all times: the superheated vapour pressure at 45°C. Higher or lower values may be used if agreed upon by the society, see Sec.4 [3.3.2] .2; 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, or
.5 the maximum total discharge or loading head of the cargo piping system considering all possible pumping arrangements or the relief valve setting on a pipeline system.

Guidance note:
Note minimum design pressure \( P_0 \), requirements given in [4.1.1]

4.1.3 Those parts of the liquid piping systems that may be subjected to surge pressures shall be designed to withstand this pressure.

4.1.4 The design pressure of the outer pipe or duct of gas fuel systems shall not be less than the maximum working pressure of the inner gas pipe. Alternatively, for gas fuel piping systems with a working pressure greater than 1 MPa, the design pressure of the outer duct shall not be less than the maximum built-up
5 Cargo system valve requirements

5.1 General requirements

5.1.1 Every cargo tank and piping system shall be fitted with manually operated valves for isolation purposes as specified in this section.

5.1.2 In addition, remotely operated valves shall also be fitted, as appropriate, as part of the "Emergency Shutdown (ESD) System". The purpose of this ESD system is to stop cargo flow or leakage in the event of an emergency when cargo liquid or vapour transfer is in progress. The ESD system is intended to return the cargo system to a safe static condition so that any remedial action can be taken. Due regard shall be given in the design of the ESD system to avoid the generation of surge pressures within the cargo transfer pipework. The equipment to be shut down on ESD activation includes: manifold valves during loading or discharge, any pump or compressor, etc., transferring cargo internally or externally (e.g. to shore or another ship/barge) plus cargo tank valves, if the MARVS exceeds 0.07 MPa.

5.2 Cargo tank connections

5.2.1 All liquid and vapour connections, except for safety relief valves and liquid level gauging devices, shall have shut-off valves located as close to the tank as practicable. These valves shall provide full closure and shall be capable of local manual operation; they may also be capable of remote operation.

5.2.2 For cargo tanks with a MARVS exceeding 0.07 MPa, the above connections shall also be equipped with remotely controlled ESD valves. These valves shall be located as close to the tank as practicable. A single valve may be substituted for the two separate valves provided the valve complies with the requirements of Sec.18 [2.2] and provides full closure of the line.

5.2.3 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.

5.2.4 When the design temperature of cargo pipes is below -55°C, the connections to the tank shall be designed so as to reduce thermal stresses at cooling-down periods.

5.3 Cargo manifold connections

5.3.1 One remotely controlled ESD valve complying with Sec.18 [2.2] shall be provided at each cargo transfer connection in use to stop liquid and vapour transfer to or from the ship. Transfer connections not in use shall be isolated with suitable blank flanges.

5.3.2 If the cargo tank MARVS exceeds 0.07 MPa, an additional manual valve shall be provided for each transfer connection in use, and may be inboard or outboard of the ESD valve to suit the ship's design.

5.3.3 Excess flow valves may be used in lieu of ESD valves if the diameter of the pipe protected does not exceed 50 mm. Excess flow valves shall close automatically at the rated closing flow of vapour or liquid as specified by the manufacturer. The piping including fittings, valves and appurtenances protected by an excess flow valve shall have a capacity greater than the rated closing flow of the excess flow valve. Excess flow valves may be designed with a bypass not exceeding the area of a 1.0 mm diameter circular opening to allow equalization of pressure after a shutdown activation.
5.3.4 Cargo tank connections for gauging or measuring devices need not be equipped with excess flow valves or ESD valves, provided that the devices are constructed so that the outward flow of tank contents cannot exceed that passed by a 1.5 mm diameter circular hole.

5.3.5 All pipelines or components which may be isolated in a liquid full condition shall be protected with relief valves for thermal expansion and evaporation unless pipe is designed for the saturation pressure corresponding to the temperature of +45°C of any cargo to be transported. 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.

Guidance note:
Note that this requirement is applicable for isolated piping segment above 0.05m$^3$.

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5.3.6 All pipelines or components which may be isolated automatically due to a fire with a liquid volume of more than 0.05 m$^3$ entrapped shall be provided with PRVs (Pressure Release Valve) sized for a fire condition.

Guidance note:
Note that this requirement is applicable for remotely operated valves controlled by the ESD system.

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5.3.7 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 transfer system.

6 Cargo transfer arrangements

6.1 General

6.1.1 Where cargo transfer is by means of cargo pumps that are not accessible for repair with the tanks in service, at least two separate means shall be provided to transfer cargo from each cargo tank and the design shall be such that failure of one cargo pump or means of transfer will not prevent the cargo transfer by another pump or pumps, or other cargo transfer means.

6.1.2 The procedure for transfer of cargo by gas pressurization shall preclude lifting of the relief valves during such transfer. Gas pressurization may be accepted as a means of transfer of cargo for those tanks where the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation. If the cargo tank relief valves or set pressure are changed for this purpose, as it is permitted in accordance with Sec.8 [2.2.4] and Sec.8 [2.2.5], the new set pressure is not to exceed $P_h$ as is defined in Sec.4 [3.3].

6.1.3 Sprayers or similar devices shall be fitted for even cooling of the cargo tanks.

6.2 Vapour return connections

6.2.1 Connections for vapour return to the shore installations shall be provided.

6.3 Cargo tank vent piping systems

6.3.1 The pressure relief system shall be connected to a vent piping system designed to minimize the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, control stations and machinery spaces, or other spaces where it may create a dangerous condition.
6.4 Cargo sampling connections

6.4.1 Connections to cargo piping systems for taking cargo liquid samples shall be clearly marked and shall be designed to minimize the release of cargo vapours. For vessels permitted to carry cargoes noted as toxic in Sec.19, the sampling system shall be of a closed loop design to ensure that cargo liquid and vapour are not vented to atmosphere.

6.4.2 Liquid sampling systems shall be provided with two valves on the sample inlet. One of these valves shall be of the multi-turn type to avoid accidental opening, and shall be spaced far enough apart to ensure that they can isolate the line if there is blockage, by ice or hydrates for example.

6.4.3 On closed loop systems, the valves on the return pipe shall also comply with [6.4.2].

6.4.4 The connection to the sample container shall comply with recognized standards and be supported so as to be able to support the weight of a sample container. Threaded connections shall be tack-welded, or otherwise locked, to prevent them being unscrewed during the normal connection and disconnection of sample containers. The sample connection shall be fitted with a closure plug or flange to prevent any leakage when the connection is not in use.

6.4.5 Sample connections used only for vapour samples may be fitted with a single valve in accordance with [5], [8] and [13], and shall also be fitted with a closure plug or flange.

6.5 Cargo filters

6.5.1 The cargo liquid and vapour systems shall be capable of being fitted with filters to protect against damage by foreign objects. Such filters may be permanent or temporary, and the standards of filtration shall be appropriate to the risk of debris etc., entering the cargo system. Means shall be provided to indicate that filters are becoming blocked. Means shall be provided to isolate, depressurize and clean the filters safely.

\textit{Guidance note:}

Blockage of filters can be determined by use of the pressure indicators in the cargo system.

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7 Installation requirements

7.1 Design for expansion and contraction

7.1.1 Provision shall be made to protect the piping, piping system and components and cargo tanks from excessive stresses due to thermal movement and from movements of the tank and hull structure. The preferred method outside the cargo tanks is by means of offsets, bends or loops, but multi-layer bellows may be used if offsets, bends or loops are not practicable.

7.2 Precautions against low-temperature

7.2.1 Low temperature piping shall be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at shore connections and at pump seals, protection for the hull beneath shall be provided.

7.2.2 Protection for the hull beneath shall be provided for ships intended to carry liquefied gases with boiling points lower than -15°C. The protecting arrangement shall consist of a liquid-tight insulation, e.g. 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.

7.3 Water curtain

7.3.1 For cargo temperatures below -110°C, a water distribution system shall be fitted in way of the hull under the shore connections to provide a low-pressure water curtain for additional protection of the hull steel and the ship's side structure. This system is in addition to the requirements of Sec.11 [3.1.1] .4, and shall be operated when cargo transfer is in progress.

7.4 Bonding

7.4.1 Where tanks or cargo piping and piping equipment are separated from the ship's structure by thermal isolation, provision shall be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections shall be electrically bonded. Except where bonding straps are used, it shall be demonstrated that the electrical resistance of each joint or connection is less than 1MΩ.

Guidance note:
The value of resistance 1MΩ 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.

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8 Piping fabrication and joining details

8.1 General

8.1.1 The requirements of this section apply to piping inside and outside the cargo tanks. Relaxation from these requirements may be accepted by the society for piping inside cargo tanks and open-ended piping.

8.1.2 In general the piping system shall be joined by welding with a minimum of flange connections. Gaskets shall be of a type designed to prevent blow-out.

Guidance note:
Gasket should prevent blow out by having a design like stainless spiral wound, recess flanges, protective stainless steel ring etc.

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8.2 Direct connections

8.2.1 The following direct connection of pipe lengths, without flanges, may be considered:

.1 butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than -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 backup on the first pass. For design pressures in excess of 1 MPa and design temperatures of -10°C or colder, backing rings shall be removed.
.2 slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, shall only be used for instrument lines and open-ended lines with an external diameter of 50 mm or less and design temperatures not colder than -55°C, and

.3 screwed couplings complying with recognized standards shall only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

8.3 Flanged connections

8.3.1 Flanges in flange connections shall be of the welded neck, slip-on or socket welded type.

8.3.2 Flanges shall comply with recognized standards for their type, manufacture and test. For all piping except open ended, the following restrictions apply:

.1 for design temperatures colder than -55°C, only welded neck flanges shall be used, and

.2 for design temperatures colder than -10°C, slip-on flanges shall not be used in nominal sizes above 100 mm and socket welded flanges shall not be used in nominal sizes above 50 mm.

8.4 Expansion joints

8.4.1 Where bellows and expansion joints are provided in accordance with [7.1], the following requirements apply:

.1 if necessary, bellows shall be protected against icing and

.2 slip joints shall not be used except within the cargo tanks.

8.5 Other connections

8.5.1 Piping connections other than those mentioned above, may be accepted upon consideration in each case.

9 Welding, post-weld heat treatment and non-destructive testing

9.1 General

9.1.1 Welding shall be carried out in accordance with Sec.6 [5].

9.2 Post-weld heat treatment

9.2.1 Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Society may waive the requirements for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.
9.3 Non-destructive testing

9.3.1 In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the requirements of this paragraph, the following tests shall be required:

.1 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with design temperatures colder than -10°C, or with inside diameters of more than 75 mm, or wall thicknesses greater than 10 mm

.2 when such butt welded joints of piping sections are made by automatic welding procedures upon special approved by Society, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10% of each joint. If defects are revealed, the extent of examination shall be increased to 100% and shall include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to enable Society to assess the ability of the manufacturer to produce satisfactory welds consistently, and

.3 for other butt-welded joints of pipes not covered by .1 and .2, spot radiographic or ultrasonic inspection 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 subjected to radiographic or ultrasonic inspection.

9.3.2 The radiographs shall be assessed according to ISO 10675 and shall at least meet the criteria for level 2 on general areas and level 1 on critical areas as given in Pt.2 Ch.4 Sec.7 [5.1].

10 Installation requirements for cargo piping outside the cargo area

10.1 Bow and stern loading arrangements

10.1.1 The following provisions shall apply to cargo piping and related piping equipment located outside the cargo area:

.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 weather decks and shall be at least 0.8 m inboard, except for athwartships shore connection piping. Such piping shall be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location it shall also be capable of being separated, by means of a removable spool piece and blank flanges, when not in use, and

.2 the piping shall be full penetration butt-welded and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at the shore connection.

.3 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.
10.2 Turret compartment transfer systems

10.2.1 The following provisions shall apply to liquid and vapour cargo piping where it is run outside the cargo area:

.1 cargo piping and related piping equipment outside the cargo area shall have only welded connections, and
.2 the piping shall be full penetration butt welded, and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at connections to cargo hoses and the turret connection.

10.3 Gas fuel piping

10.3.1 Gas fuel piping, as far as practicable, shall have welded joints. Those parts of the gas fuel piping that are not enclosed in a ventilated pipe or duct according to Sec.16 [4.3], and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be subjected to full radiographic or ultrasonic inspection.

11 Piping system component requirements

11.1 General

11.1.1 Piping scantlings: piping systems shall be designed in accordance with this chapter.

11.1.2 The following criteria shall be used for determining pipe wall thickness. The wall thickness of pipes shall not be less than, in mm:

\[
t = \frac{(t_o + b + c)}{(1 - \frac{a}{100})}
\]

where \( t_o \) is the theoretical thickness in mm, determined by the following formula

\[
t_o = \frac{PD}{(2Ke + P)}
\]

with:

- \( P \) = design pressure in MPa referred to in [4]
- \( D \) = outside diameter in mm
- \( K \) = allowable stress in N/mm² referred to in [11.2]
- \( e \) = efficiency factor equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases, an efficiency factor of less than 1.0, in accordance with recognized standards, may be required, depending on the manufacturing process.
allowance for bending in mm. The value of $b$ shall be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, $b$ shall be:

$$b = b = \frac{Dt_0}{2.5r}$$

with:

- $r = \text{mean radius of the bend in mm}$
- $c = \text{corrosion allowance in mm}. \text{If corrosion or erosion is expected, the wall thickness of the piping shall be increased over that required by other design requirements. This allowance shall be consistent with the expected life of the piping, and}$
- $a = \text{negative manufacturing tolerance for thickness in }\%.$

11.1.3 The minimum thickness shall be in accordance with Pt.4 Ch.6 Sec.8 Table 3 for austenitic stainless steel, and Table 2 “Pipes in general” for C-Mn steel.

11.1.4 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness shall be increased over that required by [11.1.2] or, if this is impracticable or would cause excessive local stresses, these loads may be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to: supporting structures, ship deflections, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.

11.2 Allowable stress

11.2.1 For pipes, the allowable stress to be considered in the formula for $t$ in [11.2] is the lower of the following values:

$$K = \min\left(\frac{R_m}{A}, \frac{R_{eH}}{B}\right)$$

where:

- $R_m = \text{specified minimum tensile strength at room temperature in N/mm}^2 \text{ as given in Sec.1};$ and
- $R_{eH} = \text{specified minimum yield stress at room temperature in N/mm}^2 \text{ as given in Sec.1}.$

If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

The values of $A$ and $B$ shall not be taken less than $A=2.7$ and $B=1.8.$

11.2.2 For pipes made of materials other than steel, the allowable stress shall be considered by the Society.
11.3 High pressure gas fuel outer pipes or ducting scantlings

11.3.1 In fuel gas piping systems of design pressure greater than the critical pressure, the tangential membrane stress of a straight section of pipe or ducting shall not exceed the tensile strength divided by 1.5, i.e. $R_m/1.5$ when subjected to the design pressure specified in [4]. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

**Guidance note:**
For high-pressure piping the design pressure of the ducting should be taken as the higher of the following:
- the maximum built up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space
- local instantaneous peak pressure in way of the rupture $p^*$: this pressure shall be taken as the critical pressure and is given by the following expression:

$$p = \frac{p_0}{k}$$

$p_0$ = maximum working pressure of the inner pipe

$k = \frac{C_p}{C_v}$ constant pressure specific heat divided by the constant volume specific heat

$k = 1.31$ for CH4

The tangential membrane stress of a straight pipe should not exceed the tensile strength divided by 1.5 ($R_m/1.5$) when subjected to the above pressure. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes. As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports must then be submitted.

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11.4 Stress analysis

11.4.1 When the design temperature is $-110^\circ\text{C}$ or lower, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship for each branch of the piping system shall be submitted. For temperatures above $-110^\circ\text{C}$, a stress analysis may be required by the Society in relation to such matters as the design or stiffness of the piping system and the choice of materials. In any case, consideration shall be given to thermal stresses even though calculations are not submitted. The analysis may be carried out according to Pt.4 Ch.6 or to a recognised code of practice accepted by the Society.

11.5 Flanges, valves and fittings

11.5.1 Flanges, valves and other fittings shall comply with recognized standards, taking into account the material selected and the design pressure defined in [4]. For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted.

11.5.2 For flanges not complying with a recognized standard, the dimensions of flanges and related bolts shall be to the satisfaction of the Society.

11.5.3 All emergency shutdown valves shall be of the “fire closed” type, see [13.1.1] and Sec.18 [2.2].

**Guidance note:**
Fire closed means valve shall be fail close type and made of materials having melting temperature above 925°C.

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11.5.4 The design and installation of expansion bellows shall be in accordance with recognized standards and be fitted with means to prevent damage due to over-extension or compression.

**Guidance note:***

Means to prevent damage due to over-extension and compression i.e. anchoring supports forward and aft are to be fitted.

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11.6 Ships' cargo hoses

11.6.1 Liquid and vapour hoses used for cargo transfer shall be compatible with the cargo and suitable for the cargo temperature.

11.6.2 Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, shall be designed for a bursting pressure not less than five times the maximum pressure the hose will be subjected to during cargo transfer.

11.6.3 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 upper and lower 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 of 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 services other than ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure shall not be less than 1 MPa.

12 Materials

12.1 General

12.1.1 The choice and testing of materials used in piping systems shall comply with the requirements of section 6, taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of material of open-ended vent piping, providing the temperature of the cargo at the pressure relief valve setting is not lower than -55°C, and provided no liquid discharge to the vent piping can occur. Similar relaxations may be permitted under the same temperature conditions to open-ended piping inside cargo tanks, excluding discharge piping and all piping inside membrane and semi-membrane tanks.

12.1.2 Materials having a melting point (solidus temperature) 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.

12.2 Cargo piping insulation system

12.2.1 Cargo piping systems shall be provided with a thermal insulation system as required to minimize heat leak into the cargo during transfer operations and to protect personnel from direct contact with cold surfaces.

12.2.2 Where applicable, due to location or environmental conditions, insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage.
12.2.3 Where the cargo piping system is of a material susceptible to stress corrosion cracking in the presence of a salt-laden atmosphere, adequate measures to avoid this occurring shall be taken by considering material selection, protection of exposure to salty water and/or readiness for inspection.

13 Testing and construction

13.1 Valves

13.1.1 Prototype testing
Each type of valve intended to be used at a working temperature below -55°C shall be subject to design assessment and the following type tests witnessed by Society’s representative:

.1 each size and type of valve shall be subjected to seat tightness testing over the full range of operating pressures for bi-directional flow and cryogenic temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates shall be to the requirements of the Society. During the testing, satisfactory operation of the valve shall be verified.

.2 the flow or capacity shall be certified to a recognized standard for each size and type of valve

Guidance note:
Normally only applicable for cargo piping pressure relief valves.

.3 pressurized components shall be pressure tested to at least 1.5 times the design pressure

.4 for emergency shutdown valves, with materials having melting temperatures (solidus temperature) lower than 925°C, the type testing shall include a fire test to a standard acceptable to the Society

.5 for valves other than safety valves, a seat and stem leakage test at a pressure equal to 1.1 times the design pressure.

13.1.2 Production testing
All valves are to be tested at the plant of manufacturer in the presence of the Society's representative. Testing is to include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves as given in [13.1.1].3, seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves. In addition, cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55°C. The set pressure of safety valves is to be tested at ambient temperature.

As an alternative to the above, if so requested by the relevant Manufacturer, the certification of a valve may be issued subject to the following:

— the valve has been approved as required by [13.1.1] for valves intended to be used at a working temperature below -55°C, and
— the manufacturer has a recognized quality system that has been assessed and certified by the Society subject to periodic audits, and
— the quality control plan contains a provision to subject each valve to a hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves and seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves. The set pressure of safety valves is to be tested at ambient temperature. The manufacturer is to maintain records of such tests, and
— cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55°C.

Guidance note:
Cargo tank pressure relief valves are covered separately in Sec.8 [2].
13.2 Expansion bellows

13.2.1 The following prototype tests shall be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and where required by the Society, on those installed within the cargo tanks:

.1 elements of the bellows, not pre-compressed, shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than five minutes

.2 a pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation

.3 a cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature, and

.4 a cyclic fatigue test (ship deformation) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2 000 000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

13.3 Piping system testing requirements

13.3.1 The requirements of this section shall apply to piping inside and outside the cargo tanks.

13.3.2 After assembly, all cargo and process piping shall be subjected to a strength test with a suitable fluid. The test pressure shall be at least 1.5 times the design pressure (1.25 times the design pressure where the test fluid is compressible) for liquid lines and 1.5 times the maximum system working pressure (1.25 times the maximum system working pressure where the test fluid is compressible) for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board shall be tested to at least 1.5 times the design pressure.

Guidance note:
If testing is done with a compressible fluid, safety considerations must be taken.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

13.3.3 After assembly on board, each cargo and process piping system shall be subjected to a leak test using air, or other suitable medium to a pressure depending on the leak detection method applied.

13.3.4 In double wall gas-fuel piping systems the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

13.3.5 All piping systems, including valves, fittings and associated equipment for handling cargo or vapours, shall be tested under normal operating conditions not later than at the first loading operation, in accordance with approved programme.

13.4 Emergency shutdown valves

The closing characteristics of emergency shutdown valves used in liquid cargo piping systems shall be tested to demonstrate compliance with Sec.18 [2.2.3] The ESD valves with actuators shall be function tested when the valve is subjected to full working pressure. This testing may be carried out on board after installation.
13.5 Pumps

13.5.1 Prototype testing
Each size and type of pump is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of the Society's representative. In lieu of prototype testing, satisfactory in-service experience, of an existing pump submitted by the manufacturer may be considered. Prototype testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. In addition, for shaft driven deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the minimum design temperature. The full length of shafting is not required for the spin test, but must be of sufficient length to include at least one bearing and sealing arrangements.

After completion of tests, the pump is to be opened out for examination.

13.5.2 Production testing
All pumps are to be tested at the plant of manufacturer in the presence of the Society's representative. Testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water.

As an alternative to the above, if so requested by the relevant Manufacturer, the certification of a pump may be issued subject to the following:

— The pump has been approved as required by [13.5.1] or [13.5.2], and
— The manufacturer has a recognised quality system that has been assessed and certified by the Society subject to periodic audits, and
— The quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.

13.6 Cargo process pressure vessels

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

13.6.2 Materials in cargo process pressure vessels, welding procedure tests and production weld tests shall be in accordance with Sec.6, while pressure testing shall be in accordance Sec.22 [7.1.1] as type C tank.
SECTION 6 MATERIALS OF CONSTRUCTION, QUALITY CONTROL AND MARKING

1 General

1.1 Definitions

1.1.1 Where reference is made to A, B, D, E, AH, DH, EH and FH hull structural steels, these steel grades are hull structural steels according to Pt.2 Ch.2 Sec.2 ("H" means high strength steels of corresponding grade).

1.1.2 A piece is the rolled product from a single slab or billet or from a single ingot, if this is rolled directly into plates, strips, sections or bars.

1.1.3 A batch is the number of items or pieces to be accepted or rejected together, on the basis of the tests to be carried out on a sampling basis. The size of a batch is given in rules Pt.2 Ch.4.

1.1.4 Normalizing rolling (NR) and controlled rolling (CR) is a rolling procedure in which the final rolling temperature is controlled within a certain range above the Ar3 temperature so that the austenite completely re-crystallises. After the final pass, air cooling produces a fine grained ferrite-pearlite microstructure comparable to that obtained after normalising heat treatment.

1.1.5 Thermo-mechanical rolling (TM) and thermo-mechanical controlled processing (TMCP) is a rolling procedure in which both the rolling temperatures and reductions and, when used, accelerated cooling conditions are controlled. Generally, a high proportion of the rolling reduction is carried out close to the Ar3 temperature and may involve the rolling in the austenite-ferrite dual phase temperature region. After the final pass, either air cooling or accelerated cooling, excluding quenching, is used. Final rolling in the same temperature range as used for NR followed by accelerated cooling is considered to be a TM procedure. Unlike NR the properties conferred by TM cannot be reproduced by subsequent normalising heat treatment.

1.1.6 Accelerated cooling (AcC) is a process that aims to improve mechanical properties by controlled cooling with rates higher than air cooling, immediately after the final TM operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalizing or other heat treatment.

2 Scope

2.1 General requirements

2.1.1 This section gives the requirements for metallic and non-metallic materials used in the construction of the cargo system. This includes requirements for joining processes, production process, personnel qualification, NDT and inspection and testing including production testing. The requirements for rolled materials, forgings and castings are given in [4] and Table 1 to Table 5. The requirements for weldments are given in [5], and the guidance for non-metallic materials is given in App.A. Material manufacturers shall be approved by Society according to the requirements of Pt.2, ensuring that a quality assurance/quality control program is implemented.

2.1.2 The manufacture, testing, inspection and documentation shall be in accordance with Pt.2.

2.1.3 Where post-weld heat treatment is specified or required, the properties of the base material shall be determined in the heat-treated condition, in accordance with Pt.2 and the applicable table of this section. The weld properties shall be determined in the heat treated condition in accordance with Pt.2 and in accordance
with [5]. However, in cases where a post-weld heat treatment is applied the test requirements may be modified at the discretion of the Society.

2.1.4 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.

2.1.5 Steels for low temperature application shall follow the requirements of Pt.2 Ch.2 in addition to the requirements given herein.

2.1.6 Fabrication (welding, NDT, etc.) shall follow the requirements of Pt.2 Ch.4 in addition to the requirements given herein.

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

2.1.8 For certain cargoes as specified in Sec.19, special requirements for materials apply.

2.1.9 Thermal insulation materials shall be in compliance with the requirements of Sec.4 [2.8].

3 General test requirements and specifications

3.1 Tensile tests

3.1.1 Tensile testing shall be carried out in accordance with Pt.2 Ch.1.

3.1.2 Tensile strength, yield stress and elongation shall meet the requirements of Pt.2 Ch.2, unless otherwise approved by the Society.
3.2 Toughness tests

3.2.1 Acceptance tests for metallic materials shall include Charpy V-notch toughness tests, unless otherwise approved by the Society.

The largest size Charpy V-notch specimens possible for the material thickness shall be machined with the centreline of the specimens (C/L specimen) located as near as practicable to a line midway between the surface and the centre of the plate thickness, and with the notch direction perpendicular to the surface as shown in Figure 1 and Figure 2. The distance from the surface of the material to the specimen shall be approximately 1 to 2 mm.

The specified Charpy V-notch requirements are minimum average energy values for three full size (10 mm × 10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens shall be in accordance with Pt.2 Ch.1. The testing and requirements for specimen width smaller than 5 mm shall be in accordance with a recognized standard. Minimum average values for subsized specimens shall be:

<table>
<thead>
<tr>
<th>Charpy V-notch specimen size (mm)</th>
<th>Minimum average energy of three specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 x 10</td>
<td>KV</td>
</tr>
<tr>
<td>10 x 7.5</td>
<td>5/6 KV</td>
</tr>
<tr>
<td>10 x 5</td>
<td>2/3 KV</td>
</tr>
</tbody>
</table>

where:

\[ KV = \text{the energy values (J) specified in Table 1 to Table 4.} \]

Only one individual value may be below the specified average value, provided it is not less than 70 % of that value.

3.2.2 For base metal, the test specimen location and notch location is indicated in Figure 1.

![Figure 1 Orientation of base metal test specimen](image)
3.2.3 For a weld test specimen, test specimen location and notch locations are indicated in Figure 2. For double-V butt welds, the specimens shall be machined from the side containing the last weld run.

Figure 2 Orientation of weld test specimen

The specimens shall be taken at each of the following notch locations as shown in Figure 2:

1. centerline of the weld  
2. fusion line  
3. in heat-affected zone (HAZ), 1 mm from the fusion line  
4. in HAZ, 3 mm from the fusion line  
5. in HAZ, 5 mm from the fusion line

3.3 For retesting, see Pt.2 Ch.1. Bend test

3.3.1 The bend test may be omitted as a base material acceptance test, but is required for weld tests. Where a bend test is performed, this shall be done in accordance with Pt.2 Ch.1.

3.3.2 The bend tests for the welds shall be transverse to the welding direction, and may be face, root or side bend test at the discretion of the Society. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels. For bend tests of welds, reference is given to Pt.2 Ch.4.

3.4 Section observation and other testing

3.4.1 Macrosection, microsection observations and hardness tests may also be required by the Society, and they shall be carried out in accordance with Pt.2 Ch.1, where required.
4 Requirements for metallic materials

4.1 General requirements for metallic materials

4.1.1 Metallic materials shall in general follow the requirements of Pt.2 Ch.2 in addition to the requirements given herein.

4.1.2 The requirements for materials of construction are shown in the tables as follows:

1. Table 1: plates, pipes (seamless and welded), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C

2. Table 2: plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to -55°C

3. Table 3: plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below -55°C and down to -165°C

4. Table 4: pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0°C and down to -165°C

5. Table 5: plates and sections for hull structures required by Sec.4 [5.1.1].2 and Sec.4 [5.1.1].3
Table 1: Plates, pipes (seamless and welded) 1) 2), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C

<table>
<thead>
<tr>
<th>CHEMICAL COMPOSITION AND HEAT TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>° carbon-manganese steel</td>
</tr>
<tr>
<td>° fully killed fine grain steel</td>
</tr>
<tr>
<td>° small additions of alloying elements by agreement with the Society</td>
</tr>
<tr>
<td>° composition limits shall follow the relevant requirements of Pt.2.</td>
</tr>
<tr>
<td>° normalized, or quenched and tempered 4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling frequency</td>
</tr>
<tr>
<td>° plates</td>
</tr>
<tr>
<td>each “piece” to be tested</td>
</tr>
<tr>
<td>° sections and forgings</td>
</tr>
<tr>
<td>each “batch” to be tested.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>° tensile properties</td>
</tr>
<tr>
<td>specified minimum yield stress not to exceed 410 N/mm²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Toughness (Charpy V-notch test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>° plates</td>
</tr>
<tr>
<td>transverse test pieces. Minimum average energy value (KV) 27J</td>
</tr>
<tr>
<td>° sections and forgings</td>
</tr>
<tr>
<td>longitudinal test pieces. Minimum average energy (KV) 41J</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thickness t in mm</th>
<th>Test temperature in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>t ≤ 20</td>
<td>0</td>
</tr>
<tr>
<td>20 &lt; t ≤ 40 3)</td>
<td>-20</td>
</tr>
</tbody>
</table>

1) For seamless pipes and fittings normal practice applies. The use of longitudinally and spirally welded pipes shall be specially approved by the Society.
2) Charpy V-notch impact tests are not required for pipes.
3) This table is generally applicable for material thicknesses up to 40 mm. Proposals for greater thicknesses shall be approved by the Society.
4) Steels with delivery conditions NR (CR) or TM may be used as an alternative.
5) Materials with specified minimum yield stress exceeding 410 N/mm² may be approved by the Society. For these materials, particular attention shall be given to the hardness of the welds and heat affected zones.
Table 2 Plates, sections and forgings ¹ for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to -55°C maximum thickness 25 mm ²

<table>
<thead>
<tr>
<th>CHEMICAL COMPOSITION AND HEAT TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>carbon-manganese steel</td>
</tr>
<tr>
<td>fully killed, aluminium treated fine grain steel</td>
</tr>
<tr>
<td>chemical composition (ladle analysis)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>S</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.16% max ³)</td>
<td>0.7-1.60%</td>
<td>0.1-0.50%</td>
<td>0.025% max</td>
<td>0.025% max</td>
</tr>
</tbody>
</table>

Optional additions: alloys and grain refining elements may be generally in accordance with the following:

<table>
<thead>
<tr>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>Cu</th>
<th>Nb</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8% max</td>
<td>0.25% max</td>
<td>0.08% max</td>
<td>0.35% max</td>
<td>0.05% max</td>
<td>0.1% max</td>
</tr>
</tbody>
</table>

Al content total 0.02% min (Acid soluble 0.015% min)

<table>
<thead>
<tr>
<th>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling frequency</td>
</tr>
<tr>
<td>plates</td>
</tr>
<tr>
<td>each &quot;piece&quot; to be tested</td>
</tr>
<tr>
<td>sections and forgings</td>
</tr>
<tr>
<td>each &quot;batch&quot; to be tested</td>
</tr>
</tbody>
</table>

| Mechanical properties                         |
| tense properties                               |
| specified minimum yield stress not to exceed  |
| 410 N/mm²                                      |

| Toughness (Charpy V-notch test)               |
| plates                                        |
| transverse test pieces. minimum average       |
| energy value (KV) 27J                         |
| sections and forgings                         |
| longitudinal test pieces. minimum average     |
| energy (KV) 41J                               |

| test temperature                               |
| 5°C below the design temperature or -20°C, whichever is lower |
1) The Charpy V-notch and chemistry requirements for forgings for low temperature service are given in Pt.2 Ch.2.

2) For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows:

<table>
<thead>
<tr>
<th>Material thickness in mm</th>
<th>Test temperature in °C</th>
</tr>
</thead>
<tbody>
<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>
<tr>
<td>t &gt; 40</td>
<td>temperature approved by the Society</td>
</tr>
</tbody>
</table>

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

Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°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) Steels with delivery conditions NR (CR) or TM may be used as an alternative.

5) Materials with specified minimum yield stress exceeding 410 N/mm² may be approved by the Society. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

**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 3 may be necessary.
Table 3 Plates, sections and forgings  for cargo tanks, secondary barriers and process pressure vessels for design temperatures below -55°C and down to -165°C  maximum thickness 25 mm

<table>
<thead>
<tr>
<th>Minimum design temperature in °C</th>
<th>Chemical composition See note 5 and heat treatment</th>
<th>Impact test temperature in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>-60</td>
<td>1.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP 6)</td>
<td>-65</td>
</tr>
<tr>
<td>-65</td>
<td>2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP 6) 7)</td>
<td>-70</td>
</tr>
<tr>
<td>-90</td>
<td>3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP 6) 7)</td>
<td>-95</td>
</tr>
<tr>
<td>-105</td>
<td>5% nickel steel – normalized or normalized and tempered or quenched and tempered 6) 7) 8)</td>
<td>-110</td>
</tr>
<tr>
<td>-165</td>
<td>9% nickel steel – double normalized and tempered or quenched and tempered 6)</td>
<td>-196</td>
</tr>
<tr>
<td>-165</td>
<td>austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated 9)</td>
<td>-196</td>
</tr>
<tr>
<td>-165</td>
<td>aluminium alloys; such as type 5083 annealed</td>
<td>not required</td>
</tr>
<tr>
<td>-165</td>
<td>austenitic Fe-Ni alloy (36% nickel). Heat treatment as agreed</td>
<td>not required</td>
</tr>
</tbody>
</table>

**TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS**

<table>
<thead>
<tr>
<th>Sampling frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>plates each “piece” to be tested</td>
</tr>
<tr>
<td>sections and forgings each “batch” to be tested</td>
</tr>
</tbody>
</table>

**Toughness (Charpy V-notch test)**

| plates transverse test pieces. minimum average energy value (KV) 27J |
| sections and forgings longitudinal test pieces. minimum average energy (KV) 41J |
1) The impact test required for forgings used in critical applications shall be subject to special consideration by the Society.

2) The requirements for design temperatures below -165°C shall be specially agreed with the Society.

3) For materials 1.5% Ni, 2.25% Ni, 3.5% Ni and 5% Ni, with thicknesses greater than 25 mm, the impact tests shall be conducted as follows:

<table>
<thead>
<tr>
<th>Material thickness (mm)</th>
<th>Test temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 &lt; t ≤ 30</td>
<td>10°C below design temperature</td>
</tr>
<tr>
<td>30 &lt; t ≤ 35</td>
<td>15°C below design temperature</td>
</tr>
<tr>
<td>35 &lt; t ≤ 40</td>
<td>20°C below design temperature</td>
</tr>
</tbody>
</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 requirements (e.g. test temperature, test specimen location and acceptance criteria) shall be specially considered.

4) For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used. However, for thickness more than 40 mm, see last paragraph of note 3.

5) The chemical composition limits shall be in accordance with Pt.2 Ch.2.

6) Nickel steels with delivery condition TM shall be specially approved by the Society.

7) A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Society.

8) A specially heat treated 5% nickel steel, for example triple heat treated 5% nickel steel, may be used down to -165°C, provided that the impact tests are carried out at -196°C.

9) The impact test may be omitted, subject to agreement with the Society.
Table 4 Pipes (seamless and welded)\(^1\), forgings\(^2\) and castings\(^2\) for cargo and process piping for design temperatures below 0°C and down to -165°C\(^3\) maximum thickness 25 mm

<table>
<thead>
<tr>
<th>Minimum design temperature in °C</th>
<th>Chemical composition(^5) and heat treatment</th>
<th>Impact test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Test temp. in °C</td>
</tr>
<tr>
<td>-55</td>
<td>carbon-manganese steel. Fully killed fine grain. Normalized or as agreed(^6)</td>
<td>-4)</td>
</tr>
<tr>
<td>-65</td>
<td>2.25% nickel steel. Normalized, normalized and tempered or quenched and tempered(^6)</td>
<td>-70</td>
</tr>
<tr>
<td>-90</td>
<td>3.5% nickel steel. Normalized, normalized and tempered or quenched and tempered(^6)</td>
<td>-95</td>
</tr>
<tr>
<td>-165</td>
<td>9% nickel steel(^7). Double normalized and tempered or quenched and tempered</td>
<td>-196</td>
</tr>
<tr>
<td></td>
<td>austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347. Solution treated(^8)</td>
<td>-196</td>
</tr>
<tr>
<td></td>
<td>aluminium alloys; such as type 5083 annealed</td>
<td>not required</td>
</tr>
</tbody>
</table>

**TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS**

- **Sampling frequency**
  - each “batch” to be tested

- **Toughness (Charpy V-notch test)**
  - impact test: longitudinal test pieces

**Notes**

1) The use of longitudinally or spirally welded pipes shall be specially approved by the Society.
2) The requirements for forgings and castings for low temperature service are given in Pt.2 Ch.2.
3) The requirements for design temperatures below -165°C shall be specially agreed with the Society.
4) The test temperature shall be 5°C below the design temperature or -20°C, whichever is lower.
5) The composition limits shall be in accordance with Pt.2 Ch.2, steels for low temperature service.
6) A lower design temperature may be specially agreed with the Society for quenched and tempered materials.
7) This grade is not suitable for castings.
8) Impact tests may be omitted, subject to agreement with the Society.
Table 5 Plates and sections for hull structures required by Sec.4 [5.1.1] .2 and Sec.4 [5.1.1] .3

<table>
<thead>
<tr>
<th>Steel significant temperature in °C</th>
<th>Maximum thickness (mm) for steel grades in accordance with Pt.2 Ch.2 Sec.1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VL A</td>
</tr>
<tr>
<td>0 and above 2) -5 and above 3)</td>
<td>Normal practice</td>
</tr>
<tr>
<td>Down to -5</td>
<td>15</td>
</tr>
<tr>
<td>Down to -10</td>
<td>x</td>
</tr>
<tr>
<td>Down to -20</td>
<td>x</td>
</tr>
<tr>
<td>Down to -30</td>
<td>x</td>
</tr>
<tr>
<td>Below -30</td>
<td>In accordance with Table 2 except that the thickness limitation given in Table 2 and in footnote 2 of that table does not apply.</td>
</tr>
</tbody>
</table>

«x» means steel grade not to be used.
1) H means "High strength steel".
2) for the purpose of Sec.4 [5.1.1] .3
3) for the purpose of Sec.4 [5.1.1] .2

5 Welding of metallic materials and non-destructive testing

5.1 General

5.1.1 Fabrication (welding, NDT, etc.) shall in general follow the requirements of Pt.2 Ch.4 in addition to the requirements given herein.

5.1.2 This section shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steels, but these tests may be adapted for other materials. At the discretion of the Society, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

5.2 Welding consumables

5.2.1 Consumables intended for welding of cargo tanks shall be type approved by the Society. See [5.1.1]

5.3 Welding procedure tests for cargo tanks and process pressure vessels

5.3.1 For all butt welds and essential fillet welds of cargo tanks and process pressure vessels, approved welding procedure specifications (WPS) qualified by welding procedure qualification test (WPQT) is required, ref. Pt.2 Ch.4.

The test assemblies shall be representative of:

.1 each type of base material
.2 each type of consumable and welding process, and
.3 each welding position.
5.3.2 For butt welds in plates, the test assemblies shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test shall be in accordance with Pt.2 Ch.4. Radiographic or ultrasonic testing may be performed at the option of the fabricator or the Society. Fillet welding procedure tests are to be in accordance with the Society’s practice. In such cases consumables are to be selected which exhibit satisfactory impact properties.

5.3.3 The following welding procedure tests for cargo tanks and process pressure vessels shall be carried out in accordance with [3], with specimens made from each test assembly:

1. cross-weld tensile tests;
2. longitudinal all-weld testing in accordance with Pt.2 Ch.4, where required by the Society
3. transverse bend tests, which may be face, root or side bends. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels
4. one set of three Charpy V-notch impact tests, generally at each of the following locations, as shown in Table 2:
   1. centerline of the weld
   2. fusion line
   3. 1 mm from the fusion line
   4. 3 mm from the fusion line
   5. 5 mm from the fusion line, and
5. macro section, micro section and hardness survey may also be required by the Society.

5.3.4 Each test shall satisfy the following requirements:

1. tensile tests: cross-weld tensile strength shall not be less than the specified minimum tensile strength for the appropriate parent materials. The Society may also require that the transverse weld tensile strength is not to be less than the specified minimum tensile strength (SMTS) for the weld metal, in cases where the weld metal has a lower SMTS than that of the parent material. For aluminium alloys, reference shall be made to Sec.4 [4.3.2] with regard to the requirements for weld metal strength of under-matched welds (where the weld metal has a lower tensile strength than the parent metal). In every case, the position of fracture shall be recorded for information
2. bend tests: no fracture is acceptable after a 180° bend over a former of a diameter maximum four times the thickness of the test pieces, unless stricter requirements are specially required by or agreed with the Society, and
3. Charpy V-notch impact tests: Charpy V-notch tests shall be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (KV), shall be no less than 27 J. The weld metal requirements for subsize specimens and single energy values shall be in accordance with [3.2]. The results of fusion line and heat-affected zone impact tests shall show a minimum average energy (KV) in accordance with the transverse or longitudinal requirements of the base material, whichever is applicable, and for subsize specimens, the minimum average energy (KV) shall be in accordance with [3.2]. If the material thickness does not permit machining of either full-size or standard subsize specimens, the testing procedure and acceptance standards shall be approved by the Society.

5.3.5 Procedure tests for fillet welding shall be in accordance with recognized standards. In such cases, consumables shall be so selected that exhibit satisfactory impact properties.

5.4 Welding procedure tests for piping

5.4.1 Welding procedure tests for piping shall be carried out and shall be similar to those detailed for cargo tanks in [5.3]. Unless otherwise specially agreed with the Society, the tests shall satisfy the requirements given in [5.3.5].
5.5 Production weld tests

5.5.1 For all cargo tanks and process pressure vessels, except integral and membrane tanks, production weld tests shall generally be performed for approximately each 50 m of butt-weld joints and shall be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks shall be performed, except that the number of tests may be reduced subject to agreement with the Society. Tests, other than those specified in [5.5.2] to [5.5.5] may be required for cargo tanks or secondary barriers at the discretion of the Society.

5.5.2 The production tests for type A and type B independent tanks and semi-membrane tanks shall include the following tests: Bend tests and, where required for procedure tests, one set of three Charpy V-notch tests. The tests shall be made for each 50 m of weld. The Charpy V-notch tests shall be made with specimens having the notch alternately located in the center of the weld and in the heat-affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches shall be in the center of the weld.

5.5.3 For type C independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in [5.5.2]. The test requirements are specified in [5.3.5].

5.5.4 The quality assurance/quality control programme shall ensure the continued conformity of the production welds as defined in the fabricators quality manual.

5.5.5 Production tests for integral and membrane tanks are to be specially agreed with the Society. The test requirements for integral and membrane tanks are the same as the applicable test requirements listed in [5.3].

5.6 Non-destructive testing

5.6.1 All test procedures and acceptance standards shall be in accordance with Pt.2 Ch.4, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall be used, in principle, to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but, in addition, supplementary radiographic testing at selected locations shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained.

5.6.2 For type A independent tanks and semi-membrane tanks, where the design temperature is below -20°C, and for type B independent tanks, regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks shall be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in [5.6.1].

5.6.3 Where the design temperature is higher than -20°C, all full penetration butt welds in way of intersections and at least 10 % of the remaining full penetration welds of tank structures shall be subjected to radiographic testing or ultrasonic testing under the same conditions as described in [5.6.1].

5.6.4 In each case, the remaining tank structure, including the welding of stiffeners and other fittings and attachments, shall be examined by magnetic particle or dye penetrant methods, as considered necessary.

5.6.5 For type C independent tanks, the extent of non-destructive testing shall be total or partial according to recognized standards, but the controls to be carried out shall not be less than the following:

1. total non-destructive testing referred to in Sec.22 [2.8.4]:

Radiographic testing:
Part 5 Chapter 7 Section 6

5.6.6 The quality assurance/quality control programme shall ensure the continued conformity of the non-destructive testing of welds, as defined in the fabricators quality manual.

5.6.7 Inspection of piping shall be carried out in accordance with the requirements of Sec.5.

5.6.8 The secondary barrier shall be non-destructive tested for internal defects as considered necessary. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell shall be tested by radiographic testing.

6 Other requirements for construction in metallic materials

6.1 General

6.1.1 Inspection and non-destructive testing of welds shall be in accordance with the requirements of [5.5] and [5.6]. Where higher standards or tolerances are assumed in the design, they shall also be satisfied.

6.2 Independent tank

6.2.1 For type C tanks and type B tanks primarily constructed of bodies of revolution, the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, shall comply with recognized standards as accepted by the Society. The tolerances shall also be related to the buckling analysis referred to in Sec.21 [3.2.3] and Sec.22 [2.1.3].

6.2.2 For type C tanks of carbon and carbon-manganese steel, post-weld heat treatment shall be performed after welding, if the design temperature is below -10°C. Post-weld heat treatment in all other cases and for materials other than those mentioned above shall be to recognized standards. The soaking temperature and holding time shall be to the recognized standards.
6.2.3 In the case of type C tanks and 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 and subject to the following conditions:

1. complicated welded pressure vessel parts such as sumps or domes with nozzles, with adjacent shell plates shall be heat treated before they are welded to larger parts of the pressure vessel
2. the mechanical stress relieving process shall preferably be carried out during the hydrostatic pressure test required by Sec.22 [2], by applying a higher pressure than the test pressure required by Sec.22 [2.1.2]. The pressurizing medium shall be water
3. for the water temperature, Sec.22 [2.1.1], 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 on board, in a manner which will give the same stresses and stress distribution as when supported by its regular saddles or supporting structure
5. the maximum stress relieving pressure shall be held for 2 h per 25 mm of thickness, but in no case less than 2 h
6. the upper limits placed on the calculated stress levels during stress relieving shall be the following:
   .1 equivalent general primary membrane stress: 0.9 $R_{eH}$
   .2 equivalent stress composed of primary bending stress plus membrane stress: 1.35 $R_{eH}$

where $R_{eH}$ is the specific lower minimum yield stress or 0.2 % proof stress at test temperature of the steel used for the tank

7. strain measurements will normally be required to prove these limits for at least the first tank of a series of identical tanks built consecutively. The location of strain gauges shall be included in the mechanical stress relieving procedure to be submitted in accordance with [6.2.3]
8. the test procedure shall demonstrate that a linear relationship between pressure and strain is achieved at the end of the stress relieving process when the pressure is raised again 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 paid to plates exceeding 30 mm in thickness
10. steels which have a ratio of yield stress to ultimate tensile strength greater than 0.8 shall generally not be mechanically stress relieved. If, however, the yield stress is raised by 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, and
14. the procedure for mechanical stress relieving shall be to a recognized standard.

6.3 Secondary barriers

6.3.1 During construction, the requirements for testing and inspection of secondary barriers shall be approved or accepted by the Society (see Sec.4 [2.4.2] .5 and .6).

6.4 Semi-membrane tanks

6.4.1 For semi-membrane tanks, the relevant requirements in [6] for independent tanks or for membrane tanks shall be applied as appropriate.

6.5 Membrane tanks
6.5.1 The quality assurance/quality control programme shall ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures shall be developed during the prototype testing programme.

7 Non-metallic materials

7.1 General

7.1.1 The information in the attached App.A is given for guidance in the selection and use of these materials, based on the experience to date.

8 Hull materials

8.1 Inner hull structure

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

8.1.2 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 5 if the steel significant temperature calculated according to Sec.4 [5.1] 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 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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8.2 Outer hull structure

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

8.2.2 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 (Sec.4 [5.1]) is below -5°C due to the effect of the low temperature cargo, in which case the material shall be in accordance with Table 5 assuming the ambient air and sea temperatures of 5°C and 0°C respectively.

8.2.3 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.

8.3 Secondary barrier

8.3.1 Hull material forming the secondary barrier shall be in accordance with Table 2. Metallic materials used in secondary barriers not forming part of the hull structure should be in accordance with Table 2 or Table 3 as applicable. Insulation materials forming a secondary barrier shall comply with the requirements of Sec.4 [2.8]. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by Table 2Table 2 should be carried into the adjacent deck or side shell plating, where applicable to a suitable extent.
9 Marking of tanks, pipes and valves

9.1 General requirements

9.1.1 General requirements regarding marking of valves are given in Pt.4 Ch.6 Sec.3.

9.1.2 Language
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.

9.1.3 Marking plates
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.

9.1.4 Marking of tanks, pipes and valves
Every independent tank type C shall have a marking plate reading as follows:
— tank no.
— design pressure in MPa
— maximum cargo density in kg/m$^3$
— lowest permissible temperature in °C
— capacity of the tank in m$^3$ at 98% filled or at maximum filling
— test pressure in MPa
— 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 [3.1].
— test pressure, see Sec.4 [5.2.3].

All valves shall be clearly marked to indicate where the connected pipelines lead.

9.1.5 Marking of tank connections
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 7 CARGO PRESSURE-TEMPERATURE CONTROL

1 Methods of control

1.1 General requirements

1.1.1 With the exception of tanks including cargo system are designed to withstand full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, cargo tanks' pressure and temperature shall be maintained at all times within their design range by either one, or a combination of, the following methods:

1 re-liquefaction of cargo vapours
2 thermal oxidation of vapours, i.e. Gas Combustion;
3 pressure accumulation, and
4 liquid cargo cooling.

1.1.2 For certain cargoes, where required by Sec.17, the cargo containment system 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.

1.1.3 Venting of the cargo to maintain cargo tank pressure and temperature is not acceptable except in emergency situations. The Administration may permit certain cargoes to be controlled by venting cargo vapours to the atmosphere at sea. This may also be permitted in port with the permission of the port Administration.

2 Design of systems

2.1 General requirements

2.1.1 For normal service, the upper ambient design temperature shall be:
— sea: 32°C
— air: 45°C

For service in particularly hot or cold zones, these design temperatures shall be increased or decreased, to the satisfaction of the Society. The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere.
2.1.2 The design boil-off rate is the maximum evaporated cargo from the cargo tanks at stable pressure and temperature below the cargo tanks PRVs setting as given in [1.1.1] under the conditions given in [2.1.1].

Guidance note:

Table 1 Boil-off handling for Gas Combustion Unit (GCU) or re-liquefaction plant for methane (LNG).

<table>
<thead>
<tr>
<th>Propulsion</th>
<th>Primary</th>
<th>Secondary</th>
<th>Capacity and redundancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>diesel</td>
<td>re-liquefaction</td>
<td>Re-liquefaction</td>
<td>2 x 100% design boil-off gas capacity re-liquefaction units. Common cold box may be accepted.</td>
</tr>
<tr>
<td>diesel</td>
<td>re-liquefaction</td>
<td>GCU</td>
<td>1 x 100% design boil-off gas capacity re-liquefaction unit. 1 x 100% design boil-off gas capacity GCU.</td>
</tr>
<tr>
<td>diesel</td>
<td>GCU</td>
<td>GCU</td>
<td>1 x 100% design boil-off gas capacity GCU with redundant fans, igniters, gas flow control valves and combustion control systems, or 2 x 100% design boil-off gas capacity independent GCUs, or 3 x 50% design boil-off gas capacity independent GCUs</td>
</tr>
<tr>
<td>dual fuel diesel and gas only</td>
<td>GCU</td>
<td>GCU</td>
<td>1 x 100% design boil-off gas capacity GCU with redundant fans, igniters, gas flow control valve and combustion control system, or 2 x 100% design boil-off gas capacity independent GCUs; or 3 x 50% design boil-off gas capacity independent GCUs</td>
</tr>
</tbody>
</table>

Note that gas fired boiler or inert gas generator can be used as GCU.

---end---of---guidance---note---

3 Re-liquefaction of cargo vapours

3.1 General requirements

3.1.1 The re-liquefaction system may be arranged in one of the following ways:

.1 a direct system where evaporated cargo is compressed, condensed and returned to the cargo tanks
.2 an indirect system where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed
.3 a combined (cascade) system where evaporated cargo is compressed and condensed in a cargo/refrigerant heat exchanger and returned to the cargo tanks, and
.4 if the re-liquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases, as far as reasonably practicable, are disposed of without venting to atmosphere.

The requirements of Sec.17 and Sec.19 may preclude the use of one or more of these systems or may specify the use of a particular system.

3.1.2 For re-liquefaction of methane (LNG) the control and monitoring requirements for such installations is given in Sec.13 [12].

3.2 Compatibility

3.2.1 Refrigerants used for re-liquefaction shall be compatible with the cargo they may come into contact with. In addition, when several refrigerants are used and may come into contact, they shall be compatible with each other.
3.2.2 The heat exchange may take place either remotely from the cargo tank or by cooling coils fitted inside or outside the cargo tank.

4 Thermal oxidation of vapours, i.e. gas combustion

4.1 General

4.1.1 Maintaining the cargo tank pressure and temperature by means of thermal oxidation of cargo vapours, as defined in Sec.1 [3.1] and Sec.16 [2]. This is permitted only for LNG cargoes. In general:

.1 Thermal oxidation systems shall exhibit no externally visible flame and shall maintain the uptake exhaust temperature below 535°C.
.2 Arrangement of spaces where oxidation systems are located shall comply with Sec.16 [3] and supply systems shall comply with Sec.16 [4].
.3 If waste gases coming from any other system are to be burnt, the oxidation system shall be designed to accommodate all anticipated feed gas compositions.

4.1.2 Thermal oxidation of vapour system or GCU may be accepted as only method for cargo tanks’ pressure and temperature control on following conditions
— able to handle applicable design boil-off rate, i.e. design boil-off minus hotel loads.
— redundancy is arranged for fans (combustion and dilution), igniters, gas flow control valve(s) and control system.

Guidance note:
The amount of boil-off gas that can be consumed at all ship operations including harbour operations is defined as the base load (hotel load). This base load may be subtracted from the maximum design boil-off rate to establish the design boil-off capacity of the gas combustion units.

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4.1.3 A GCU control system includes both combustion control and burner management.

Guidance note:
A redundant GCU control system is a system with dual processors and single I/O or a single processor with an independent manual/remote control system.

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4.2 Oxidation systems

4.2.1 Oxidation system shall comply with the following:
.1 each thermal oxidation system shall have a separate uptake
.2 each thermal oxidation system shall have a dedicated forced draught system, and
.3 combustion chambers and uptakes of thermal oxidation systems shall be designed to prevent any accumulation of gas.

4.3 Burners

4.3.1 Burners shall be designed to maintain stable combustion under all design firing conditions.
4.4 Safety

4.4.1 Suitable devices shall be installed and arranged to ensure that gas flow to the burner is cut off unless satisfactory ignition has been established and maintained.

4.4.2 Each oxidation system shall have provision to manually isolate its gas fuel supply from a safely accessible position.

4.4.3 Provision shall be made for automatic purging the gas supply piping to the burners by means of an inert gas, after the extinguishing of these burners.

4.4.4 In case of flame failure of all operating burners for gas or oil or for a combination thereof, the combustion chambers of the oxidation system shall be automatically purged before relighting.

4.4.5 Arrangements shall be made to enable the combustion chamber to be manually purged.

4.4.6 The control and monitoring requirements is given in Sec.13 [11],

5 Pressure accumulation systems

5.1 General requirements

5.1.1 The containment system insulation, design pressure or both shall be adequate to provide for a suitable margin for the operating time and temperatures involved. No additional pressure and temperature control system is required.

Guidance note:
Pressure accumulation will be necessary for period of at least 21 days or period required by the flag administration.

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6 Liquid cargo cooling

6.1 General requirements

6.1.1 The bulk cargo liquid may be refrigerated by coolant circulated through coils fitted either inside the cargo tank or onto the external surface of the cargo tank.

7 Segregation

7.1 General requirements

7.1.1 Where two or more cargoes that may react chemically in a dangerous manner are carried simultaneously, separate systems as defined in Sec.1 [3.1], each complying with availability criteria as specified in [8], shall be provided for each cargo. For simultaneous carriage of two or more cargoes that are not reactive to each other but where, due to properties of their vapour, separate systems are necessary, separation may be by means of isolation valves.
8 Availability

8.1 General requirements

8.1.1 The availability of the system and its supporting auxiliary services shall be such that:

.1 in case of a single failure of a mechanical non-static component or a component of the control systems, the cargo tanks’ pressure and temperature can be maintained within their design range without affecting other essential services
.2 redundant piping systems are not required
.3 heat exchangers that are solely necessary for maintaining the pressure and temperature of the cargo tanks within their design ranges shall have a stand-by heat exchanger, unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external resources. Where an additional and separate method of cargo tank pressure and temperature control is fitted that is not reliant on the sole heat exchanger, then a standby heat exchanger is not required, and
.4 for any cargo heating or cooling medium, provisions shall be made to detect the leakage of toxic or flammable vapours into an otherwise non-hazardous area or overboard in accordance with Sec.13 [6]. Any vent outlet from this leak detection arrangement shall be to a non-hazardous area and be fitted with a flame screen.

9 Cargo heating arrangements

9.1 General requirements

9.1.1 Requirements for water systems and steam systems are identical to those of Pt.4 Ch.6 Sec.5, unless otherwise stated.

9.1.2 The heating media shall be compatible with the cargo and comply with the temperature requirements given in Sec.5 [1.1.4].

9.1.3 For heating of cargoes where gas detection with regard to toxic effects are required by column f in the List of Products in Sec.17, the heating medium shall not be returned to the machinery space. For heating of other cargoes, the medium may be returned to the engine room provided a degassing tank with gas detector is arranged, See Sec.13 [6.1.2] .6. The degassing tank shall be located in the cargo area.
SECTION 8 VENT SYSTEM FOR CARGO CONTAINMENT SYSTEM

1 General

1.1 General requirements

1.1.1 All cargo tanks shall be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold space and interbarrier spaces, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system. Pressure control systems specified in Sec.7 shall be independent of the pressure relief systems.

2 Pressure relief systems

2.1 General requirements

2.1.1 Cargo tanks, including deck tanks, shall be fitted with a minimum of two pressure relief valves (PRVs), each being of equal size within manufacturer's tolerances and suitably designed and constructed for the prescribed service.

2.1.2 Interbarrier spaces shall be provided with pressure relief devices.

— For membrane systems, the designer shall demonstrate adequate sizing of interbarrier space PRVs.
— For type B tanks the relieving capacity of pressure relief devices of interbarrier spaces shall be determined on the basis of the leakage rate determined in accordance with Sec.4 [2.5.2] or as given for type A tanks in [5].
— For type A tanks, see requirements given in [5].

Guidance note:

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

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

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

2.2.1 PRVs shall be prototype tested. Type tests shall include:

.1 verification of relieving capacity
.2 cryogenic testing when operating at design temperatures colder than -55°C
.3 seat tightness testing, and
.4 pressure containing parts are pressure tested to at least 1.5 times the design pressure.

Guidance note:
PRV can be tested according to ISO 21013-1:2008 – Cryogenic vessels – Pressure-relief accessories for cryogenic service – part 1: Recloseable pressure-relief valves; and ISO 4126-1; 2004 Safety devices for protection against excessive pressure – part 1 and part 4: Safety valves.

---end---of---guidance---note---

2.2.2 Each PRV shall be tested to ensure that:

.1 it opens at the prescribed pressure setting, with an allowance not exceeding ± 10% for 0 to 0.15 MPa,
   ± 6% for 0.15 to 0.3 MPa, ± 3% for 0.3 MPa and above
.2 seat tightness at 90% of the set pressure is acceptable; and
.3 pressure containing parts are to withstand at least 1.5 times the design pressure.

2.2.3 PRVs shall be set and sealed in the presence of a surveyor, and recorded by a sealing certificate, including the valves' set pressure, shall be retained on board the ship. The set pressure shall be sealed by the use of a robust non-corrosive wire.

2.2.4 Cargo tanks may be permitted to have more than one relief valve set pressure in the following cases:

.1 installing two or more properly set and sealed PRVs and providing means, as necessary, for isolating the valves not in use from the cargo tank, or
.2 installing relief valves whose settings may be changed by the use of a previously approved device not requiring pressure testing to verify the new set pressure. All other valve adjustments shall be sealed.

2.2.5 Changing the set pressure under the provisions of [2.2.4] and the corresponding resetting of the alarms referred to in Sec.13 [4.1.3] shall be carried out under the supervision of the master in accordance with approved procedures and as specified in the ship's operating manual. Changes in set pressure shall be recorded in the ship's log and a sign shall be posted in the cargo control room, if provided, and at each relief valve, stating the set pressure.

2.2.6 In the event of a failure of a cargo tank PRV, a safe means of emergency isolation shall be available.

.1 Procedures shall be provided and included in the cargo operations manual, see Sec.18 [1].
.2 The procedures shall allow only one of the cargo tanks installed PRVs to be isolated.
.3 Isolation of the PRV shall be carried out under the supervision of the master. This action shall be recorded in the ship's log and a sign posted in the cargo control room, if provided, and at the PRV.
.4 The tank shall not be loaded until the full relieving capacity is restored.

2.2.7 Each PRV installed on a cargo tank shall be connected to a venting system, which shall be:

.1 so constructed that the discharge will be unimpeded and directed vertically upwards at the exit
.2 arranged to minimize the possibility of water or snow entering the vent system
.3 arranged such that the height of vent exits shall not be less than B/3 or 6 m, whichever is the greater, above the weather deck, and
.4 6 m above working areas and walkways.
2.2.8 Cargo PRV vent exits shall be arranged at a distance at least equal to \( B \) or 25 m, whichever is less, from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, other non-hazardous areas, exhaust outlet from machinery or from furnace installations onboard. For ships less than 90 m in length, smaller distances may be permitted.

2.2.9 All other vent outlets connected to the cargo containment system shall be arranged at a distance of at least 10 m from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas.

2.2.10 All other cargo vent outlets not dealt with in other sections shall be arranged in accordance with [2.2.7], [2.2.8] and [2.2.9]. Means shall be provided to prevent liquid overflow from vent mast outlets, due to hydrostatic pressure from spaces to which they are connected.

2.2.11 If cargoes that react in a dangerous manner with each other are carried simultaneously, a separate pressure relief system shall be fitted for each one.

2.2.12 In the vent piping system, means for draining liquid from places where it may accumulate shall be provided, preferably in the form of special condensation pots. The PRVs and piping shall be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

2.2.13 Suitable protection screens of not more than 13 mm square mesh shall be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow. Other requirements for protection screens apply when carrying specific cargoes, see Sec.17 [1.8] and Sec.17 [11].

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

2.2.15 PRVs shall be connected to the highest part of the cargo tank above deck level. PRVs shall be positioned on the cargo tank so that they will remain in the vapour phase at the maximum filling limit (\( FL \)) as defined in Sec.15, under conditions of 15° list and 0.015\( L_{LL} \) trim, where \( L_{LL} \) is defined in Sec.1 [3.1].29.

2.2.16 The adequacy of the vent system fitted on tanks loaded in accordance with Sec.15 [1.5.2] shall be demonstrated using Assembly resolution A.829(19) on 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 purposes of this paragraph, vent system means:

1. the tank outlet and the piping to the PRV
2. the PRV
3. the piping from the PRVs to the location of discharge to the atmosphere, including any interconnections and piping that joins other tanks.

3 Vacuum protection systems

3.1 General requirements

3.1.1 Cargo tanks not designed to withstand a maximum external pressure differential 0.025 MPa, or tanks that cannot withstand the maximum external pressure differential 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 thermal oxidation, shall be fitted with:

1. 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 maximum external designed pressure differential of the cargo tank, or
.2 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.

3.1.2 Subject to the requirements of Sec.17, the vacuum relief valves shall admit an inert gas, cargo vapour or air to the cargo tank and shall be arranged to minimize 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.

3.1.3 The vacuum protection system shall be capable of being tested to ensure that it operates at the prescribed pressure.

4 Sizing of pressure relieving system

4.1 Sizing of pressure relief valves

4.1.1 PRVs 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 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:

\[ Q = F G A^{0.82} \]

where:

\( Q \) = minimum required rate of discharge of air in m\(^3\)/s at standard conditions of 273.15 Kelvin (K) and 0.1013 MPa;

\( F \) = fire exposure factor for different cargo types:

- 1.0 for tanks without insulation located on deck
- 0.5 for tanks above the deck when insulation is approved by the Society. Approval will be based on the use of a fireproofing material, the thermal conductance of insulation, and its stability under fire exposure
- 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 weather decks, the fire exposure factor shall be determined on the basis of the surface areas above and below deck.

\( G \) = gas factor taken equal to:

\[ G = \frac{12.4}{L D} \sqrt{\frac{Z T}{M}} \]

with:
\[ T = \text{temperature in degrees Kelvin at relieving conditions, i.e. 120\% of the pressure at which the pressure relief valve is set} \]

\[ L = \text{latent heat of the material being vaporized at relieving conditions, in kJ/kg} \]

\[ D = \text{a constant based on relation of specific heats } k \text{ and is calculated as follows:} \]

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

\[ k = \text{ratio of specific heats at relieving conditions, and the value of which is between 1.0 and 2.2. If } k \text{ is not known, } D = 0.606 \text{ shall be used} \]

\[ Z = \text{compressibility factor of the gas at relieving conditions; if not known, } Z = 1.0 \text{ shall be used, and} \]

\[ M = \text{molecular mass of the product.} \]

The gas factor of each cargo to be carried shall be determined and the highest value shall be used for PRV sizing.

\[ A = \text{external surface area of the tank in } m^2, \text{ as defined in Sec.1 [3.1], for different tank types, as shown in Figure 1:} \]
Cylindrical tanks with spherically dished, hemispherical or semi-ellipsoidal heads or spherical tanks

Prismatic tanks

Bilobe tanks

Horizontal cylindrical tanks arrangement
Figure 1 External surface area of tank

The required mass flow of air in kg/s at relieving conditions is given by:

\[ M_{\text{air}} = Q \cdot \rho_{\text{air}} \]

where:

\[ \rho_{\text{air}} = \text{density of air at 273.15 K and 0.1013 MPa.} \]
\[ \rho_{\text{air}} = 1.293 \text{ kg/m}^3. \]

4.2 Sizing of vent pipe system

4.2.1 Pressure losses upstream and downstream of the PRVs, shall be taken into account when determining their size to ensure the flow capacity required by [4.1].

4.3 Upstream pressure losses

4.3.1 The pressure drop in the vent line from the tank to the PRV inlet shall not exceed 3% of the valve set pressure at the calculated flow rate, in accordance with [4.1].

Guidance note:
An inlet pressure drop above 3% of MARVS may be accepted for pilot operated valves with remote sensing lines which are not affected by the inlet pipe pressure drops providing the sizing calculation includes the effect of inlet pressure drop.

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4.3.2 Pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome.

4.3.3 Pressure losses in remotely sensed pilot lines shall be considered for flowing type pilots.

4.4 Downstream pressure losses

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

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

- for unbalanced PRVs: 10% of MARVS
- for balanced PRVs: 30% of MARVS
- for pilot operated PRVs: 50% of MARVS.

Alternative values provided by the PRV manufacturer may be accepted.

4.4.3 To ensure stable PRV operation, the blow-down shall not be less than the sum of the inlet pressure loss and 0.02 MARVS at the rated capacity.
5 Pressure relief devices

5.1 General

5.1.1 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 devices which shall open when the pressure exceeds 0.025 MPa.

Guidance note:
For hold spaces where insulation is on the hull side and not on the cargo tank, special considerations related to the necessary pressure relief arrangement will be taken to suit the applicable design.

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5.1.2 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:

\[ Q_{sa} = 3.4 A_c \frac{D}{\rho_v} \sqrt{h} \]

where:

- \( Q_{sa} \) = minimum required discharge rate of air in m\(^3\)/s at standard conditions of 273.15 K, 0.1013 MPa
- \( A_c \) = design crack opening area in m\(^2\)
- \( D \) = maximum crack opening width in m
- \( \delta \) = 0.2 t m
- \( t \) = thickness of tank bottom plating in m
- \( \ell \) = design crack length in m equal to the diagonal of the largest plate panel of the tank bottom, see Figure 2
- \( h \) = maximum liquid height above tank bottom plus 10 × MARVS in m
- \( \rho \) = density of product liquid phase in kg/m\(^3\), at the set pressure of the interbarrier space relief device
- \( \rho_v \) = density of product vapour phase in kg/m\(^3\), at the set pressure of the interbarrier space relief device and a temperature of 273.15 K

\[ A_c = \frac{\pi \delta \ell}{4} \]
Figure 2 Design crack length, ℓ

Guidance note:
See IACS UI GC9.

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5.1.3 The pressure relief hatches covered by [5.1.2] shall be constructed to avoid risk of damage by expected external forces.

5.1.4 Pressure relief devices covered by [5.1.2] need not be arranged to comply with the requirements of [2.2.7], [2.2.8] and [2.2.9] related to vent outlets.
SECTION 9 CARGO CONTAINMENT SYSTEM ATMOSPHERIC CONTROL

1 Atmosphere control within the cargo containment system

1.1 General requirements

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

1.1.2 For flammable cargoes, the system shall be designed to eliminate the possibility of a flammable mixture existing in the cargo tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.

Guidance note:
All cargo tanks operations should be carried out in such a way that flammable atmosphere within the tank will not occur. 
---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.1.3 Piping systems that may contain flammable cargoes shall comply with [1.1.1] and [1.1.2].

1.1.4 A sufficient number of gas sampling points shall be provided for each cargo tank and cargo piping system to adequately monitor the progress of atmosphere change. Gas sampling connections shall be fitted with a single valve above the main deck, sealed with a suitable cap or blank. See Sec.5 [6.4].

1.1.5 Inert gas utilized in these procedures may be provided from the shore or from the ship.

1.1.6 Gas freeing system shall not be permanently connected to cargo tanks or cargo piping system. Such connection shall be portable means, like flexible hoses or spool pieces.

1.2 Atmosphere control within the hold spaces (cargo containment systems other than type C independent tanks)

1.2.1 Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring full or partial secondary barriers shall be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage, which shall be sufficient for normal consumption for at least 30 days.

1.2.2 Alternatively, subject to the restrictions specified in Sec.17, the spaces referred to in [1.2.1] requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the cargo tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand shall be provided.

1.2.3 For non-flammable gases, the spaces referred to in [1.2.1] and [1.2.2] may be maintained with a suitable dry air or inert atmosphere.

1.2.4 For membrane containments which has need for continues supply of inert gas (nitrogen) to the containment system [1.2.1] redundancy on all active components should be provided, if not shipboard storage is provided.
1.3 Environmental control of spaces surrounding type C independent tanks

1.3.1 Spaces surrounding cargo tanks that do not have 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 with dry air provided by suitable air drying equipment. If the cargo is carried at ambient temperature, the requirement for dry air or inert gas is not applicable.

1.4 Inerting

1.4.1 Inerting refers to the process of providing a non-combustible environment. Inert gases shall be compatible chemically and operationally at all temperatures likely to occur within the spaces and the cargo. The dew points of the gases shall be taken into consideration.

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

1.4.3 Where inert gas is stored at temperatures below 0°C, either as a liquid or as a vapour, the storage and supply system shall be designed so that the temperature of the ship’s structure is not reduced below the limiting values imposed on it.

1.4.4 Arrangements to prevent the backflow of cargo vapour into the inert gas system that are suitable for the cargo carried, shall be provided. If such plants are located in machinery spaces or other spaces outside the cargo area, two non-return valves or equivalent devices and, in addition, a removable spool piece shall be fitted in the inert gas main in the cargo area. When not in use, the inert gas system shall be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.

Guidance note:
This applies for inert system for the cargo system. For nitrogen system intended for auxiliary systems, e.g. nitrogen purging to insulation spaces, interbarrier spaces and shaft seals, a double block and bleed arrangement is acceptable for backflow prevention.

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

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

Guidance note:
This applies to detection of leakage through secondary barrier.

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2 Inert gas production on board

2.1 General requirements

2.1.1 The equipment shall be capable of producing inert gas with an oxygen content at no time greater than 5 % by volume, subject to the special requirements of Sec.17. 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.17.
2.1.2 An inert gas system shall have pressure controls and monitoring arrangements appropriate to the cargo containment system.

2.1.3 Spaces containing inert gas generation plants shall have no direct access to accommodation spaces, service spaces or control stations, but may be located in machinery spaces. Inert gas piping shall not pass through accommodation spaces, service spaces or control stations.

2.1.4 Combustion equipment for generating inert gas shall not be located within the cargo area. Special consideration may be given to the location of inert gas generating equipment using a catalytic combustion process.

2.1.5 Where fitted, a nitrogen receiver or buffer tank shall be installed in a dedicated compartment or in the separate compartment containing the air compressor and the generator, or be located in the cargo area. Where the nitrogen receiver or buffer tank is installed in an enclosed space, the access shall be arranged only from the open deck and the access door shall open outwards.
Where a separate compartment is provided it shall be fitted with an independent mechanical extraction ventilation system, providing 6 air changes per hour. A low oxygen alarm shall be fitted. The compartment shall have no direct access to accommodation spaces, service spaces or control stations.

**Guidance note:**
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.5 or for chemical tankers, Ch.6.

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**Guidance note:**
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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2.1.6 Control and monitoring of inert gas generator is given in Sec.13 [13].

2.1.7 Control and monitoring of nitrogen generator is given in Sec.13 [14],
SECTION 10 ELECTRICAL INSTALLATIONS

1 General

1.1 General

1.1.1 The requirements in this chapter are additional to those given in Pt.4 Ch.8. Relaxation from these rules may be accepted for ships built to carry only non-flammable products.

1.1.2 In order to facilitate the selection of appropriate electrical apparatus an 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 are given in this section.

Guidance note:
With reference to IEC 60079-20, the following temperature class and equipment groups can be used:

<table>
<thead>
<tr>
<th>Product</th>
<th>Temperature class</th>
<th>Equipment group</th>
</tr>
</thead>
<tbody>
<tr>
<td>methane (LNG)</td>
<td>T1</td>
<td>IIA</td>
</tr>
<tr>
<td>LPG (propane, butane)</td>
<td>T2</td>
<td>IIA</td>
</tr>
<tr>
<td>ethylene</td>
<td>T1</td>
<td>IIB</td>
</tr>
</tbody>
</table>

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1.2 Definitions

For the purpose of this section, unless expressly provided otherwise, the definitions below shall apply.

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

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

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

1.2.4 Zone 2 hazardous area is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so infrequently and for a short period only.

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

1.3 General requirements

1.3.1 Electrical installations shall be such as to minimize the risk of fire and explosion from flammable products.

1.3.2 Electrical installations shall be accordance to [1.1.2].
1.3.3 Electrical equipment or wiring shall not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

1.3.4 Where electrical equipment is installed in hazardous areas as provided in [1.3.2] it shall be selected, installed and maintained in accordance with standards not inferior to those acceptable to the Society. Equipment for hazardous areas shall be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Society. Automatic isolation of non-certified equipment on detection of a flammable gas shall not be accepted as an alternative to the use of certified equipment.

1.3.5 To facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones as given in [1.2].

1.3.6 Electrical generation and distribution systems, and associated control systems, shall be designed such that a single fault will not result in the loss of ability to maintain cargo tank pressures, as required by Sec.7 [8.1.1].1 and hull structure temperature, as required by Sec.4 [5.1.1].6, within normal operating limits. Failure modes and effects shall be analysed and documented to a standard not inferior to those acceptable to the Society.

   Guidance note:
   IEC 60812, Edition 2.0 2006-01 "Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)".

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

1.3.8 Electrical depth sounding or log devices and impressed current cathodic protection system anodes or electrodes shall be housed in gastight enclosures.

   Guidance note:
   Gas tight enclosure is required only if the equipment is located in a hazardous area.

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1.3.9 Submerged cargo pump motors and their supply cables may be fitted in cargo containment systems. Arrangements shall be made to automatically shut down the motors in the event of low-liquid level. This may be accomplished by sensing low pump discharge pressure, low motor current, or low liquid level. This shutdown shall be alarmed at the cargo control station. Cargo pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.

2 Area classification

2.1 General requirements

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

2.1.2 Areas and spaces other than those classified in [2.2], shall be subject to special consideration. The principles of the IEC standards [1.1.2] shall be applied.

2.1.3 Area classification of a space may be dependent of ventilation as specified in IEC 60092-502, Table 1. Requirements to such ventilation are given in Sec.12 [3.1.6] to Sec.12 [3.1.8].
2.1.4 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.12 [3]

2.1.5 Ventilation ducts shall have the same area classification as the ventilated space.

2.2 Tankers carrying flammable liquefied gases

2.2.1 Hazardous areas Zone 0
The interiors of cargo tanks, interbarrier spaces and, only hold spaces where the tank requires a secondary barrier, 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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2.2.2 Hazardous areas zone 1
.1 hold spaces for tanks not requiring secondary barrier, void spaces adjacent to, above and below integral cargo tanks
.2 cofferdams and permanent (for example, segregated) ballast tanks adjacent to cargo tanks
.3 cargo compressor room arranged with ventilation according to Sec.12 [3.1.7]
.4 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
.5 spaces, other than cofferdam, adjacent to a cargo tank boundary or a secondary barrier (for example, trunks, passageways and hold)
.6 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, sounding pipes, cargo vapour outlets.

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.7 areas on open deck, or semi-enclosed spaces on open deck 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 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.
.9 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.
.10 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.
.11 compartments for cargo hoses.
.12 enclosed or semi-enclosed spaces in which pipes containing cargoes are located.
2.2.3 Hazardous areas zone 2

.1 areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1 as specified in [2.2.2], if not otherwise specified in this standard

.2 spaces 4 m beyond the cylinder and 4 m beyond the sphere defined in [[2.2.2].7]

.3 she spaces forming an air-lock as defined in Sec.1 [3.1]

.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 [[2.2.2].10] and [[2.2.3].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.

2.3 Electrical installations in cargo area and adjacent to this area

In addition to [1.3.2], installations as specified in [2.3] are accepted.

2.3.1 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.

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.

2.3.2 Additional requirements may apply for certain cargoes according to Sec.17 and Sec.19.

3 Inspection and testing

3.1 General requirements

3.1.1 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.

3.1.2 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 required ventilation failure alarm operates correctly.

3.1.3 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.

3.1.4 Where interlocking and shutdown arrangements are required (such as for submerged cargo pumps), they shall be tested.

3.1.5 Intrinsically safe circuits shall be verified to ensure that the equipment and wiring are correctly installed.

3.1.6 Verification of the physical installation shall be documented by yard. The documentation shall be available for the Society's surveyor at the site.

4 Maintenance

4.1 General requirements

4.1.1 The maintenance manual referred to in Sec.1 [4], 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.

4.1.2 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.
SECTION 11 FIRE PROTECTION AND EXTINCTION

1 Fire safety requirements

1.1 General requirements

1.1.1 The requirements for tankers in SOLAS chapter II-2 to ships, irrespective of tonnage including ships of less than 500 gross tonnage, except that:

1.1.2 regulations 4.5.1.6 and 4.5.10 do not apply

1.2 regulation 10.2 as applicable to cargo ships, and regulations 10.4 and 10.5 shall apply as they would apply to tankers of 2000 gross tonnage and over

1.3 regulation 10.5.6 shall apply to ships of 2000 gross tonnage and over

1.4 the following regulations of SOLAS chapter II-2 related to tankers do not apply and are replaced by requirements of this chapter as detailed below:

<table>
<thead>
<tr>
<th>SOLAS Regulation</th>
<th>Replaced by</th>
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<tbody>
<tr>
<td>10.10</td>
<td>[6]</td>
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<tr>
<td>4.5.1.1 and 4.5.1.2</td>
<td>Sec.3</td>
</tr>
<tr>
<td>4.5.5</td>
<td>Relevant sections</td>
</tr>
<tr>
<td>10.8</td>
<td>[3] and [4]</td>
</tr>
<tr>
<td>10.9</td>
<td>[5]</td>
</tr>
<tr>
<td>10.2</td>
<td>[2.1]</td>
</tr>
</tbody>
</table>

.5 regulations 13.3.4 and 13.4.3 shall apply to ships of 500 gross tonnage and over.

Guidance note:
The IGC Code is in general the governing regulatory instrument for fire control equipment and arrangement in the cargo area, replacing the requirements of SOLAS chapter II-2.

1.1.2 All sources of ignition shall be excluded from spaces where flammable vapour may be present, except as otherwise provided in Sec.10 and Sec.16.

1.1.3 The provisions of this section shall apply in conjunction with Sec.3.

1.1.4 For the purposes of fire fighting, any weather deck areas above cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space shall be included in the cargo area.

2 Fire mains and hydrants

2.1 General requirements

2.1.1 All ships, irrespective of size, carrying products that are subject to the Chapter shall comply with the requirements of regulation II-2/10.2 of the SOLAS Convention, except that the required fire
pump capacity and fire main and water service pipe diameter shall not be limited by the provisions of regulations II-2/10.2.2.4.1 and II-2/10.2.1.3, when a fire pump is used to supply the water spray system, as permitted by [3.1.3]. The capacity of this fire pump shall be such that these areas can be protected when simultaneously supplying two jets of water from fire hoses with 19 mm nozzles at a pressure of at least 0.5 MPa.

2.1.2 The arrangements shall be such that at least two jets of water can reach any part of the deck in the cargo area and those portions of the cargo containment system and tank covers that are above the deck. The necessary number of fire hydrants shall be located to satisfy the above arrangements and to comply with the requirements of regulations II-2/10.2.1.5.1 and II-2/10.2.3.3 of the SOLAS convention, with hose lengths as specified in regulation II-2/10.2.3.1.1. In addition, the requirements of regulation II-2/10.2.1.6 shall be met at a pressure of at least 0.5 MPa.

2.1.3 Stop valves shall be fitted in any crossover provided and in the fire main or mains in a protected location, before entering the cargo area and at intervals ensuring isolation of any damaged single section of the fire main, so that [2.1.2] can be complied with using not more than two lengths of hoses from the nearest fire hydrant. The water supply to the fire main serving the cargo area shall be a ring main supplied by the main fire pumps or a single main supplied by fire pumps positioned fore and aft of the cargo area, one of which shall be independently driven.

2.1.4 All nozzles shall be of an approved dual purpose type, i.e. spray/jet type, incorporating a shutoff.

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

3 Water spray system

3.1 General requirements

3.1.1 On ships carrying flammable or toxic products, or both, a water application system, which may be based on water spray nozzles, for cooling, fire prevention and crew protection shall be installed to cover:

.1 exposed cargo tank domes, any exposed parts of cargo tanks and any part of cargo tank covers that may be exposed to heat from fires in adjacent equipment containing cargo such as exposed booster pumps/heaters/re-gasification or re-liquefaction plants, hereafter addressed as gas process units, positioned on weather decks
.2 exposed on-deck storage vessels for flammable or toxic products
.3 gas process units, positioned on deck
.4 cargo liquid and vapour discharge and loading connections, including the presentation flange and the area where their control valves are situated, which shall be at least equal to the area of the drip trays provided
.5 all exposed emergency shut-down (ESD) valves in the cargo liquid and vapour pipes, including the master valve for supply to gas consumers
.6 exposed boundaries facing the cargo area, such as bulkheads of superstructures and deckhouses normally manned, cargo machinery spaces, store-rooms containing high fire risk items and cargo control rooms. Exposed horizontal boundaries of these areas do not require protection unless detachable cargo piping connections are arranged above or below. Boundaries of unmanned forecastle structures not containing high fire-risk items or equipment do not require water-spray protection
.7 exposed lifeboats, life rafts and muster stations facing the cargo area, regardless of distance to cargo area, and
.8 any semi-enclosed cargo machinery spaces and semi-enclosed cargo motor room

Ships intended for operation as listed in Sec.1 [2.1.5], shall be subject to special consideration and covered by Pt.6, Ch.30.
3.1.2 The system shall be capable of covering all areas mentioned in [3.1.1] with a uniformly distributed water application rate of at least 10 l/m²/minute for the largest projected horizontal surfaces and 4 l/m²/minute for vertical surfaces. For structures having no clearly defined horizontal or vertical surface, the capacity of the water application shall not be less than the projected horizontal surface multiplied by 10 l/m²/minute.

3.1.3 On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated rundown from higher areas. Stop valves shall be fitted in the spray water application main supply line(s), at intervals not exceeding 40 m, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position outside of the cargo area. A section protecting any area included in [3.1.1].1 and [3.1.1].2 shall cover at least the entire athwartship tank grouping in that area. Any gas process unit(s) included in [3.1.1].3 may be served by an independent section.

3.1.4 The capacity of the water application pumps shall be capable of simultaneous protection of the greater of the following:

1. any two complete athwartship tank groupings, including any gas process units within these areas; or
2. for ships intended for operation as listed in Sec.1 [2.1.5], necessary protection subject to special consideration under [3.1.1] of any added fire hazard and the adjacent athwartship tank grouping are covered in Pt.6 Ch.4 Sec.8,

in addition to surfaces specified in [3.1.1].4 to [3.1.1].8. Alternatively, the main fire pumps may be used for this service, provided that their total capacity is increased by the amount needed for the water-spray application system. In either case a connection, through a stop valve, shall be made between the fire main and water-spray application system main supply line outside of the cargo area.

3.1.5 The boundaries of superstructures and deckhouses normally manned, and lifeboats, life-rafts and muster areas facing the cargo area, shall also be capable of being served by one of the fire pumps or the emergency fire pump, if a fire in one compartment could disable both fire pumps.

3.1.6 Water pumps normally used for other services may be arranged to supply the water spray application system main supply line.

3.1.7 All pipes, valves, nozzles and other fittings in the water application systems shall be resistant to corrosion by seawater. Piping, fittings and related components within the cargo area (except gaskets) shall be designed to withstand 925°C. The water application system shall be arranged with in-line filters to prevent blockage of pipes and nozzles. In addition, means shall be provided to back flush the system with fresh water.

Guidance note:

- Water spray pipes should be provided with drain holes or valves at the lowest points. Also forward flushing through the nozzles is recommended.

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

3.1.9 After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.
4 Dry chemical powder fire-extinguishing systems

4.1 General requirements

4.1.1 Ships in which the carriage of flammable products is intended shall be fitted with fixed dry chemical powder fire-extinguishing systems, approved by the Society based on the Guidelines for the approval of fixed dry chemical powder fire-extinguishing systems for the protection of ships carrying liquefied gases in bulk (MSC. 1/Circ. 1315), for the purpose of firefighting on the deck in the cargo area, including any cargo liquid and vapour discharge and loading connections on deck and bow or stern cargo handling areas, as applicable.

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

4.1.3 The dry chemical powder fire-extinguishing system shall be designed with not less than two independent units. Any part required to be protected by [4.1.2] shall be capable of being reached from not less than two independent units with associated controls, pressurizing medium fixed piping, monitors or hand hose lines. For ships with a cargo capacity of less than 1000 m³, only one such unit need be fitted. A monitor shall be arranged to protect any load/unload connection area and be capable of actuation and discharge both locally and remotely. The monitor is not required to be remotely aimed if it can deliver the necessary powder to all required areas of coverage from a single position. One hose line shall be provided at both port- and starboard side at the end of the cargo area facing the accommodation and readily available from the accommodation.

4.1.4 The capacity of a monitor shall be not less than 10 kg/s. Hand hose lines shall be non-kinkable and be fitted with a nozzle capable of on/off operation and discharge at a rate not less than 3.5 kg/s. The maximum discharge rate shall allow operation by one man. The length of a hand hose line shall not exceed 33 m. Where fixed piping is provided between the powder container and a hand hose line or monitor, the length of piping shall not exceed that length which is capable of maintaining the powder in a fluidized state during sustained or intermittent use, and which can be purged of powder when the system is shut down. Hand hose lines and nozzles shall be of weather-resistant construction or stored in weather resistant housing or covers and be readily accessible.

4.1.5 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.

4.1.6 Ships fitted with bow, stern load/unload connections shall be provided with independent dry powder unit protecting the cargo liquid and vapour piping, aft or forward of the cargo area, by hose lines and a monitor covering the bow, stern load/unload complying with the requirements of [4.1.1] to[4.1.5].

4.1.7 Ships intended for operation as listed in Sec.1 [2.1.5] are covered in Pt.6 Ch.4 and for dedicated storage vessels are subject to special considerations.

4.1.8 After installation, the pipes, valves, fittings and assembled systems shall be subjected to a tightness test and functional testing of the remote and local release stations. The initial testing shall also include a discharge of sufficient amounts of dry chemical powder to verify that the system is in proper working order. All distribution piping shall be blown through with dry air to ensure that the piping is free of obstructions.

Guidance note:
At least one dry chemical powder hose and one monitor shall be tested for each ship.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
5 Enclosed spaces containing cargo handling equipment

5.1 General requirements

5.1.1 Enclosed spaces meeting the criteria of cargo machinery spaces in Sec.1 [3.1], and the cargo motor room within the cargo area of any ship, shall be provided with a fixed fire-extinguishing system complying with the provisions of the FSS Code and taking into account the necessary concentrations/application rate required for extinguishing gas fires.

5.1.2 Enclosed spaces meeting the criteria of cargo machinery spaces in Sec.3 [3], within the cargo area of ships that are dedicated to the carriage of a restricted number of cargoes, shall be protected by an appropriate fire-extinguishing system for the cargo carried.

5.1.3 Turret compartments of any ship shall be protected by internal water spray, with an application rate of not less than 10 ℓ/m²/minute of the largest projected horizontal surface. If the pressure of the gas flow through the turret exceeds 4 MPa, the application rate shall be increased to 20 ℓ/m²/minute. The system shall be designed to protect all internal surfaces.

6 Firefighters' outfits

6.1 General requirements

6.1.1 Every ship carrying flammable products shall carry firefighter's outfits complying with the requirements of regulation II-2/10.10 of the SOLAS Convention, as follows:

Table 2

<table>
<thead>
<tr>
<th>Total capacity</th>
<th>Number of outfits</th>
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<tbody>
<tr>
<td>5000 m³ and below</td>
<td>4</td>
</tr>
<tr>
<td>above 5000 m³</td>
<td>5</td>
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</tbody>
</table>

6.1.2 Additional requirements for safety equipment are given in Sec.14.

6.1.3 Any breathing apparatus required as part of a fire-fighter's outfit shall be a self-contained compressed air-operated breathing apparatus having a capacity of at least 1200ℓ of free air.
SECTION 12 ARTIFICIAL VENTILATION IN CARGO AREA

1 Spaces required to be entered during normal handling operations

1.1 General requirements

1.1.1 Electric motor rooms, cargo compressor and pump rooms, spaces containing cargo handling equipment and other enclosed spaces where cargo vapours may accumulate shall be fitted with fixed artificial ventilation systems capable of being controlled from outside such spaces. The ventilation shall be run continuously to prevent the accumulation of toxic and/or flammable vapours, with a means of monitoring acceptable to the Society to be provided. A warning notice requiring the use of such ventilation prior to entering shall be placed outside the compartment.

1.1.2 Artificial ventilation inlets and outlets shall be arranged to ensure sufficient air movement through the space to avoid accumulation of flammable, toxic or asphyxiant vapours, and to ensure a safe working environment.

1.1.3 The ventilation system shall have a capacity of not less than 30 changes of air per hour, based upon the total volume of the space. As an exception, non-hazardous cargo control rooms may have eight changes of air per hour.

1.1.4 Where a space has an opening into an adjacent more hazardous space or area, it shall be maintained at an over-pressure. It may be made into a less hazardous space or non-hazardous space by over-pressure protection.

1.1.5 Ventilation ducts, air intakes and exhaust outlets serving artificial ventilation systems shall be positioned in as given in [3].

1.1.6 Ventilation ducts serving hazardous areas shall not be led through accommodation, service and machinery spaces or control stations or other non-hazardous spaces, except as allowed in Sec.16.

1.1.7 Electric motors driving fans shall be placed outside the ventilation ducts that may contain flammable vapours, unless the motor is certified for the same hazard zone as the space served. Ventilation fans shall not produce a source of ignition in either the ventilated space or the ventilation system associated with the space. For hazardous areas, ventilation fans and ducts, adjacent to the fans, shall be of non-sparking construction, as defined below:

1. Impellers or housing of non-metallic construction, with due regard being paid to the elimination of static electricity
2. Impellers and housing of non-ferrous materials
3. Impellers and housing of austenitic stainless steel;
4. Ferrous impellers and housing with not less than 13 mm design tip clearance
5. Impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing.

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.

1.1.8 Where fans are required by this section, full required ventilation capacity for each space shall be available after failure of any single fan or spare parts shall be provided comprising; a motor, starter spares and complete rotating element, including bearings of each type.
1.1.9 Protection screens of not more than 13 mm square mesh shall be fitted to outside openings of ventilation ducts.

1.1.10 Where spaces are protected by pressurization the ventilation shall be designed and installed as given in [3].

1.1.11 Starters for fans for ventilation of non-hazardous spaces in cargo area, 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.

Guidance note:
The principles of ventilation should the standard International Electrotechnical Commission, in particular, to publication IEC 60092-502:1999.

1.1.12 The installation 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 1MΩ.

2 Spaces not normally entered

2.1 General requirements

2.1.1 Enclosed spaces where cargo vapours may accumulate shall be capable of being ventilated to ensure a safe environment when entry into them is necessary. This shall be capable of being achieved without the need for prior entry.

Guidance note:
Spaces not normally entered are cofferdams, double bottoms, duct keels, pipe tunnels and hold spaces for independent cargo tanks.

2.1.2 For permanent installations, the capacity of 8 air changes per hour shall be provided and for portable systems, the capacity of 16 air changes per hour.

2.1.3 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.

2.1.4 Fans or blowers shall be clear of personnel access openings, and shall comply with [1.1.7].

3 Ventilation arrangement and capacity requirements

3.1 General requirements

3.1.1 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.

3.1.2 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.

3.1.3 Air outlets from non-hazardous spaces shall be located outside hazardous areas.

3.1.4 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.

3.1.5 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.

3.1.6 The exhaust outlets for hazardous space, 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.

3.1.7 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.

3.1.8 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.

---e-n-d-o-f-g-u-i-d-a-n-c-e-n-o-t-e---

3.1.9 Air lock spaces shall be mechanically ventilated at an overpressure relative to the adjacent open deck hazardous area.

3.1.10 Other spaces situated on or above cargo deck level (e.g. Cargo Handling Gear lockers) may be accepted with natural ventilation only.
3.2 Non-hazardous spaces

3.2.1 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, automatic or programmed disconnection of electrical installations is required according to IEC 60092-502, Table 5.
SECTION 13 INSTRUMENTATION AND AUTOMATION

1 General

1.1 General requirements

1.1.1 Each cargo tank shall be provided with a means for indicating level, pressure and temperature of the cargo. Pressure gauges and temperature indicating devices shall be installed in the liquid and vapour piping systems, in cargo refrigeration and thermal oxidation installation (GCU).

1.1.2 If loading and unloading of the ship is 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.

1.1.3 Instruments shall be tested to ensure reliability under the working conditions and re-calibrated at regular intervals. Test procedures for instruments and the intervals between re-calibration shall be in accordance with manufacturer’s recommendations and shall be submitted for review by Society.

1.1.4 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).

1.1.5 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.

2 Level indicators for cargo tanks

2.1 General requirements

2.1.1 Each cargo tank shall be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the cargo tank is operational. The device(s) shall be designed to operate throughout the design pressure range of the cargo tank and at temperatures within the cargo operating temperature range.

2.1.2 Where only one liquid level gauge is fitted it shall be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

2.1.3 Cargo tank liquid level gauges may be of the following types, subject to special requirements for particular cargoes shown in column ‘g’ in the table of Sec.19:

.1 indirect devices, which determine the amount of cargo by means such as weighing or in-line flow metering
.2 closed devices, which do not penetrate the cargo tank, such as devices using radio-isotopes or ultrasonic devices
.3 closed devices, which penetrate the cargo tank, but which form part of a closed system and keep the cargo from being released, such as float type systems, electronic probes, magnetic probes and bubble tube indicators. If a closed gauging device is not mounted directly onto the tank, it shall be provided with a shutoff valve located as close as possible to the tank, and

.4 restricted devices, which penetrate the tank and when in use permit a small quantity of cargo vapour or liquid to escape to the atmosphere, 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 diameter or equivalent area, unless the device is provided with an excess flow valve.

3 Overflow control

3.1 General requirements

3.1.1 Except as provided in [3.1.4] each cargo tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

3.1.2 An additional sensor operating independently of the high liquid level alarm shall automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full.

Guidance note:
The high liquid level alarm [3.1.1] and the additional sensor [3.1.2] shall be implemented in systems that are complete independent of each other. One of these may be combined with level gauging system [2.1.1].

--- end of guidance note ---

3.1.3 The emergency shutdown valve referred to in Sec.5 [5] and Sec.18 [2] may be used for this purpose. If another valve is used for this purpose, the same information as referred to in Sec.18 [2.2.3] shall be available on board. During loading, whenever the use of these valves may possibly create a potential excess pressure surge in the loading system, alternative arrangements such as limiting the loading rate shall be used.

3.1.4 A high liquid level alarm and automatic shut-off of cargo tank filling need not be required when the cargo tank:

.1 is a pressure tank with a volume not more than 200 m$^3$, or

.2 is 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.

3.1.5 The position of the sensors in the tank shall be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking when cargo tank has been in gas free condition, testing of high level alarms shall be conducted by raising the cargo liquid level in the cargo tank to the alarm point.

3.1.6 All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, shall be capable of being functionally tested. Systems shall be tested prior to cargo operation.

3.1.7 Where arrangements are provided for overriding the overflow control system, they shall be such that inadvertent operation is prevented. When this override is operated continuous visual indication shall be given at the relevant control station(s) and the navigating bridge.

3.1.8 When pumps situated in different tanks discharge into a common header, unintended stop of a pump shall be alarmed at the centralized cargo control position.
4 Pressure monitoring

4.1 General requirements

4.1.1 The vapour space of each cargo tank shall be provided with a direct reading gauge. Additionally, an indirect indication shall be provided at the control position required by [1.1.2]. Maximum and minimum allowable pressures shall be clearly indicated.

4.1.2 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm shall be provided on the navigating bridge and at the control position required by [1.1.2]. Alarms shall be activated before the set pressures are reached.

4.1.3 For cargo tanks fitted with PRVs, which can be set at more than one set pressure in accordance with Sec.8 [2.2.4], high-pressure alarms shall be provided for each set pressure.

4.1.4 Each cargo-pump discharge line and each liquid and vapour cargo manifold shall be provided with at least one pressure indicator.

4.1.5 Local-reading manifold pressure indication shall be provided to indicate the pressure between ship's manifold valves and hose connections to the shore.

4.1.6 Hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indication.

4.1.7 All pressure indications provided shall be capable of indicating throughout the operating pressure range.

5 Temperature indicating devices

5.1 General requirements

5.1.1 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 lowest temperature for which the cargo tank has been approved by the society shall be clearly indicated, by means of a sign on or near the temperature indicating devices.

5.1.2 The temperature indicating devices shall be capable of providing temperature indication across the expected cargo operating temperature range of the cargo tanks.

5.1.3 Where thermowells are fitted they shall be designed to minimize failure; due to fatigue in normal service.

Guidance note:
See also requirements related to temperature indication devices [7.2].

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

6 Gas detection

6.1 General requirements
6.1.1 Gas detection equipment shall be installed to monitor the integrity of the cargo containment, cargo handling and ancillary systems in accordance with this section.

6.1.2 A permanently installed system of gas detection and audible and visual alarms shall be fitted in:

.1 all enclosed cargo and cargo machinery spaces (including turrets compartments) containing gas piping, gas equipment or gas consumers
.2 other enclosed or semi-enclosed spaces where cargo vapours may accumulate including interbarrier spaces and hold spaces for independent tanks other than type C
.3 airlocks
.4 the spaces in gas fired internal combustion engines, referred to in Sec.16 [7.3.3]
.5 ventilation hoods and gas ducts required by Sec.16;
.6 cooling/heating circuits, including degassing tank if fitted, as required by Sec.7 [8.1.1];
.7 inert gas generator supply headers, and
.8 motor rooms for cargo handling machinery.

Guidance note:
Related to [6.1.2].7 gas detection should be fitted for the pipe section between the inert gas generator and devices preventing back flow.

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

6.1.3 Gas detection equipment shall be designed, installed and tested and shall be suitable for the cargoes to be carried in accordance with column 'f' in table of Sec.19.

6.1.4 Where indicated in column 'f' of Sec.19 ships certified for carriage of non-flammable products, oxygen deficiency monitoring shall be fitted in cargo machinery spaces and cargo tank hold spaces. Furthermore, oxygen deficiency monitoring equipment shall be installed in enclosed or semi-enclosed spaces containing equipment that may cause an oxygen-deficient environment such as nitrogen generators, inert gas generators or nitrogen cycle refrigerant systems.

6.1.5 In the case of products that are toxic or both toxic and flammable, except when column 'h' in the table of Sec.19 refers to Sec.17 [1.4.3], portable equipment can be used for the detection of toxic products as an alternative to a permanently installed system. This equipment shall be used prior to personnel entering the spaces listed in [6.1.2] and at 30-minute intervals while they remain in the space.

6.1.6 In the case of toxic gases, hold spaces and interbarrier spaces shall be provided with a permanently installed piping system for obtaining gas samples from the spaces. Gas from these spaces shall be sampled and analysed from each sampling head location.

6.1.7 Permanently installed gas detection shall be of the continuous detection type, capable of immediate response. Where not used to activate safety shutdown functions required by [6.1.9] and Sec.16, the sampling type detection may be accepted.

6.1.8 When sampling type gas detection equipment is used the following requirements shall be met:

.1 the gas detection equipment shall be capable of sampling and analysing for each sampling head location sequentially at intervals not exceeding 30 minutes
.2 individual sampling lines from sampling heads to the detection equipment shall be fitted, and
.3 pipe runs from sampling heads shall not be led through non-hazardous spaces except as permitted by [6.1.9].

6.1.9 The gas detection equipment may be located in a non-hazardous space, provided that the detection equipment such as sample piping, sample pumps, solenoids and analysing units are located in a fully enclosed steel cabinet with the door sealed by a gasket. The atmosphere within the enclosure shall be continuously monitored. At gas concentrations above 30 % lower flammable limit (LFL) inside the enclosure, the gas detection equipment shall be automatically shut down.
6.1.10 Where the enclosure cannot be arranged directly on the forward bulkhead, sample pipes shall be of steel or equivalent material and be routed on their shortest way. Detachable connections, except for the connection points for isolating valves required in [6.1.11] and analysing units, are not permitted.

6.1.11 When gas sampling equipment is located in non-hazardous space, a flame arrester and a manual isolating valve shall be fitted in each of the gas sampling lines. The isolating valve shall be fitted on the non-hazardous side. Bulkhead penetrations of sample pipes between hazardous and non-hazardous areas shall maintain the integrity of the division penetrated. The exhaust gas shall be discharged to the open air in a non-hazardous area.

6.1.12 In every installation, the number and the positions of detection heads shall be determined with due regard to the size and layout of the compartment, the compositions and densities of the products intended to be carried and the dilution from compartment purging or ventilation and stagnant areas.

6.1.13 Any alarms status within a gas detection system required by this section shall initiate an audible and visible alarm:

.1 on the navigation bridge
.2 at the relevant control station(s) where continuous monitoring of the gas levels is recorded, and
.3 at the gas detector readout location.

6.1.14 In the case of flammable products, the gas detection equipment provided for hold spaces and interbarrier spaces that are required to be inerted shall be capable of measuring gas concentrations of 0 % to 100 % by volume.

6.1.15 Alarms shall be activated when the vapour concentration by volume reaches the equivalent of 30 % of the LFL in air.

6.1.16 For membrane containment systems, the primary and secondary insulation spaces shall be able to be inerted and their gas content analysed individually. The alarm in the secondary insulation space shall be set in accordance with [6.1.15] that in the primary space is set at a value approved by the Society.

6.1.17 For other spaces described by [6.1.2], alarms shall be activated when the vapour concentration reaches 30 % LFL and safety functions required by Sec.16 shall be activated before the vapour concentration reaches 60 % LFL. The crankcases of internal combustion engines that can run on gas shall be arranged to alarm before 100 % LFL.

6.1.18 Gas detection equipment shall be so designed that it may readily be tested. Testing and calibration shall be carried out at regular intervals. Suitable equipment for this purpose shall be carried on board and be used in accordance with the manufacturer's recommendations. Permanent connections for such test equipment shall be fitted.

6.1.19 Every ship shall be provided with at least two sets of portable gas detection equipment that meet the requirement of [6.1.3].

6.1.20 A suitable instrument for the measurement of oxygen levels in inert atmospheres shall be provided.

7 Additional requirements for containment systems requiring a secondary barrier

7.1 Integrity of barriers

7.1.1 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 consist of appropriate gas detecting devices according to [6]. However, the instrumentation need not be capable of locating the area where liquid cargo leaks through the primary barrier or where liquid cargo is in contact with the secondary barrier.

7.2 Temperature indication devices

7.2.1 The number and position of temperature indicating devices shall be appropriate to the design of the containment system and cargo operation requirements.

7.2.2 When cargo is carried in a cargo containment system with a secondary barrier, at a temperature lower than -55°C, temperature indicating devices 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, alarm of temperatures approaching the lowest for which the hull steel is suitable.

7.2.3 If cargo is to 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 a sufficient number of temperature indicating devices to verify that unsatisfactory temperature gradients do not occur.

7.2.4 For the purposes of design verification and determining the effectiveness of the initial cooldown procedure on a single or series of similar ships, one tank shall be fitted with devices in excess of those required in [7.2.1]. These devices may be temporary or permanent and only need to be fitted to the first vessel, when a series of similar ships is built.

8 Automation systems

8.1 General requirements

8.1.1 The requirements of this section shall apply where automation systems are used to provide instrumented control, monitoring/alarm or safety functions required by this chapter.

Guidance note:
The below requirements in this section are additional to those given in Pt.4 Ch.9.

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

8.1.2 Automation systems shall be designed, installed and tested.

8.1.3 Hardware shall be capable of being demonstrated to be suitable for use in the marine environment by type approval or other means.

8.1.4 Software shall be designed and documented for ease of use, including testing, operation and maintenance.

8.1.5 The user interface shall be designed such that the equipment under control can be operated in a safe and effective manner at all times.

8.1.6 Automation systems shall be arranged such that a hardware failure or an error by the operator does not lead to an unsafe condition. Adequate safeguards against incorrect operation shall be provided.

8.1.7 Appropriate segregation shall be maintained between control, monitoring/alarm and safety functions to limit the effect of single failures. This shall be taken to include all parts of the Automation Systems that are required to provide specified functions, including connected devices and power supplies.
8.1.8 Automation systems shall be arranged such that the software configuration and parameters are protected against unauthorized or unintended change.

8.1.9 A management of change process shall be applied to safeguard against unexpected consequences of modification. Records of configuration changes and approvals shall be maintained on board.

8.1.10 Processes for the development and maintenance of integrated systems shall be in accordance with programme accepted by class. These processes shall include appropriate risk identification and management.

Guidance note:

---end of guidance note---

9 System integration

9.1 General requirements

9.1.1 Essential safety functions shall be designed such that risks of harm to personnel or damage to the installation or the environment are reduced to a level acceptable to the Society, both in normal operation and under fault conditions. Functions shall be designed to fail safe. Roles and responsibilities for integration of systems shall be clearly defined and agreed by relevant parties.

Guidance note:
Essential safety functions in this context are defined as a safety function required by this rule chapter, i.e. a system that initiate an action to prevent escalation of potential hazard.

---end of guidance note---

9.1.2 Functional requirements of each component sub-system shall be clearly defined to ensure that the integrated system meets the functional and specified safety requirements and takes account of any limitations of the equipment under control.

Guidance note:
Integrated system in this context is defined as a system which includes a combination of the two or more of the following functions control, monitoring and safety as required in this chapter. Integration of functions is permitted only for systems where independence is not required.

---end of guidance note---

9.1.3 Key hazards of the integrated system shall be identified using appropriate risk based techniques.

9.1.4 The integrated system shall have a suitable means of reversionary control.

Guidance note:
Reversionary control in this context is defined as alternative means of control that may be local manual or local automatic, whichever is chosen has to be suitable for the needs of the end user.

---end of guidance note---

9.1.5 Operation with an integrated system shall be at least as effective as it would be with individual standalone equipment or systems.

9.1.6 The integrity of essential machinery or systems, during normal operation and fault conditions, shall be demonstrated.
9.1.7 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.

10 Hold leakage alarm

10.1 General requirements

10.1.1 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.

11 Monitoring of thermal oxidation vapour systems (GCU)

11.1 General requirements

11.1.1 Monitoring of thermal oxidation vapour system (GCU) shall be as given in Table 1:

Table 1 Monitoring of thermal oxidation vapour system

<table>
<thead>
<tr>
<th>Item/Parameter</th>
<th>Alarm</th>
<th>Shut down</th>
</tr>
</thead>
<tbody>
<tr>
<td>flame failure</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>loss of combustion air supply</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>loss of cooling air/dilution air supply</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>BOG inlet temperature</td>
<td>L</td>
<td>LL</td>
</tr>
<tr>
<td>combustion gas exit temperature [HH at 535 °C]</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>methane gas concentration in gas pipe duct</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>loss of ventilation in gas pipe duct, alternatively loss of N2 pressure</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>fire detection in GCU space</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>X when happens, L Low, LL Low Low, H High, HH High High.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12 Monitoring of re-liquefaction plants

12.1 General requirements

12.1.1 Monitoring of re-liquefaction system (Brayton cycle) for methane (LNG) shall be as given in Table 2:

Table 2 Monitoring of reliquefaction system

<table>
<thead>
<tr>
<th>Item/Parameter*</th>
<th>Alarm</th>
<th>Shut down</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOG compressor, gas outlet temp.</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>BOG compressor, gas outlet pressure</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>Item/Parameter*</td>
<td>Alarm</td>
<td>Shut down</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td>BOG compressor, gas inlet pressure</td>
<td>H/L</td>
<td></td>
</tr>
<tr>
<td>BOG compressor, gas inlet/outlet temp. diff.</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>BOG compressor, gas inlet temp.</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>BOG compressor, vibrations</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>BOG compressor, lube oil press</td>
<td>L</td>
<td>LL</td>
</tr>
<tr>
<td>BOG compressor, bearings</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>BOG pre-cooler level</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>vapour header pressure</td>
<td>H/L</td>
<td>LL</td>
</tr>
<tr>
<td>LNG separator level</td>
<td>H/L</td>
<td></td>
</tr>
<tr>
<td>LNG separator, pressure</td>
<td>H/L</td>
<td></td>
</tr>
<tr>
<td>N₂ compressor gas inlet pressure</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>N₂ compressor gas inlet temp.</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>N₂ compressor gas outlet pressure</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>N₂ compressor/expander, vibrations</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>N₂ compressor/expander lube oil press</td>
<td>L</td>
<td>LL</td>
</tr>
<tr>
<td>N₂ compressor, bearings</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>N₂ high press/low press differential</td>
<td>X</td>
<td>HH</td>
</tr>
<tr>
<td>cold box enclosure, gas concentration</td>
<td>—</td>
<td>— H</td>
</tr>
<tr>
<td>— methane</td>
<td>— L</td>
<td></td>
</tr>
<tr>
<td>— oxygen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cooling water press.</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>cooling water outlet temp.</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>N₂ compressor room, O₂ concentration</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>N₂ compressor room, loss of ventilation</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>N₂ rejection column, level</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>N₂ rejection column, pressure</td>
<td>H/L</td>
<td></td>
</tr>
<tr>
<td>BOG compressor room O₂ concentration</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>BOG compressor room HC gas concentration</td>
<td>H</td>
<td>X</td>
</tr>
<tr>
<td>BOG compressor room fire detection</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>BOG compressor room, loss of ventilation</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>ESD activated</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>cargo tanks overfill danger</td>
<td>H</td>
<td>HH</td>
</tr>
<tr>
<td>loss of power supply to control and monitoring system</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
### 13 Monitoring of inert gas generator

#### 13.1 General requirements

**13.1.1** Monitoring of inert gas generator shall be as given in Table 3:

*Table 3 Monitoring of inert gas generator*

<table>
<thead>
<tr>
<th>Failure</th>
<th>Alarm</th>
<th>Shutdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>oxygen content &gt; 5%</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>high water level in scrubber</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>low water pressure / flow to scrubber</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>failure of blowers</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>flame failure</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>power failure instrumentation</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>insufficient fuel supply</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

### 14 Monitoring of nitrogen generator

#### 14.1 General arrangement

**14.1.1** Monitoring of nitrogen gas generator shall be as given in Table 4:

*Table 4 Monitoring of nitrogen gas generator*

<table>
<thead>
<tr>
<th>Failure</th>
<th>Alarm</th>
<th>Shutdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>high oxygen content &gt; 5%</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>high temperature of nitrogen</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>low pressure of nitrogen</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>low pressure feed air supply</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>high temperature feed air supply</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>power failure instrumentation</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>block and bleed valve faulty operation</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>valve positions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Guidance note:
The safety shutdowns required by [14] may be handled by the same control system as the control and alarm functions, i.e. exempted from the independency requirement of Pt.4 Ch.9 Sec.3 [1.1.3].

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---
SECTION 14 PERSONNEL PROTECTION

1 General requirements for all products

1.1 Protective equipment

1.1.1 Suitable protective equipment, including eye protection shall be provided for protection of crew members engaged in normal cargo operations, taking into account the characteristics of the products being carried.

1.1.2 Personal protective and safety equipment required shall be kept in suitable, clearly marked lockers located in readily accessible places.

1.1.3 The compressed air equipment shall be inspected at least once a month by a responsible officer and the inspection logged in the ship’s records. This equipment shall also be inspected and tested by a competent person at least once a year.

1.2 First-aid equipment

1.2.1 A stretcher that is suitable for hoisting an injured person from spaces below deck shall be kept in a readily accessible location.

1.2.2 The ship shall have on board medical first aid equipment, including oxygen resuscitation equipment, based on the requirements of the Medical First Aid Guide (MFAG) for the cargoes to be carried.

1.3 Safety equipment

1.3.1 Sufficient, but not less than three complete sets of safety equipment shall be provided in addition to the firefighter’s outfits required by Sec.11 [6.1]. Each set shall provide adequate personal protection to permit entry and work in a gas-filled space. This equipment shall take into account the nature of the cargoes to be carried.

1.3.2 Each complete set of safety equipment shall consist of:

.1 one self-contained positive pressure air breathing apparatus incorporating full face mask, not using stored oxygen and having a capacity of at least 1200 litres of free air. Each set shall be compatible with that required by Sec.11 [6.1]

.2 protective clothing, boots and gloves

.3 steel cored rescue line with belt, and

.4 explosion proof lamp.

1.3.3 An adequate supply of compressed air shall be provided and shall consist of:

.1 at least one fully charged spare air bottle for each breathing apparatus required by [1.3.1], in accordance with the requirements of Sec.11 [6.1]

.2 an air compressor of adequate capacity capable of continuous operation, suitable for the supply of high pressure air of breathable quality, and

.3 a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by [1.3.1].
2 Personal protection requirements for individual products

2.1 General requirements

Provisions of [2] shall apply to ships carrying products for which those paragraphs are listed in column 'i' in the table of Sec.19.

2.1.1 Suitable respiratory and eye protection suitable for emergency escape purposes shall be provided for every person on board, subject to the following

1. Filter type respiratory protection is unacceptable.
2. Self-contained breathing apparatus is normally to have a duration of service of at least 15 min, and
3. Emergency escape respiratory protection shall not be used for fire-fighting or cargo handling purposes and should be marked to that effect.

2.1.2 One or more suitably marked decontamination showers and eyewash stations shall be available on deck, taking into account the size and layout of vessel. The showers and eyewashes shall be operable in all ambient conditions.

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 cargo compressor room. For small ship's reduced number of showers and eye wash can be considered.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.1.3 The protective clothing required under [1.3.2].2 shall be gastight.
SECTION 15 FILLING LIMIT OF CARGO TANKS

1 General

1.1 Definitions

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

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

1.1.3 Reference temperature means, for the purposes of this section only:

1. when no cargo vapour pressure/temperature control, as referred to in Sec.7, is provided, the temperature corresponding to the vapour pressure of the cargo at the set pressure of the PRVs, and
2. when a cargo vapour pressure/temperature control, as referred to in Sec.7, is provided, the temperature of the cargo upon termination of loading, during transport or at unloading, whichever is the greatest.

1.1.4 Ambient design temperature for unrestricted service means sea temperature of 32°C and air temperature of 45°C. However, lesser values of these temperatures may be accepted by the Society 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. Conversely, higher values of these temperatures may be required for ships permanently operating in areas of high ambient temperature.

1.2 General requirements

1.2.1 The maximum filling limit of cargo tanks shall be so determined that the vapour space has a minimum volume at reference temperature allowing for:

1. tolerance of instrumentation such as level and temperature gauges
2. volumetric expansion of the cargo between the PRV set pressure and the maximum allowable rise stated in Sec.8 [4], and
3. an operational margin to account for liquid drained back to cargo tanks after completion of loading, operator reaction time and closing time of valves, see Sec.5 [5] and Sec.18 [2.2.4].

1.3 Default filling limit

1.3.1 The default value for the filling limit (FL) of cargo tanks is 98 % at the reference temperature. Exceptions to this value shall meet the requirements of [1.4].

1.4 Determination of increased filling limit

1.4.1 A filling limit greater than the limit of 98 % specified in [1.3] on condition that, under the trim and list conditions specified in Sec.8 [2.2.15] may be permitted, providing:

1. no isolated vapour pockets are created within the cargo tank
2. the PRV inlet arrangement shall remain in the vapour space, and
3. allowances need to be provided for:
1.4.2 In no case shall a filling limit exceeding 99.5 % at reference temperature be permitted.

1.5 Maximum loading limit

1.5.1 The maximum loading limit (LL) to which a cargo tank may be loaded shall be determined by the following formula:

\[ LL = FL \frac{\rho_R}{\rho_L} \]

where:

- \( LL \) = loading limit as defined in [1.1.2] expressed in %age
- \( FL \) = filling limit as specified in [1.3] or [1.4] expressed in %age
- \( \rho_R \) = relative density of cargo at the reference temperature, and
- \( \rho_L \) = relative density of cargo at the loading temperature.

1.5.2 The Society may allow type C tanks to be loaded according to the formula in [1.5.1] with the relative density \( \rho_R \) as defined below, provided that the tank vent system has been approved in accordance with Sec.8 [2.2.16].

\[ \rho_R = \text{relative density of cargo at the highest temperature that the cargo may reach upon termination of loading, during transport, or at unloading, under the ambient design temperature conditions described in [1.1.4].} \]

This paragraph does not apply to products requiring a type 1G ship.

2 Information to be provided to the master

2.1 Documentation

2.1.1 A document shall be provided to the vessel specifying the maximum allowable loading limits for each cargo tank and product, at each applicable loading temperature and maximum reference temperature. The information in this document shall be approved by the Society.

2.1.2 Pressures at which the PRVs have been set shall also be stated in the document.

2.1.3 A copy of the above document shall be permanently kept on board by the master.
SECTION 16 USE OF GAS FUEL

1 General

1.1 Requirements

1.1.1 Except as provided for in [9], Methane (LNG) is the only cargo whose vapour or boil-off gas may be utilized in machinery spaces of category A, and in these spaces it may be utilized only in systems such as boilers, inert gas generators, internal combustion engines, gas combustion unit (GCU) and gas turbines.

1.1.2 Alarm and safety systems shall comply with the requirements in this section and Pt.4 Ch.9. A dedicated gas safety system, independent of the gas control system, shall be arranged in accordance with the general principles in Pt.4 Ch.9 Sec.3 [1.1.3].

2 Use of cargo vapour as fuel

2.1 General requirements

This section addresses the use of cargo vapour as fuel in systems such as boilers, inert gas generators, internal combustion engines, Gas Combustion Units (GCU) and gas turbines.

2.1.1 For vaporized LNG, the fuel supply system shall comply with the requirements of [4.1] to [4.3].

2.1.2 For vaporized LNG, gas consumers shall exhibit no visible flame and shall maintain the uptake exhaust temperature below 535°C.

Guidance note:
Thermal oxidation of vapours is covered in Sec.7 [4].

3 Arrangement of spaces containing gas consumers

3.1 General requirements

3.1.1 Spaces in which gas consumers are located shall be fitted with a mechanical ventilation system that is arranged to avoid areas where gas may accumulate, taking into account the density of the vapour and potential ignition sources. The ventilation system shall be separated from those serving other spaces.

3.1.2 Gas detectors shall be fitted in these spaces, particularly where air circulation is reduced. The gas detection system shall comply with the requirements of Sec.13.

3.1.3 Electrical equipment located in the double wall pipe or duct specified in [4.3] shall comply with the requirements of Sec.10.

3.1.4 All vents and bleed lines that may contain or be contaminated by gas fuel shall be routed to a safe location external to the machinery space and be fitted with a flame screen.
4 Gas fuel supply

4.1 General requirements

4.1.1 The requirements of [4] shall apply to gas fuel supply piping outside of the cargo area. Fuel piping shall not pass through accommodation spaces, service spaces, electrical equipment rooms or control stations. The routeing of the pipeline shall take into account potential hazards due to mechanical damage, such as stores or machinery handling areas.

4.1.2 Provision shall be made for inerting and gas-freeing that portion of the gas fuel piping systems located in the machinery space.

Guidance note:
Alarm and automatic stop of fuel gas compressors will provide necessary prevention against excessive vacuum.

---end---of---guidance---note---

4.2 Leak detection

4.2.1 Continuous monitoring and alarms shall be provided to indicate a leak in the piping system in enclosed spaces and shut down the relevant gas fuel supply.

4.3 Routeing of fuel supply pipes

4.3.1 Fuel piping may pass through or extend into enclosed spaces other than those mentioned in [4.1], provided it fulfils one of the following conditions:

.1 a double wall design with the space between the concentric pipes pressurized with inert gas at a pressure greater than the gas fuel pressure. The isolating valve, as required by [4.5], closes automatically upon loss of inert gas pressure, or
.2 installed in a pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour, and be arranged to maintain a pressure less than the atmospheric pressure. The mechanical ventilation is in accordance with Sec.12 as applicable. The ventilation is always in operation when there is fuel in the piping and the isolating valve, as required by [4.5], closes automatically if the required air flow is not established and maintained by the exhaust ventilation system. The inlet or the duct may be from a non-hazardous machinery space and the ventilation outlet is in a safe location.

Guidance note:
Condensation in annular space in double wall fuel gas piping shall be prevented, e.g. by heating fuel gas to temperature or drying ventilation air.

---end---of---guidance---note---

4.4 Requirements for gas fuel with pressure greater than 1 MPa

4.4.1 Fuel delivery lines between the high pressure fuel pumps/compressor and consumers shall be protected with a double-walled piping system capable of containing a high pressure line failure, taking into account the effects of both pressure and low temperature. A single walled pipe in the cargo area up to the isolating valve(s) required by [4.6] is acceptable.

4.4.2 The arrangement in [(4.3.1).2] may also be acceptable providing the pipe or trunk is capable of containing a high pressure line failure, according to the requirements of [4.7] and taking into account the
effects of both pressure and possible low temperature and providing both inlet and exhaust of the outer pipe or trunk are in the cargo area.

4.5 Gas consumer isolation

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

4.6 Spaces containing gas consumers

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

4.6.2 If the double barrier around the gas supply system is not continuous due to air inlets or other openings, or if there is any point where single failure will cause leakage into the space, it shall be possible to isolate the gas fuel supply to each individual space with an individual master gas fuel valve, which shall be located within the cargo area. It shall operate under the following circumstances:

1. automatically by:
   1. gas detection within the space
   2. leak detection in the annular space of a double walled pipe
   3. leak detection in other compartments inside the space, containing single walled gas piping
   4. loss of ventilation in the annular space of a double walled pipe
   5. loss of ventilation in other compartments inside the space, containing single walled gas piping
2. manually from within the space, and at least one remote location.

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

1. automatically by:
   1. leak detection in the annular space of a double walled pipe served by that individual master valve
   2. leak detection in other compartments containing single-walled gas piping that is part of the supply system served by that individual master valve
   3. loss of ventilation or loss of pressure in the annular space of a double walled pipe
2. manually from within the space, and at least one remote location.

4.7 Piping and ducting construction

4.7.1 Gas fuel piping in machinery spaces shall comply with Sec.5 [1] to Sec.5 [9], as applicable. The piping shall, as far as practicable, have welded joints. Those parts of the gas fuel piping that are not enclosed in a ventilated pipe or duct according to [4.3], and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be fully radiographed.
4.8 Gas detection

4.8.1 Gas detection systems provided in accordance with the requirements of this section shall activate the alarm at 30 % LFL and shut down the master gas fuel valve required by [4.6] at not more than 60 % LFL. See also Sec.13 [6.1.17].

5 Gas fuel plant and related storage tanks

5.1 Provision of gas fuel

5.1.1 All equipment, e.g. heaters, compressors, vaporizers, filters, for conditioning the cargo and/or cargo boil-off vapour for its use as fuel, and any 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.12 [1] and be equipped with a fixed fire-extinguishing system, according to Sec.11 [5], and with a gas detection system according to Sec.13 [6], as applicable.

5.2 Remote stops and alarm

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

5.2.2 The fuel supply equipment shall be automatically stopped in the case of low suction pressure or fire detection. The requirements of Sec.18 [2.1.1] need not apply to gas fuel compressors or pumps when used to supply gas consumers.

5.2.3 Alarm should be given for abnormal pressure in the gas fuel supply line or for failure of the valve control actuating medium.

5.3 Heating and cooling mediums

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

5.4 Piping and pressure vessels

5.4.1 Piping or pressure vessels fitted in the gas fuel supply system shall comply with Sec.5.

6 Special requirements for main boilers

6.1 Arrangements

6.1.1 Each boiler shall have a separate exhaust uptake.

6.1.2 Each boiler shall have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.
6.1.3 Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.

6.2 Combustion equipment

6.2.1 The burner systems shall be of dual type, suitable to burn either: oil fuel or gas fuel alone, or oil and gas fuel simultaneously.

   Guidance note:
   This requirement does not apply to auxiliary boilers.

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

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

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

6.3 Safety

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

6.3.2 On the pipe of each gas burner a manually operated shut-off valve shall be fitted.

6.3.3 Provisions shall be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

6.3.4 The automatic fuel changeover system required by [6.2.3] shall be monitored with alarms to ensure continuous availability.

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

6.3.6 Arrangements shall be made to enable the boilers to be manually purged.

6.3.7 Oxygen content in the exhaust gas line shall be indicated

6.3.8 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.

6.3.9 The extent of monitoring of gas fired boilers shall comply with the requirements specified in Pt.4 Ch.7 for oil fired boilers.

6.3.10 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
7 Special requirements for gas-fired internal combustion engines

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

7.1 Arrangements

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

7.1.2 Each engine shall have its own separate exhaust.

7.1.3 The exhausts shall be configured to prevent any accumulation of un-burnt gaseous fuel.

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

7.1.5 Each engine shall be fitted with vent systems independent of other engines for crankcases, sumps and cooling systems.

7.2 Combustion equipment

7.2.1 Prior to admission of gas fuel, correct operation of the pilot oil injection system on each unit shall be verified.

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

7.2.3 For dual fuel engines fitted with a pilot oil injection system an automatic system shall be fitted to change over from gas fuel operation to oil fuel operation with minimum fluctuation of the engine power.

7.2.4 In the case of unstable operation on engines with the arrangement in [7.2.3] when gas firing, the engine shall automatically change to oil fuel mode.

7.3 Safety

7.3.1 During stopping of the engine the gas fuel shall be automatically shut-off before the ignition source.

7.3.2 Arrangements shall be provided to ensure that there is no unburned gas fuel in the exhaust gas system prior to ignition.

7.3.3 Crankcases, sumps, scavenge spaces and cooling system vents shall be provided with gas detection, see Sec.13 [6.1.17].

Guidance note:
Gas detection in crankcase vent will be acceptable. One common gas detector for crankcase vent of multi engines is acceptable. For sump tanks, scavenge spaces and cooling water vents individual sensors is required.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
7.3.4 Provision shall be made within the design of the engine to permit continuous monitoring of possible sources of ignition within the crank case. Instrumentation fitted inside the crankcase shall be in accordance with the requirements of Sec.10.

7.3.5 A means shall be provided to monitor and detect poor combustion or mis-firing that may lead to unburned gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply shall be shut down. Instrumentation fitted inside the exhaust system shall be in accordance with the requirements of Sec.10.

8 Special requirements for gas turbine

8.1 Arrangements

8.1.1 Each turbine shall have its own separate exhaust.

8.1.2 The exhausts shall be appropriately configured to prevent any accumulation of un-burnt gas fuel.

8.1.3 Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration of explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be lead to a non-hazardous location, away from personnel.

8.2 Combustion equipment

An automatic system shall be fitted to change over easily and quickly from gas fuel operation to oil fuel operation with minimum fluctuation of the engine power.

8.3 Safety

8.3.1 Means shall be provided to monitor and detect poor combustion that may lead to unburned gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply shall be shut down.

8.3.2 Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.

9 Alternative fuels and technologies

9.1 General requirements

9.1.1 If acceptable to the Society, other cargo gases may be used as fuel, providing that the same level of safety as natural gas in this section is ensured.

9.1.2 The use of cargoes identified as toxic in Sec.19 are not permitted.

9.1.3 For cargoes other than LNG, the fuel supply system shall comply with the requirements of [4.1], [4.2], [4.3] and [5], as applicable, and shall include means for preventing condensation of vapour in the system.

9.1.4 Liquefied gas fuel supply systems shall comply with [4.5].

9.1.5 In addition to the requirements of [4.3.1].2, both ventilation inlet and outlet shall be in a non-hazardous area external to the machinery space.
10 Gas only installations

10.1 General requirements and safety

10.1.1 The requirements given in [10] apply for single fuel installations with Gas only.

10.1.2 The fuel supply system shall be arranged with full redundancy with separate master gas valves and full segregation all the way from the cargo tanks to the consumer, so that a single failure does not lead to loss of propulsion, power generation or other main function.

10.1.3 Power supply to spray water and fire main pumps shall be provided by power source not depending on gas supply.

Guidance note:

This requirement means that the spray water pumps must be driven by diesel engine or alternatively one of the generators driven by diesel or duel fuel engine.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

10.1.4 Each fuel gas system shall be fitted with its own set of independent gas control and gas safety systems.

10.1.5 Gas supply lines with master gas valves should be located as far as possible from each other.

11 Gas fuel operation manual

11.1 General requirements

11.1.1 A gas fuel operational manual as shall be kept onboard and can be part of the required operation manual required in Sec.18 [1]. The gas fuel operation manual is in general to give information regarding the following:

.1 Descriptions of main components in the gas fuel supply system
.2 A general description of how the fuel system is intended to work
.3 Description of the safety shut-down system for the gas fuel supply system
.4 Safety pre-cautions related to maintenance
.5 Relevant drawings of the gas fuel installation, including:
   — fuel gas piping diagram
   — fuel gas system arrangement plan
   — ventilation systems
SECTION 17 SPECIAL REQUIREMENTS

1 General
The provisions of this section are applicable where reference is made in column 'i' in the table of Sec.19. These are requirements additional to the general requirements of the rule set.

1.1 Materials of construction

1.1.1 Materials that may be exposed to cargo during normal operations shall be resistant to the corrosive action of the gases. In addition, the following materials of construction for cargo tanks and associated pipelines, valves, fittings and other items of equipment normally in direct contact with the cargo liquid or vapour, shall not be used for certain products as specified in column 'i' in the table at Sec.19:

1. mercury, copper and copper-bearing alloys, and zinc
2. copper, silver, mercury, magnesium and other acetylide-forming metals
3. aluminium and aluminium-bearing alloys
4. copper, copper alloys, zinc and galvanized steel
5. aluminium, copper and alloys of either, and
6. copper and copper-bearing alloys with greater than 1% copper.

1.2 Independent tanks

1.2.1 Products shall be carried in independent tanks only.

1.2.2 Products shall be carried in type C independent tanks and the provisions of Sec.7 [1.1.2] shall apply. The design pressure of the cargo tank shall take into account any padding pressure or vapour discharge unloading pressure.

1.3 Refrigeration systems

1.3.1 Only the indirect system described in Sec.7 [3.1.1].2 shall be used.

1.3.2 For a ship engaged in the carriage of products that readily form dangerous peroxides, re-condensed cargo shall not be allowed to form stagnant pockets of uninhibited liquid. This may be achieved either by:

1. using the indirect system described in Sec.7 [3.1.1].2, with the condenser inside the cargo tank, or
2. using the direct system or combined system described in Sec.7 [3.1.1].1 and Sec.7 [3.1.1].3, respectively, or the indirect system described in Sec.7 [3.1.1].2 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.

1.3.3 If the ship is to consecutively carry products as specified in [1.3.2] with a ballast passage between, all uninhibited liquid shall be removed prior to the ballast voyage. If a second cargo is to 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 cargo system.
1.4 Cargoes requiring type 1G ship

1.4.1 All butt-welded joints in cargo piping exceeding 75 mm in diameter shall be subject to 100 % radiography.

1.4.2 Gas sampling lines shall not be led into or through non-hazardous areas. Alarms referred to in Sec.13 [6.1.2] shall be activated when the vapour concentration reaches the threshold limiting value.

1.4.3 The alternative of using portable gas detection equipment in accordance with Sec.13 [6.1.5] shall not be permitted.

1.4.4 Cargo control rooms shall be located in a non-hazardous area and, additionally, all instrumentation shall be of the indirect type.

1.4.5 Personnel shall be protected against the effects of a major cargo release by the provision of a space within the accommodation area that is designed and equipped to the satisfaction of the Society.

1.4.6 Notwithstanding the provision in Sec.3 [2.1.4].3, access to forecastle spaces shall not be permitted through a door facing the cargo area unless airlock in accordance with Sec.3 [6] is provided.

1.4.7 Notwithstanding the provision in Sec.3 [2.1.7], access to control rooms and machinery spaces of turret systems shall not be permitted through doors facing the cargo area.

1.5 Exclusion of air from vapour spaces

Air shall be removed from 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 inert gas shall at no time be greater than 0.2% by volume, or

.2 control of cargo temperatures such that a positive pressure is maintained at all times.

1.6 Moisture control

For gases that are non-flammable and may become corrosive or react dangerously with water, moisture control shall be provided to ensure that cargo tanks are dry before loading and that, during discharge, dry air or cargo vapour is introduced to prevent negative pressures. For the purposes of this paragraph, dry air is air that has a dew point of -45°C or below at atmospheric pressure.

1.7 Inhibition

1.7.1 Care shall be taken to ensure that the cargo is sufficiently inhibited to prevent self-reaction, e.g. polymerization or dimerization, at all times during the voyage. Ships shall be provided with a certificate from the manufacturer stating:

.1 name and amount of inhibitor added
.2 date inhibitor was added and the normally expected duration of its effectiveness
.3 any temperature limitations affecting the inhibitor, and
.4 the action to be taken shall the length of the voyage exceed the effective lifetime of the inhibitors.
1.8 Flame screens on vent outlets

1.8.1 When carrying a cargo referenced to this section, cargo tank vent outlets shall be provided with readily renewable and effective flame screens or safety heads of an approved type. Due attention shall be paid to 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. Flame screens shall be removed and replaced by protection screens in accordance with Sec.8 [2.2.13] when carrying cargoes not referenced to this section.

1.9 Maximum allowable quantity of cargo per tank

1.9.1 When carrying a cargo referenced to in this section, the quantity of the cargo shall not exceed 3000 m$^3$ in any one tank.

1.10 Cargo pumps and discharge arrangements

1.10.1 The vapour space of cargo tanks equipped with submerged electric motor pumps shall be inerted to a positive pressure prior to loading, during carriage and during unloading of flammable liquids.

1.10.2 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.

1.10.3 Inert gas displacement may be used for discharging cargo from type C independent tanks provided the cargo system is designed for the expected pressure.

2 Ammonia

2.1 General requirements

2.1.1 Anhydrous ammonia may cause stress corrosion cracking in containment and process systems made of carbon-manganese steel or nickel steel. To minimize the risk of this occurring, measures detailed in [2.1.2] to [2.1.8] shall be taken, as appropriate.

2.1.2 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$^2$, and with an actual yield strength not exceeding 440 N/mm$^2$. 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$^2$ shall be used, or
.2 cargo tanks, etc., shall be post-weld stress relief heat treated, or
.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, or
.4 the ammonia shall contain not less than 0.1% w/w water and the master shall be provided with documentation confirming this.

2.1.3 If carbon-manganese steels with higher yield properties are used other than those specified in [2.1.2], the completed cargo tanks, piping, etc., shall be given a post-weld stress relief heat treatment.

2.1.4 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 [2.1.1].
2.1.5 The tensile and yield properties of the welding consumables shall exceed those of the tank or piping material by the smallest practical amount.

2.1.6 Nickel steel containing more than 5% nickel and carbon-manganese steel, not complying with the requirements of [2.1.2] and [2.1.3], are particularly susceptible to ammonia stress corrosion cracking and shall not be used in containment and piping systems for the carriage of this product.

2.1.7 Nickel steel containing not more than 5% nickel may be used provided the carriage temperature complies with the requirements specified in [2.1.2].

2.1.8 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 function of the carriage temperature $T$ in the table below:

### Table 1 Ammonia stress corrosion cracking

<table>
<thead>
<tr>
<th>$T$ in °C</th>
<th>$O_2$ in % by volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30 and below</td>
<td>0.90</td>
</tr>
<tr>
<td>-20</td>
<td>0.50</td>
</tr>
<tr>
<td>-10</td>
<td>0.28</td>
</tr>
<tr>
<td>0</td>
<td>0.16</td>
</tr>
<tr>
<td>+10</td>
<td>0.10</td>
</tr>
<tr>
<td>+20</td>
<td>0.05</td>
</tr>
<tr>
<td>+30</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Oxygen % for intermediate temperatures may be obtained by direct interpolation.

### 3 Chlorine

3.1 Cargo containment system

3.1.1 The capacity of each tank shall not exceed 600 m$^3$ and the total capacity of all cargo tanks shall not exceed 1200 m$^3$.

3.1.2 The tank design vapour pressure shall not be less than 1.35 MPa, see also Sec.7 [1.1.2] and [1.2.2].

3.1.3 Parts of tanks protruding above the upper deck shall be provided with protection against thermal radiation, taking into account total engulfment by fire.

3.1.4 Each tank shall be provided with two PRVs. A bursting disc of appropriate material shall be installed between the tank and the PRVs. The rupture pressure of the bursting disc shall be 1 bar lower than the opening pressure of the pressure relief valve, which shall be set at the design vapour pressure of the tank but not less than 1.35 MPa bar gauge. 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.
3.1.5 Outlets from PRVs 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.

3.1.6 The national regulations and the port Administration may require that chlorine is carried in a refrigerated state at a specified maximum pressure.

3.2 Cargo piping systems

3.2.1 Cargo discharge shall be performed by means of compressed chlorine vapour from shore, dry air or another acceptable gas, or fully submerged pumps. Cargo discharge compressors on board ships shall not be used for this. The pressure in the vapour space of the tank during discharging shall not exceed 1.05 MPa.

3.2.2 The design pressure of the cargo piping system shall be not less than 2.1 MPa. The internal diameter of the cargo pipes shall not exceed 100 mm. Only pipe bends shall be accepted for compensation of pipeline thermal movement. The use of flanged joints shall be restricted to a minimum and, when used the flanges, shall be of the welding neck type with tongue and groove.

3.2.3 Relief valves of the cargo piping system shall discharge to the absorption plant, and the flow restriction created by this unit shall be taken into account when designing the relief valve system, see also Sec.8 [2.2.16].

3.3 Materials

3.3.1 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.

3.3.2 The tanks shall be thermally stress relieved. Mechanical stress relief shall not be accepted as an equivalent.

3.4 Instrumentation, safety devices

3.4.1 The ship shall be provided with a chlorine absorbing plant with a connection 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.

3.4.2 During the gas-freeing of cargo tanks, vapours shall not be discharges to the atmosphere.

3.4.3 A gas detecting system shall be provided that is capable of monitoring chlorine concentrations of at least 1 ppm by volume. Sample points shall be located:

1. near the bottom of the hold spaces
2. in the pipes from the safety relief valves
3. at the outlet from the gas absorbing plant
4. at the inlet to the ventilation systems for the accommodation, service and machinery spaces and control stations, and
5. on deck – at the forward end, midships and the after end of the cargo area.

This is only required to be used during cargo handling and gas-freeing operations.

The gas detection system shall be provided with an audible and visual alarm with a set point of 5 ppm.
3.4.4 Each cargo tank shall be fitted with a high-pressure alarm giving an audible alarm at a pressure equal to 1.05 MPa.

3.5 Personnel protection
The enclosed space required by [1.4.5] shall meet the following requirements:

1. the space shall be easily and quickly accessible from the weather decks and from accommodation spaces by means of air locks and shall be capable of being rapidly closed gastight
2. one of the decontamination showers required by Sec.14 [2.1.2] shall be located near the weather decks airlock to the space
3. the space shall be so designed to accommodate the entire crew of the ship and be provided with a source of uncontaminated air for a period of not less than 4 hours, and
4. one set of oxygen therapy equipment shall be carried in the space.

3.6 Filling limits for cargo tanks
3.6.1 The requirements of Sec.15 [1.1.3] .2 do not apply when it is intended to carry chlorine.
3.6.2 The chlorine content of the gas in the vapour space of the cargo tank after loading shall be greater than 80 % by volume.

4 Ethylene oxide

4.1 General requirements
4.1.1 For the carriage of ethylene oxide the requirements of [8] shall apply, with the additions and modifications as given in this section.
4.1.2 Deck tanks shall not be used for the carriage of ethylene oxide.
4.1.3 Stainless steels types 416 and 442, as well as cast iron, shall not be used in ethylene oxide cargo containment and piping systems.
4.1.4 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.
4.1.5 Ethylene oxide shall be discharged only by deepwell pumps or inert gas displacement. The arrangement of pumps shall comply with [8.1.15].
4.1.6 Ethylene oxide shall be carried refrigerated only and maintained at temperatures of less than 30°C.
4.1.7 PRVs shall be set at a pressure of not less than 0.55 MPa. The maximum set pressure shall be specially approved by the Society.
4.1.8 The protective padding of nitrogen gas, as required by [8.1.27], 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.
4.1.9 Before loading, and at all times when the cargo tank contains ethylene oxide liquid or vapour, the cargo tank shall be inerted with nitrogen.
4.1.10 The water-spray system required by [8.1.29] and that are required by Sec.11 [3] shall operate automatically in a fire involving the cargo containment system.

4.1.11 A jettisoning arrangement shall be provided to allow the emergency discharge of ethylene oxide in the event of uncontrollable self-reaction.

5 Separate piping systems

5.1 General

5.1.1 Separate piping systems, as defined in Sec.1 [3.1] shall be provided.

6 Methyl acetylene-propadiene mixtures

6.1 General requirements

6.1.1 Methyl acetylene-propadiene mixtures shall be suitably stabilized for transport. Additionally, upper limits of temperatures and pressure during the refrigeration shall be specified for the mixtures.

6.1.2 Examples of acceptable, stabilized compositions are:

.1 composition 1

.1 maximum methyl acetylene to propadiene molar ratio of 3 to 1
.2 maximum combined concentration of methyl acetylene and propadiene of 65 mol %
.3 minimum combined concentration of propane, butane, and isobutane of 24 mol %, of which at least one third (on a molar basis) shall be butanes and one third propane
.4 maximum combined concentration of propylene and butadiene of 10 mol %

.2 composition 2

.1 maximum methyl acetylene and propadiene combined concentration of 30 mol %
.2 maximum methyl acetylene concentration of 20 mol %
.3 maximum propadiene concentration of 20 mol %
.4 maximum propylene concentration of 45 mol %
.5 maximum butadiene and butylenes combined concentration of 2 mol %
.6 minimum saturated C4 hydrocarbon concentration of 4 mol %

and

.7 minimum propane concentration of 25 mol %.

6.1.3 Other compositions may be accepted provided the stability of the mixture is demonstrated to the satisfaction of the Society.

6.1.4 If a ship has a direct vapour compression refrigeration system this shall comply with the following requirements, subject to pressure and temperature limitations depending on the composition. For the example, the compositions given in [6.1.2], the following features shall be provided:

.1 a vapour compressor that does not raise the temperature and pressure of the vapour above 60°C and 1.75 MPa during its operation, and that does not allow vapour to stagnate in the compressor while it continues to run
.2 discharge piping from each compressor stage or each cylinder in the same stage of a reciprocating compressor shall have:
.1 two temperature-actuated shutdown switches set to operate at 60°C or less
.2 a pressure-actuated shutdown switch set to operate at 1.75 MPa bar gauge or less
.3 a safety relief valve set to relieve at 1.8 MPa bar gauge or less
.3 the relief valve required by [6.1.4] .2 and .3 shall vent to a mast meeting the requirements of Sec.8 [2.2.7], Sec.8 [2.2.8] and Sec.8 [2.2.13] and shall not relieve into the compressor suction line, and
.4 an alarm that sounds in the cargo control position and in the navigating bridge when a high-pressure switch, or a high-temperature switch, operates.

6.1.5 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 [3.1], or separate, as defined in Sec.1 [3.1], from piping and refrigeration systems for other tanks. This segregation shall apply to all liquid and vapour vent lines and any other possible connections, such as common inert gas supply lines.

7 Nitrogen

7.1 General requirements

7.1.1 Materials of construction and ancillary 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.

8 Propylene oxide and mixtures of ethylene oxide-propylene oxide with ethylene oxide content of not more than 30% by weight

8.1 General requirements

8.1.1 Products transported under the provisions of this section shall be acetylene-free.

8.1.2 Unless cargo tanks are properly cleaned, these products shall not be carried in tanks that have contained as one of the three previous cargoes any product known to catalyse polymerization, such as:

.1 anhydrous ammonia and ammonia solutions
.2 amines and amine solutions, and
.3 oxidizing substances (e.g. chlorine).

8.1.3 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 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.

8.1.4 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 traces of acidic or alkaline materials remain that might create a hazardous situation in the presence of these products.

8.1.5 Tanks shall be entered and inspected prior to each initial loading of these products to ensure freedom from contamination, 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.

8.1.6 Tanks for the carriage of these products shall be of steel or stainless steel construction.
8.1.7 Tanks that have contained these products may be used for other cargoes after thorough cleaning of tanks and associated pipework systems by washing or purging.

8.1.8 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 in accordance with recognized standards. Disc or disc faces, seats and other wearing parts of valves shall be made of stainless steel containing not less than 11% chromium.

8.1.9 Gaskets shall be constructed of materials which do not react with, dissolve in, or lower the autoignition temperature of these products and which are fire-resistant and possess adequate mechanical behaviour. The surface presented to the cargo 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 if approved by the Society.

8.1.10 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.

8.1.11 The following materials are generally found unsatisfactory for use in gaskets, packing and similar uses in containment systems for these products and would require testing before being approved:

\[\begin{align*}
.1 & \text{ neoprene or natural rubber if comes into contact with the products} \\
.2 & \text{asbestos or binders used with asbestos, and} \\
.3 & \text{materials containing oxides of magnesium, such as mineral wools.}
\end{align*}\]

8.1.12 Filling and discharge piping shall extend to within 100 mm of the bottom of the tank or any sump.

8.1.13 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.

8.1.14 During discharging operations, the pressure in the cargo tank shall be maintained above 0.007 MPa.

8.1.15 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.

8.1.16 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.

8.1.17 Cargo hoses used for transfer of these products shall be marked "FOR ALKYLENE OXIDE TRANSFER ONLY".

8.1.18 Hold spaces shall be monitored for these products. Hold spaces surrounding type A and B independent tanks shall also be inducted and monitored for oxygen. The oxygen content of these spaces shall be maintained below 2% by volume. Portable sampling equipment is satisfactory.

8.1.19 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.

8.1.20 Tanks shall be designed for the maximum pressure expected to be encountered during loading, carriage or unloading of cargo.

8.1.21 Tanks for the carriage of propylene oxide with a design vapour pressure of less than 0.06 MPa, and tanks for the carriage of ethylene oxide-propylene oxide mixtures with a design vapour pressure of less than
0.12 MPa, shall have a cooling system to maintain the cargo below the reference temperature. For reference temperatures see Sec.15 [1.1.3].

8.1.22 Pressure relief valve settings shall not be less than 0.02 MPa; for type C independent cargo tanks not greater than 0.7 MPa for the carriage of propylene oxide and not greater than 0.53 MPa for the carriage of ethylene oxide-propylene oxide mixtures.

8.1.23 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 [3.1], 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.

8.1.24 The products shall be transported only in accordance with cargo handling plans 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 the blank flanges needed to meet the above piping separation requirements. A copy of each approved cargo handling plan shall be kept on board the ship.

8.1.25 Before each initial loading of these products, and before every subsequent return to such service, 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.

8.1.26 The maximum allowable loading limits for each tank shall be indicated for each loading temperature that may be applied, in accordance with Sec.15 [1.5].

8.1.27 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 MPa 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, i.e. 99.9% by volume, 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.

8.1.28 The cargo tank vapour space shall be tested prior to and after loading to ensure that the oxygen content is 2 % by volume or less.

8.1.29 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/m² per minute. The arrangement shall ensure that any spilled cargo is washed away.

8.1.30 The water spray system shall be capable of local and remote manual operation in case of a fire involving the cargo containment system. Remote manual operation shall be arranged such that the remote starting of pumps supplying the 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.

8.1.31 When ambient temperatures permit, a pressurized water hose ready for immediate use shall be available during loading and unloading operations, in addition to the water spray requirements above.
9 Vinyl chloride

9.1 General requirements

9.1.1 In cases where polymerization of vinyl chloride is prevented by addition of an inhibitor, [1.7] is applicable. In cases where no inhibitor has been added, or the inhibitor concentration is insufficient, any inert gas used for the purposes of [1.5] shall contain no more oxygen than 0.1 % by volume. Before loading is started inert gas samples from the tanks and piping shall be analysed. When vinyl chloride is carried, a positive pressure shall always be maintained in the tanks and during ballast voyages between successive carriages.

10 Mixed C4 cargoes

10.1 General requirements

10.1.1 Cargoes that may be carried individually under the requirement of this chapter, notably butane, butylenes and butadiene, may be carried as mixtures subject to the provisions of this section. These cargoes may variously be referred to as "Crude C4", "Crude butadiene", "Crude steam-cracked C4", "Spent steam-cracked C4", "C4 stream", "C4 raffinate", or may be shipped under a different description. In all cases, the material data sheets (MSDS) shall be consulted as the butadiene content of the mixture is of prime concern as it is potentially toxic and reactive. While it is recognized that butadiene has a relatively low vapour pressure, if such mixtures contain butadiene they shall be regarded as toxic and the appropriate precautions applied.

10.1.2 If the mixed C4 cargo shipped under the terms of this section contains more than 50 % in mole of butadiene, the inhibitor precautions in [1.7] shall apply.

10.1.3 Unless specific data on liquid expansion coefficients is given for the specific mixture loaded, the filling limit restrictions of Sec.15 shall be calculated as if the cargo contained 100 % concentration of the component with the highest expansion ratio.

11 Carbon dioxide

11.1 Carbon dioxide – high purity

11.1.1 Uncontrolled pressure loss from the cargo can cause 'sublimation' and the cargo will change from the liquid to the solid state. The precise 'triple point' temperature of a particular carbon dioxide cargo shall be supplied before loading the cargo, and will depend on the purity of that cargo, and this shall be taken into account when cargo instrumentation is adjusted. The set pressure for the alarms and automatic actions described in this section shall be set to at least 0.05 MPa above the triple point for the specific cargo being carried. The 'triple point' for pure carbon dioxide occurs at 0.5 MPa and -54.4°C.

11.1.2 There is a potential for the cargo to solidify in the event that a cargo tank relief valve, fitted in accordance with Sec.8 [2], fails in the open position. To avoid this, a means of isolating the cargo tank safety valves shall be provided and the requirements of Sec.8 [2.2.6] do not apply when carrying this carbon dioxide. Discharge piping from safety relief valves shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping, so the requirements of Sec.8 [2.2.13] do not apply. Normally each cargo tank shall be provided with four safety relief valves. Means of easy isolation of each safety relief valve shall be fitted. Two valves shall always be in operation.
11.1.3 Discharge piping from safety relief valves are not required to comply with Sec.8 [2.2.7], but shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping, so the requirements of Sec.8 [2.2.13] do not apply.

11.1.4 Cargo tanks shall be continuously monitoring for low pressure when a carbon dioxide cargo is carried. An audible and visual alarm shall be given at the cargo control position and on the bridge. If the cargo tank pressure continues to fall to within 0.05 MPa of the 'triple point' for the particular cargo, the monitoring system shall automatically close all cargo manifold liquid and vapour valves and stop all cargo compressors and cargo pumps. The emergency shutdown system required by Sec.8 [2] may be used for this purpose.

11.1.5 All materials used in cargo tanks and cargo piping system shall be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the carbon dioxide cargo at the set pressure of the automatic safety system described in [11.1.1] above.

11.1.6 Cargo hold spaces, cargo compressor rooms and other enclosed spaces where carbon dioxide could accumulate shall be fitted with continuous monitoring for carbon dioxide build-up. This fixed gas detection system replaces the requirements of Sec.13 [6], and hold spaces shall be monitored permanently even if the ship has type C cargo containment.

11.1.7 Hold spaces shall be segregated from machinery, boiler spaces and accommodation spaces by at least A-0 class.

11.1.8 Oxygen deficiency monitoring shall be fitted for cargo compressor rooms and cargo hold spaces. Audible and visual alarm shall be located on the navigation bridge, in the cargo control room, the engine control room and the cargo compressor room.

11.1.9 Cargo compressor rooms shall be mechanically ventilated by 30 air changes per hour.

11.1.10 Entrances to hold spaces containing cargo tanks and compressor rooms should be preferably from open deck. Direct access from accommodation spaces, service spaces and control stations is not accepted. In case the entrance is from any enclosed space other than the spaces specified above shall have audible and visual alarm for oxygen deficiency of the hold spaces and the compressor rooms. The access door shall be open outwards.

Guidance note:
The following rule requirements in this chapter can be considered to not apply:
— requirements for ship arrangements, Sec.3 [1], Sec.3 [2], Sec.3 [3]
— requirements for electrical bonding Sec.5 [7.4]
— requirements for mechanical ventilation in cargo area: Sec.12
— requirements for fire protection and fire extinction as given in Sec.11
— requirements for area classification and electrical installations as given in Sec.10
— requirements for fusible elements as given in Sec.10 [2.3.2]
— Restricted level gauging based on "bleeding" principles may be accepted.
Note that acceptance to waive above requirements are given on case by case basis.

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

11.2 Carbon dioxide – reclaimed quality

11.2.1 The requirements of [11.1] also apply to this cargo. In addition, the materials of construction used in the cargo system shall also take account of the possibility of corrosion in case the Reclaimed Quality Carbon Dioxide cargo contains impurities such as water, Sulphur Dioxide, etc., which can cause acidic corrosion or other problems.
SECTION 18 CARGO OPERATION MANUAL AND CARGO EMERGENCY SHUTDOWN SYSTEM

1 Cargo operations manuals

1.1 General requirements

1.1.1 The ship shall be provided with copies of suitably detailed cargo system operating manuals approved by the Society such that trained personnel can safely operate the vessel with due regard to the hazards and properties of the cargoes that are permitted to be carried.

1.1.2 The content of the manuals shall include but not be limited to:

1. overall operation of the ship from dry-dock to dry-dock, including procedures for cargo tank cooldown and warm-up, transfer including ship-to-ship transfer, cargo sampling, gas-freeing, ballasting, tank cleaning and changing cargoes
2. cargo temperature and pressure control systems
3. cargo system limitations, including minimum temperatures in cargo system and inner hull, maximum pressures, transfer rates, filling limits and sloshing limitations
4. nitrogen and inert gas systems
5. fire-fighting procedures: operation and maintenance of firefighting systems and use of extinguishing agents
6. special equipment needed for the safe handling of the particular cargo;
7. fixed and portable gas detection
8. control, alarm and safety systems
9. emergency shutdown systems
10. procedures to change cargo tank pressure relief valve set pressures in accordance with Sec.8 [2.2.5] and Sec.4 [3.3.1].3, and
11. emergency procedures, including cargo tank relief valve isolation, single tank gas-freeing and entry and emergency ship-to-ship transfer operations.

1.2 Cargo information

1.2.1 Information shall be on board and available to all concerned in the form of a cargo information data sheet(s) giving the necessary data for the safe carriage of cargo. Such information shall include, for each product carried:

1. a full description of the physical and chemical properties necessary for the safe carriage and containment of the cargo;
2. reactivity with other cargoes that are capable of being carried on board in accordance with the Certificate of Fitness;
3. the actions to be taken in the event of cargo spills or leaks;
4. countermeasures against accidental personal contact;
5. fire-fighting procedures and fire-fighting media;
6. special equipment needed for the safe handling of the particular cargo; and
7. emergency procedures.

1.2.2 The physical data supplied to the master, in accordance with [1.2.1], shall include information regarding the relative cargo density at various temperatures to enable the calculation of cargo tank filling limits in accordance with the requirements of Sec.15.
1.2.3 Contingency plans in accordance with [[1.2.1].3], for spillage of cargo carried at ambient temperature, shall take account of potential local temperature reduction such as when the escaped cargo has reduced to atmospheric pressure and the potential effect of this cooling on hull steel.

2 Cargo emergency shutdown (ESD) system

2.1 General

2.1.1 A cargo emergency shutdown system shall be fitted to all ships to stop cargo flow in the event of an emergency, either internally within the ship, or during cargo transfer with ship or shore. The design of the ESD system shall avoid the potential generation of surge pressures within cargo transfer pipe work, see [2.1.4].

2.1.2 Auxiliary systems for conditioning the cargo that use toxic or flammable liquids or vapours shall be treated as cargo systems for the purposes of ESD. Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.

2.1.3 The ESD system shall be activated by the manual and automatic inputs listed in Table 1. Any additional inputs shall only be included in the ESD system if it can be shown their inclusion does not reduce the integrity and reliability of the system overall.

2.1.4 Ship's ESD systems shall incorporate a ship-shore link.

2.1.5 A functional flow chart of the ESD system and related systems shall be provided in the cargo control station and on the navigation bridge.

2.2 ESD valve requirements

2.2.1 The term ESD valve means any valve operated by the ESD system.

2.2.2 ESD valves shall be remotely operated, be of the fail closed type (closed on loss of actuating power), shall be capable of local manual closure and have positive indication of the actual valve position. As an alternative to the local manual closing of the ESD valve, a manually operated shut-off valve in series with the ESD valve shall be permitted. The manual valve shall be located adjacent to the ESD valve. Provisions must be made to handle trapped liquid shall the ESD valve close while the manual valve is also closed.

2.2.3 ESD valves in liquid piping systems shall close fully and smoothly within 30 seconds of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.

2.2.4 The closing time of the valve in seconds referred to in Sec.13 [3.1.1] to Sec.13 [3.1.3], i.e. time from shutdown signal initiation to complete valve closure, shall not be greater than:

\[ \frac{3600U}{LR} \]

where:

- \( U \) = ullage volume at operating signal level in \( \text{m}^3 \)
- \( LR \) = maximum loading rate agreed between ship and shore facility in \( \text{m}^3/\text{h} \).
The loading rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the loading hose or arm, the ship and the shore piping systems where relevant.

2.2.5 Ship-shore and ship-ship manifold connections
One ESD valve shall be provided at each manifold connection. Cargo manifold connections not being used for transfer operations shall be blanked with blank flanges rated for the design pressure of the pipeline system.

2.2.6 Cargo system valves
If cargo system valves as defined in Sec.5 [5] are also ESD valves within the meaning of [2], then the requirements of [2] shall apply.

2.3 ESD system controls

2.3.1 As a minimum, the ESD system shall be capable of manual operation by a single control on the bridge and either in the control position required by Sec.13 [1.1.2] or the cargo control room if installed, and no less than two locations in the cargo area.

**Guidance note:**
The ESD valves should 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.

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

2.3.2 The ESD shall be automatically activated on detection of a fire on the weather decks of the cargo area and/or cargo machinery spaces. As a minimum, the method of detection used on the weather decks shall cover the liquid and vapour domes of the cargo tanks, the cargo manifolds and areas where liquid piping is dismantled regularly. Detection may be by means of fusible elements designed to melt at temperatures between 98°C and 104°C, or by area fire detection methods.

2.3.3 Cargo machinery that is running shall be stopped by activation of the ESD system in accordance with the cause and effect matrix in the table below.

2.3.4 The ESD control system shall be configured so as to enable the high-level testing required in Sec.13 [3.1.5] to be carried out in a safe and controlled manner. For the purpose of the testing, cargo pumps may be operated while the overflow control system is overridden. Procedures for level alarm testing and re-setting of the ESD system after completion of the high-level alarm testing shall be included in the operation manual required by [1.1.1].
### Table 1 ESD functional arrangements

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<td></td>
<td></td>
<td>2) and</td>
<td>1)</td>
</tr>
<tr>
<td>signal from ship/shore link [2.1.4]</td>
<td>#</td>
<td>#</td>
<td>3)</td>
<td>n/a</td>
</tr>
<tr>
<td>loss of motive power to ESD valves**</td>
<td>#</td>
<td>#</td>
<td>2)</td>
<td>n/a</td>
</tr>
<tr>
<td>main electric power failure (<code>blackout</code>)</td>
<td>7)</td>
<td>7)</td>
<td>7)</td>
<td>7)</td>
</tr>
<tr>
<td>level alarm override Sec.13 [3.1.7]</td>
<td>4)</td>
<td>4) and 5)</td>
<td>#</td>
<td>1)</td>
</tr>
</tbody>
</table>

**Valves**

1. **Cargo pumps/cargo booster pumps**
2. **Spray/stripping pumps**
3. **Vapour return compressors**
4. **Fuel gas compressors**
5. **Reliquefaction plant*** including condensate return pumps, if fitted
6. **Gas combustion unit**
7. **ESD Valves**
8. **Signal to ship/shore link***
1) These items of equipment can be omitted from these specific automatic shutdown initiators provided the compressor inlets are protected against cargo liquid ingress.

2) If the fuel gas compressor is used to return cargo vapour to shore, it shall be included in the ESD system only when operating in this mode.

3) If the reliquefaction plant compressors are used for vapour return/shore line clearing, they shall be included in the ESD system only when operating in that mode.

4) The override system permitted by Sec.13 [3.1.7] may be used at sea to prevent false alarms or shutdowns. When level alarms are overridden, cargo pumps and manifold valves shall be inhibited except when high-level alarm testing carried out in accordance with [2.3.4].

5) Cargo spray or stripping pumps used to supply forcing vaporizer may be excluded from the ESD system only when operating in that mode.

6) The sensors referred to in Sec.13 [3.1.2] may be used to close automatically the tank filling valve for the individual tank where the sensors are installed, as an alternative to closing the ESD valve referred to in [2.2.5]. If this option is adopted, activation of the full ESD system shall be initiated when the high-level sensors in all the tanks to be loaded have been activated.

7) These items of equipment shall not be started automatically upon recovery of main electric power and without confirmation of safe conditions.

Remarks:

* Fusible plugs, electronic point temperature monitoring or area fire detection may be used for this purpose on deck.

** Failure of hydraulic, electric or pneumatic power for remotely operated ESD valve actuators.

*** Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.

**** Signal need not indicate the event initiating ESD.

✓ Function requirement

n/a Not applicable.

2.4 Additional shutdowns

2.4.1 The requirements of Sec.8 [3.1.1].1] to protect the cargo tank from external differential pressure may be fulfilled by using an independent low pressure trip to activate the ESD system, or as minimum to stop any cargo pumps or compressors.

2.4.2 An input to the ESD system from the overflow control system required by Sec.13 [3] may be provided to stop any cargo pumps or compressors running at the time a high level is detected, as this alarm may be due to inadvertent internal transfer of cargo from tank to tank.
SECTION 19 SUMMARY OF MINIMUM REQUIREMENTS

1 General

1.1 Explanatory notes to the summary of minimum requirements

Minimum requirements for each product are as described in Table 2.

Table 1 Description of items in Table 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Column in Table 2</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product name</td>
<td>a</td>
<td>The product name shall be used in the shipping document for any cargo offered for bulk shipments. Any additional name may be included in brackets after the product name. In some cases, the product names are not identical with the names given in previous issues of the rule set.</td>
</tr>
<tr>
<td>liquid Density</td>
<td>b</td>
<td>applicable density for guidance</td>
</tr>
</tbody>
</table>
| ship type              | c                 | 1: ship type 1G, Sec.2 [1.1.2] .1  
2: ship type 2G, Sec.2 [1.1.2] .2  
3: ship type 2PG, Sec.2 [1.1.2] .3  
4: ship type 3G, Sec.2 [1.1.2] .4 |
| independent tank type C required | d | type C independent tank, Sec.22 [1.1.2]                                                                 |
| tank environmental control | e | inert: inerting, Sec.9 [1.4]  
dry: drying, Sec.17 [1.6]  
- : no special requirements under this chapter |
| vapour detection       | f                 | F: flammable vapour detection  
T: toxic vapour detection  
F+T: flammable and toxic vapour detection  
A: asphixiant |
| gauging                | g                 | I: indirect or closed, Sec.13 [2.1.3] .1 and .2  
R: indirect, closed or restricted, Sec.13 [2.1.3]  
C: indirect or closed, Sec.13 [2.1.3] .1, .2, and .3 |
| special requirements   | i                 | When specific reference is made to Sec.14 and/or Sec.17, these requirements shall be additional to the requirements in any other column. |
| refrigerant gases      | -                 | non-toxic and non-flammable gases                                                                                                             |

Unless otherwise specified, gas mixtures containing less than 5 % total acetylenes may be transported with no further requirements than those provided for the major components.
### Table 2 summary of minimum requirements

<table>
<thead>
<tr>
<th>Product name</th>
<th>Liquid density in kg/m³ and (Temp.) at atm</th>
<th>Ship type</th>
<th>Independent tank type C required</th>
<th>Control of vapour space within cargo tanks</th>
<th>Vapour detection</th>
<th>Gauging</th>
<th>Special requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetaldehyde</td>
<td>780 (20.8°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>inert</td>
<td>F + T</td>
<td>C</td>
<td>Sec.14 [1.3.3] .1, Sec.14 [2.1.1], Sec.17 [1.3.1], Sec.17 [1.5] .1</td>
</tr>
<tr>
<td>ammonia, anhydrous</td>
<td>680 (-33.4°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>T</td>
<td>C</td>
<td>Sec.14 [2], Sec.17 [1.1.1].1, Sec.17 [2]</td>
<td></td>
</tr>
<tr>
<td>butadiene (all isomers)</td>
<td>650 (-4.5°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td>Sec.14 [2], Sec.17 [1.1.1] .2, Sec.17 [1.3.2], Sec.17 [1.3.3], Sec.17 [1.5], Sec.17 [1.7]</td>
<td></td>
</tr>
<tr>
<td>butane (all isomers)</td>
<td>600 (-0.5°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F</td>
<td>R</td>
<td>Sec.14 [2], Sec.17 [1.1.1] .1</td>
<td></td>
</tr>
<tr>
<td>butane-propane mixture</td>
<td>-</td>
<td>2G/2PG</td>
<td>-</td>
<td>F</td>
<td>R</td>
<td>Sec.14 [2], Sec.17 [1.1.1] .1</td>
<td></td>
</tr>
<tr>
<td>butylenes (all isomers)</td>
<td>630 to 640 (-6.3 to 3.7°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F</td>
<td>R</td>
<td>Sec.14 [2], Sec.17 [1.1.1] .6, Sec.17 [1.2.1], Sec.17 [1.5] .1, Sec.17 [1.8], Sec.17 [1.9], Sec.17 [1.10.2], Sec.17 [1.10.3]</td>
<td></td>
</tr>
<tr>
<td>carbon dioxide (high purity)</td>
<td>-</td>
<td>3G</td>
<td>-</td>
<td>-</td>
<td>A</td>
<td>R</td>
<td>Sec.17 [11.1]</td>
</tr>
<tr>
<td>carbon dioxide (reclaimed quality)</td>
<td>-</td>
<td>3G</td>
<td>-</td>
<td>-</td>
<td>A</td>
<td>R</td>
<td>Sec.17 [11.2]</td>
</tr>
<tr>
<td>chlorine</td>
<td>1 560 (-34°C)</td>
<td>1G</td>
<td>yes</td>
<td>dry</td>
<td>T</td>
<td>I</td>
<td>Sec.14 [2], Sec.17 [1.2.2], Sec.17 [1.3.1], Sec.17 [1.4], Sec.17 [1.6], Sec.17 [1.8], Sec.17 [3]</td>
</tr>
<tr>
<td>diethyl ether*</td>
<td>640 (34.6°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>inert</td>
<td>F + T</td>
<td>C</td>
<td>Sec.14 [2.1], Sec.14 [2.1.1], Sec.17 [1.1.1] .6, Sec.17 [1.2.1], Sec.17 [1.5] .1, Sec.17 [1.8], Sec.17 [1.9], Sec.17 [1.10.2], Sec.17 [1.10.3]</td>
</tr>
<tr>
<td>dimethylamine</td>
<td>670 (6.9°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td>Sec.14 [2], Sec.17 [1.1.1] .1</td>
<td></td>
</tr>
<tr>
<td>dimethyl Ether</td>
<td>668 (-23°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F</td>
<td>R</td>
<td>Sec.17 [8.1.9], Sec.17 [8.1.11]</td>
<td></td>
</tr>
<tr>
<td>Product name</td>
<td>Liquid density in kg/m³ and (Temp.)</td>
<td>Ship type</td>
<td>Independent tank type C required</td>
<td>Control of vapour space within cargo tanks</td>
<td>Vapour detection</td>
<td>Gauging</td>
<td>Special requirements</td>
</tr>
<tr>
<td>--------------</td>
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<td>----------------------------------</td>
<td>---------------------------------------------</td>
<td>-----------------</td>
<td>---------</td>
<td>----------------------</td>
</tr>
<tr>
<td>ethane</td>
<td>550 (-88°C)</td>
<td>2G</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ethyl chloride</td>
<td>920 (12.4°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ethylene</td>
<td>560 (-104°C)</td>
<td>2G</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ethylene oxide</td>
<td>870 (10.4°C)</td>
<td>1G</td>
<td>yes</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ethylene oxide-propylene oxide mixtures with ethylene oxide content of not more than 30% by weight*</td>
<td>-</td>
<td>2G/2PG</td>
<td>-</td>
<td>inert</td>
<td>F + T</td>
<td>C</td>
<td>Sec.14 [2.1.1], Sec.17 [1.1.1].3, Sec.17 [1.2.1], Sec.17 [1.3.1], Sec.17 [1.4], Sec.17 [1.5].1, Sec.17 [4].1, Sec.17 [4]</td>
</tr>
<tr>
<td>isoprene*, all isomers</td>
<td>680 (34°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td>Sec.14 [2.1.1], Sec.17 [1.7], Sec.17 [1.8], Sec.17 [1.10.3]</td>
</tr>
<tr>
<td>isoprene*, part refined</td>
<td>-</td>
<td>2G/2PG</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td>Sec.14 [2.1.1], Sec.17 [1.7], Sec.17 [1.8], Sec.17 [1.10.3]</td>
</tr>
<tr>
<td>isopropylamine*</td>
<td>710 (33°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td>Sec.14 [2.1.1], Sec.17 [1.1.1].4, Sec.17 [1.2.2], Sec.17 [1.3.1], Sec.17 [1.4]</td>
</tr>
<tr>
<td>methane (LNG)</td>
<td>420 (~164°C)</td>
<td>2G</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td>Sec.17 [6]</td>
</tr>
<tr>
<td>methyl acetylene-propadiene mixtures</td>
<td>-</td>
<td>2G/2PG</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td>Sec.14 [2], Sec.17 [1.1.1].3, Sec.17 [1.2.2], Sec.17 [1.3.1], Sec.17 [1.4]</td>
</tr>
<tr>
<td>methyl bromide</td>
<td>1 730 (–88°C)</td>
<td>1G</td>
<td>yes</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td>Sec.17 [1.1.1].3</td>
</tr>
<tr>
<td>methyl chloride</td>
<td>920 (–88°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td></td>
<td>Sec.17 [1.1.1].3</td>
</tr>
<tr>
<td>Product name</td>
<td>Liquid density in kg/m³ and (Temp.) at atm</td>
<td>Ship type</td>
<td>Independent tank type C required</td>
<td>Control of vapour space within cargo tanks</td>
<td>Vapour detection</td>
<td>Gauging</td>
<td>Special requirements</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------</td>
<td>-----------</td>
<td>----------------------------------</td>
<td>---------------------------------------------</td>
<td>------------------</td>
<td>---------</td>
<td>---------------------</td>
</tr>
<tr>
<td>mixed C4 cargoes</td>
<td>-</td>
<td>2G/2PG</td>
<td>-</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td>Sec.14 [2], Sec.17 [1.1.1] .2, Sec.17 [1.3.2], Sec.17 [1.3.3], Sec.17 [1.5], Sec.17 [1.7], Sec.17 [10]</td>
</tr>
<tr>
<td>monoethylamine*</td>
<td>690 (16.6°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>-</td>
<td>F + T</td>
<td>C</td>
<td>Sec.14 [2], Sec.17 [1.1.1] .1, Sec.17 [1.2.1], Sec.17 [1.8], Sec.17 [1.9], Sec.17 [1.10.1], Sec.17 [5]</td>
</tr>
<tr>
<td>nitrogen</td>
<td>808 (~196°C)</td>
<td>3G</td>
<td>-</td>
<td>-</td>
<td>A</td>
<td>C</td>
<td>Sec.17 [1.6]</td>
</tr>
<tr>
<td>pentane*, all isomers</td>
<td>630</td>
<td>2G/2PG</td>
<td>-</td>
<td>-</td>
<td>F</td>
<td>R</td>
<td>Sec.17 [1.8], Sec.17 [1.10]</td>
</tr>
<tr>
<td>Pentene*, all isomers</td>
<td>650</td>
<td>2G/2PG</td>
<td>-</td>
<td>-</td>
<td>F</td>
<td>R</td>
<td>Sec.17 [1.8], Sec.17 [1.10]</td>
</tr>
<tr>
<td>propane</td>
<td>590 (~42.3°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>-</td>
<td>F</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>propylene</td>
<td>610 (~47.7°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>-</td>
<td>F</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>propylene oxide*</td>
<td>860</td>
<td>2G/2PG</td>
<td>-</td>
<td>inert</td>
<td>F+T</td>
<td>C</td>
<td>Sec.14 [2.1], Sec.17 [1.2.1], Sec.17 [1.3.1], Sec.17 [1.5] .1, Sec.17 [1.8], Sec.17 [1.9], Sec.17 [8]</td>
</tr>
<tr>
<td>refrigerant gases</td>
<td>--</td>
<td>3G</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>sulphur dioxide</td>
<td>1 460 (~10°C)</td>
<td>1G</td>
<td>yes dry</td>
<td>T</td>
<td>C</td>
<td></td>
<td>Sec.14 [2], Sec.17 [1.2.2], Sec.17 [1.3.1], Sec.17 [1.4], Sec.17 [1.6]</td>
</tr>
<tr>
<td>vinyl chloride</td>
<td>970 (~13.9°C)</td>
<td>2G/2PG</td>
<td>-</td>
<td>-</td>
<td>F+T</td>
<td>C</td>
<td>Sec.14 [2.1], Sec.14 [2.1.1], Sec.17 [1.1.1] .2, Sec.17 [1.1.1] .3, Sec.17 [1.2.1], Sec.17 [1.5], Sec.17 [9]</td>
</tr>
<tr>
<td>vinyl ethyl ether*</td>
<td>754</td>
<td>2G/2PG</td>
<td>-</td>
<td>inert</td>
<td>F+T</td>
<td>C</td>
<td>Sec.14 [2.1], Sec.14 [2.1.1], Sec.17 [1.1.1] .2,Sec.17 [1.2.1], Sec.17 [1.5] .1, Sec.17 [7], Sec.17 [1.8], Sec.17 [9], Sec.17 [1.10.2], Sec.17 [1.10.3]</td>
</tr>
</tbody>
</table>
| Product name          | Liquid density 
in kg/m³ and (Temp.) at atm | Ship type | Independent tank type C required | Control of vapour space within cargo tanks | Vapour detection | Gauging | Special requirements                                                                 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>vinylidene chloride*</td>
<td>1 250</td>
<td>2G/2PG</td>
<td>-</td>
<td>inert</td>
<td>F+T</td>
<td>C</td>
<td>Sec.14 [2.1], Sec.14 [2.1.1], Sec.17 [1.1.1] .5, Sec.17 [1.5] .1, Sec.17 [1.7], Sec.17 [1.8], Sec.17 [1.9]</td>
</tr>
</tbody>
</table>

* this cargo is also covered by the IBC code
SECTION 20 DESIGN WITH INDEPENDENT PRISMATIC TANKS OF TYPE-A AND TYPE-B

1 Type-A tank

1.1 Design basis

1.1.1 Hull design
The hull design shall be carried out according to main class requirements in Pt.3 of the rules. In addition, the present rules for Liquefied Gas Carriers, this section give additional design requirements for Liquefied Gas Carriers with independent prismatic type A tanks.

1.1.2 Type A independent tanks are tanks primarily designed using ship-structural analysis procedures as given in Pt.3. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure \( P_0 \) shall be less than 0.07 MPa.

1.1.3 If the cargo temperature at atmospheric pressure is below -10°C, a complete secondary barrier shall be provided as required in Sec.4 [2.3]. The secondary barrier shall be designed according to Sec.4 [2.4].

1.1.4 If the cargo temperature at atmospheric pressure is at or above -55°C the hull may act as a secondary barrier based on the following:
   — the hull material shall be suitable for the cargo temperature at atmospheric pressure as required in Sec.4 [5.1.1], and
   — the design shall be such that this temperature will not result in unacceptable hull stresses.
With lower temperature a separate complete secondary barrier shall be arranged according to Sec.4 [2.4.2].

1.1.5 Cargo design density
For design the specific cargo density is to be taken as the highest density for the actual gas composition to be carried at the planned trades.

1.2 Structural analysis of cargo tanks

1.2.1 A structural analysis shall be performed taking into account the internal pressure as indicated in Sec.4 [3.3.2], and the interaction loads with the supporting and keying system as well as a reasonable part of the ship’s hull.

1.2.2 For parts, such as supporting structures, not otherwise covered by the requirements of this section, stresses shall be determined by direct calculations, taking into account the loads referred to in Sec.4 [3.2] to Sec.4 [3.5] as far as applicable, and the ship deflection in way of supporting structures.

1.2.3 The tanks with supports shall be designed for the accidental loads specified in Sec.4 [3.5]. These loads need not be combined with each other or with environmental loads.

1.2.4 Design conditions
The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to:
   ultimate limit state design condition (ULS)
   — plastic deformation
   — buckling
   accident limit state design condition (ALS)
— plastic deformation
— buckling

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

1.2.6 Thermal analysis and fatigue analysis
For conventional proven designs, and when the cargo temperature is not lower than -55°C the following applies:
— neither stationary nor transient thermal analyses need to be performed
— fatigue analysis of cargo tanks and supports may not be considered.
For novel designs, and/or when the cargo temperature is below -55°C the following applies:
— thermal analysis for material selection and thermal stress analysis is to be carried out
— fatigue analyses of the cargo tanks and the supports shall be carried out with damage factor $C_w \leq 1.0$, as specified in Pt.3 Ch.9 and DNVGL-CG-0129, Fatigue assessment of ship structure.

Guidance note:
Methods for strength analysis of hull structure and cargo tanks with prismatic Type-A tanks are given in DNVGL-CG-0133, Liquefied Gas Carriers with independent prismatic tanks.

1.3 Ultimate design condition (ULS)

1.3.1 For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (web frames, stringers, girders, stiffeners), when not calculated with FE analysis procedures, shall not exceed the lower of $R_m / 2.66$ or $R_{eh} / 1.33$ for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where $R_m$ and $R_{eh}$ are defined in Sec.4 [4.3.2].3.
However, when Finite Element calculations are carried out for the primary members, the equivalent stress $\sigma_{vm}$, as defined in Sec.4 [4.3.2].4, can be increased to the level given in [4.3.4]. Calculations shall take into account the effects of bending, shear, axial and torsional deformation as well as the hull/cargo tank interaction forces due to the deflection of the double bottom and cargo tank bottoms.

1.3.2 Tank boundary scantlings shall meet at least the requirements of the Society for deep tanks taking into account the internal pressure as indicated in Sec.4 [3.3.2] and any corrosion allowance required by Sec.4 [2.1.5].

1.3.3 The cargo tank structure shall be reviewed against potential buckling.

1.4 Accident design condition (ALS)

1.4.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in Sec.4 [2.1.4].3 and Sec.4 [3.5], as relevant.

1.4.2 When subjected to the accidental loads specified in Sec.4 [3.5], the stress shall comply with the acceptance criteria specified in [1.3], modified as appropriate, taking into account their lower probability of occurrence.
1.5 Testing

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

1.6 Special consideration for single side hull

1.6.1 Where the structural arrangement in cargo hold is similar to the single side skin bulk carrier as defined in Ch.1 Sec.6 [1.3.1] the following is to be considered.

1.6.2 Shear force correction
For the hull structure with single side skin construction, the hull girder shear strength assessment is to be carried out in accordance with Pt.3 Ch.5 Sec.2 [2] with consideration of shear force correction given in Ch.1 Sec.5 [5.2.4] if applicable. Within the cargo hold region, shear force correction shall be applied to each loading condition given in the loading manual and the loading/unloading sequences.

1.6.3 Transverse frames in side shell
The net section modulus $Z$, in Cm3, and the net shear sectional area $A_{shr}$, in cm$^2$, of side frames subjected to lateral pressure are not to be taken less than the requirement in Ch.1 Sec.2 [4.2].

1.6.4 Buckling strength of side shell plating
When the buckling strength of side shell plating is assessed by closed form method (CFM) according to DNVGL-CG-0128 Buckling analysis [3], the factors, $F_{tran}$, and $C_y$ for single side skin bulk carrier is applicable.

2 Type-B tank

2.1 Design basis

2.1.1 Hull design
The hull design shall be carried out according to main class requirements in Pt.3 of the rules. In addition, the present rules for Liquefied Gas Carriers, this section give additional design requirements for Liquefied Gas Carriers with independent prismatic type B tanks.

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

2.1.3 If the cargo temperature at atmospheric pressure is below -10°C a partial secondary barrier with a small leak protection system shall be provided as required in Sec.4 [2.3]. The small leak protection system shall be designed according to Sec.4 [2.5], typically consisting of;

- a gas detection system
- liquid containers to contain liquids
- spray shields to deflect liquids into the containers, and
- equipment to dispose of the liquid as required.
This requires analyses and/or tests to document that the likelihood of massive leakages from the primary containment is reduced to an acceptable level, and to document the type and extent of potential leakages to be used for design and dimensioning the small leak protection system.

2.1.4 Cargo design density
For design the specific cargo density is to be taken as the highest density for the actual gas composition to be carried at the planned trades.

2.2 Structural analysis of cargo tanks

2.2.1 Design conditions
The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to:

- ultimate limit state design condition (ULS)
  - plastic deformation
  - buckling.
- fatigue limit state design condition (FLS)
  - fatigue failure.
  - crack propagation analysis.
- accident limit state design condition (ALS)
  - plastic deformation
  - buckling.

Finite element analysis and/or prescriptive requirements and fracture mechanics analysis shall be applied.

Guidance note:
Methods for strength analysis of hull structure and cargo tanks with prismatic B-type tanks are given in DNVGL-CG-0133 Liquefied Gas Carriers with independent prismatic tanks.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

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

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

2.2.4 Fracture mechanics analyses
Crack propagation analyses and design against brittle fracture shall be carried out according to recognized standards, e.g. BS7910. A fracture mechanics analysis according to Sec.4 [4.3.3].6-9] is required.

2.2.5 Fatigue testing
Model tests may be required to determine stress concentration factors and fatigue life of structural elements.

2.3 Ultimate design condition (ULS)

2.3.1 Plastic deformation
For type B independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis shall not exceed:
.1 for nickel steels and carbon-manganese steels, the lesser of \( R_m/2 \) and \( R_{eh}/1.2 \)
.2 for austenitic steels, the lesser of \( R_m/2.5 \) and \( R_{eh}/1.2 \), and
.3 for aluminium alloys, the lesser of \( R_m/2.5 \) and \( R_{eh}/1.2 \).

The above figures may be amended, taking into account the locality of the stress, stress analysis methods and design condition considered in acceptance with the Society.

2.3.2 Plates and stiffeners on boundary
The thickness of the skin plate and the size of the stiffener shall not be less than those required for type A independent tanks.

2.3.3 Buckling
Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with Pt.3 Ch.8. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, lack of straightness or flatness, ovality and deviation from true circular form over a specified arc or chord length, as applicable. Reference is made to IACS Rec.47 "Shipbuilding and Repair Quality Standard".

2.4 Fatigue design condition (FLS)

2.4.1 Fatigue and crack propagation assessment shall be performed in accordance with Sec.4 [4.3.3]. The acceptance criteria shall comply with Sec.4 [4.3.3].7, Sec.4 [4.3.3].8 or Sec.4 [4.3.3].9, depending on the detectability of the defect.

2.4.2 Fatigue analysis shall consider construction tolerances.

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

2.5 Accident design condition (ALS)

2.5.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in Sec.4 [2.1.4].3 and Sec.4 [3.5], as applicable.

2.5.2 When subjected to the accidental loads specified in Sec.4 [3.5], the stress shall comply with the acceptance criteria specified in [2.3], modified as appropriate, taking into account their lower probability of occurrence.

2.6 Testing

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

.1 the test shall be performed as required in [1.5.1] for type A independent tanks, and
.2 in addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 0.9 \( R_{eh} \) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 0.75 \( R_{eh} \), the prototype test shall be monitored by the use of strain gauges or other suitable equipment.
3 Local strength of cargo tanks

3.1 Internal pressure in cargo tanks

3.1.1 Cargo tank pressure at $10^{-8}$ probability level is calculated using the acceleration ellipsoid with component accelerations corresponding to $10^{-8}$ wave encounters in the Sec.1 - General North Atlantic. The guidance formulas in Sec.4 [6.1.2] is to be applied for type A-tanks and also for type B tanks as a minimum. For type B tanks direct wave load analysis shall be carried out and the accelerations from direct wave analysis shall be used if they are more critical than the rule values calculated based on the formulas in Sec.4 [6.1.2]

3.1.2 Internal pressure including the influence on pressure head from the dome is to be calculated as described in Sec.4 [6.1.1].

3.1.3 The acceleration $a_\beta$ is calculated by combining the three component accelerations $a_x$, $a_y$ and $a_z$ values according to an ellipsoid surface, Sec.4 Figure 1. For B-tanks the acceleration shall be based on direct wave load analysis as outlined in CN hydrodynamic.

3.1.4 The internal pressure in cargo tanks given in this section is based on the assumption of tight CL bulkhead, but with one cargo dome with common vapour pressure on both sides. The filling level is assumed the same at port and starboard side for all seagoing conditions. In case of other arrangement, a case-by-case evaluation will be required.

3.2 Requirements for local scantlings

3.2.1 General

The requirement below is applicable for both A-type tanks and B-type tanks. Tank boundary scantlings shall meet at least the requirements for deep tanks taking into account internal pressure, Pt.3 Ch.6 Sec.4 [1.1.1] for plating and Pt.3 Ch.6 Sec.5 [1.1.2] for section modulus of stiffeners.

3.2.2 Tank shell plating

The net thickness requirement in mm for the tank shell plating corresponding to lateral pressure is given by:

$$t = 0.0158 \frac{P_{eq}}{\sigma_{all}} b$$

where:

$P_{eq}$ = pressure as given in [3.1], in kN/m$^2$ (1 bar = 100 kN/m$^2$)

$b$ = shortest width of plate in mm, measured along the plating as defined in Pt.3 Ch.3 Sec.7.

$\sigma_{all}$ = allowable stress in N/mm$^2$ as given in [3.2.4].

The minimum net thickness requirement in mm is:

$t_{min} = \max[0.01b;8.0]$.

Regarding corrosion additions for cargo tanks, see Sec.4 [2.1.5].
### 3.2.3 Section modulus for stiffeners

The net section modulus requirement for simple stiffeners is given by:

\[ S = \frac{b d^2}{6} \]  

where:

- \( s \) = stiffener spacing in mm as defined in Pt.3 Ch.3 Sec.7.
- \( \ell_{bdg} \) = bending span of stiffener, in m, as defined in Pt.3 Ch.3 Sec.7.
- \( f_{bdg} \) = bending moment factor taken as:
  - 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 \( f_{bdg} \) factor may be adjusted for members with boundary condition not corresponding to the above specification.

### 3.2.4 Allowable stress, \( \sigma_{all} \)

For tanks primarily constructed of plane surfaces, the nominal allowable stresses for primary supporting members (web frames, stringers, girders), secondary members (stiffeners) and tertiary members (plating), when calculated by classical analysis procedures, shall for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys not exceed the lower of:

\[ \sigma_{all} = \min\left(\frac{R_m}{C}; \frac{R_{eH}}{D}\right) \]

where:

- \( R_m \) = minimum specified tensile strength in N/mm\(^2\) at room temperature, and
- \( R_{eH} \) = yield stress in N/mm\(^2\) at room temperature, as defined in Sec.1.

The stress factors, C and D, are given in Table 1.

#### Table 1 Allowable stress factors for local scantlings, AC-II

<table>
<thead>
<tr>
<th>Stress factors</th>
<th>Primary and secondary (stiffeners)</th>
<th>Tertiary (plating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>2.66</td>
<td>-</td>
</tr>
<tr>
<td>D</td>
<td>1.33</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**Guidance note:**
Primary members should be checked with FE analysis as described in [4], whereas plates and stiffeners are checked with the prescriptive requirements in [3.2.2] and [3.2.3] with stress factors from Table 1.

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

### 3.2.5 Stiffeners with large deflections

Stiffeners supported by end bulkheads or swash bulkheads or stringers subject to relatively large deflections shall be checked by direct stress calculation using a stress factor \( D = 1.47 \) for static loads and \( D = 1.1 \) for static plus dynamic loads. Direct stress calculation can be made as given in the DNVGL-CG-0129 *Fatigue assessment of ship structure* Section 4.7.
3.2.6 Connection area
Connection area of stiffeners shall be according to Pt.3 Ch.6 Sec.7 with design pressure in [3.1.2] based on the combined total acceleration from the acceleration ellipsoid $a_{\beta}$, calculated from the acceleration components $a_x$, $a_y$ and $a_z$.

3.2.7 Sloshing loads and scantling requirements
Design formulas for sloshing loads on bulkheads, girders, web frames and stringers are given in Pt.3 Ch.10 Sec.4 [2.2] to Pt.3 Ch.10 Sec.4 [2.4], design load scenarios in Pt.3 Ch.10 Sec.4 [2.1.1] and scantling requirements for plates, stiffeners and primary supporting members in Pt.3 Ch.10 Sec.4 [3.1] and Pt.3 Ch.10 Sec.4 [3.2].
The above procedures are the base case requirements for design against inertia and impact sloshing pressures. In case of special geometries and/or novel designs the Society may require more elaborate analyses (CFD) and/or experiments.

3.2.8 Longitudinal bulkhead
Longitudinal bulkhead shall be verified based on the condition that one side of tank is filled and another side of tank is empty in harbour condition (one side overfilling). The pressure need not be applied higher than top of longitudinal bulkhead. The acceptance criteria AC-I is to be applied

4 Cargo tank and hull finite element analysis

4.1 General
4.1.1 For gas carriers with independent tanks, constructed mainly of plane surfaces, 3D structural analysis shall be carried out for the evaluation of a cargo tank, tank supports and hull structures.
An integrated cargo hold and cargo tank finite element model is to be established to determine reaction forces in supports and to assess the structural adequacy of primary members of the cargo tank, tanks supports and associated hull structure under hull girder bending, external and internal loads.

4.1.2 Model extent
For A type tanks the midship region shall be modelled as a minimum, but additional analyses for the fore and/or aft cargo hold regions may be required by the Society depending on the actual tank/ship design configuration if fore and aft region deviates significantly from the midship region. For B type tanks, in addition to the midship region fore and aft cargo hold regions are mandatory for FE analysis to be carried out.
The necessary longitudinal extent of the model will depend on the structural arrangement and the loading conditions. The analysis model shall normally extended over three hold lengths (1+1+1), where the middle tank/hold of the model is used to assess the yield and buckling strength. However, shorter models may be accepted by the Society when relevant.
The model shall cover the full breadth of the ship in order to account for asymmetric structural layout of the cargo tank/supporting hull structure and asymmetric design load conditions (heeled or unsymmetrical loading conditions).
4.2 Loading conditions and design load cases

4.2.1 General
The design load cases are to be selected based on actual loading conditions from vessel’s loading manual.

4.2.2 Selection of loading conditions
The design loading conditions shall include fully loaded condition, alternate conditions, with realistic combinations of full and empty cargo tanks, with sea pressure/tank pressure, giving maximum net loads on cargo tanks, tank supports and double bottom structures. The ship should be able to operate with any tank empty and the others full, if applicable.
The cargo tank and hull stress response shall be maximized when combining internal and external loads with hull girder bending. The worst combination of loads shall be considered.

4.2.3 Accidental loads
The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in Sec.4 [2.1.4].3 and Sec.4 [3.5], as relevant.

4.2.4 Load cases
Design load cases shall be selected to cover all relevant loading conditions for independent tanks constructed mainly of plane surfaces.
Static (S) and dynamic (D) design loads; bending moments, torsional moments (as applicable), maximum cargo accelerations and sea pressure shall be applied to the cargo hold finite element model and serve as basis for design against yield and buckling of the cargo tank, the supports and the hull structure.

4.2.5 Ship hull
The dynamic Equivalent design waves (EDWs) for ultimate strength assessment (ULS) defined in Pt.3 Ch.4 Sec.2 shall be applied.

4.2.6 Cargo containment
.1 For A-type tank and support design the following EDWs defined in Pt.3 Ch.4 Sec.2 shall be specifically considered for ULS analysis
   — for maximum vertical acceleration, BSP-1 and BSP-2 port (P) and/or starboard (S)
   — for maximum transverse acceleration, BSR-1 and BSR-2, port (P) and/or starboard (S).
The port (P) and/or starboard (S) versions shall be selected based on the geometry/symmetry of the construction.
.2 For B-tanks dynamic Ultimate Design Waves (UDWs) defined in Sec.1, shall be determined from linear hydrodynamic analyses, all headings included, maximizing
   — vertical acceleration and
   — transverse acceleration
   The procedure for determining the UDWs given in DNVGL-CG-0130, Wave Load Analysis, shall be used.
.3 In addition, the following design conditions shall be examined for both type A-tanks and type B-tanks:
   — static condition with 30 degree heel (ULS)
   — cargo tank CL bulkhead to be checked for one sided static pressure including vapour pressure, (ULS)
   — flooded condition with one tank empty at full draught with 0.67 of vertical wave bending moment in World -Wide environment or 0.54 of North Atlantic wave bending moment (ALS)
   — crash stop collision load of 0.5 g forward and 0.25 g aftwards combined with still water loads, but no dynamic hull girder loads, (ALS)
   — damaged condition with flooding in hold with empty cargo tank for checking of anti-floatation support and hull structure in way of anti-floatation support (ALS)
— damaged condition with flooding in hold with full cargo tank for checking of transverse bulkhead strength (ALS).

4.2.7 Pressure loads
Sea pressure and internal pressure, $P_{ex}$ and $P_{in}$ in kN/m$^2$, shall be as given in Pt.3 Ch.4 Sec.5 and Pt.3 Ch.4 Sec.6 respectively.

For type B-tanks the accelerations shall be determined by direct hydrodynamic analysis.
The weight of cargo tank and hull structures is to be included in the FE analysis.

4.3 Acceptance criteria for cargo hold FE analysis

4.3.1 Application
The ship hull including the double hull construction with inner hull plating and stiffeners shall be subject to ship hull design criteria with usage factors given in Pt.3 Ch.7 Sec.3 [4] for yield and Pt.3 Ch.8 Sec.1 [3] for buckling.
The cargo tanks with supports shall be subject to tank design acceptance criteria for allowable stress [4.3.4] and buckling [4.3.5].

4.3.2 Equivalent stress and summation of static and dynamic stresses
The equivalent von Mises stress in N/mm$^2$ shall be calculated according to the formula:

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

where:

$\sigma_x$ = total normal stress in x-direction, in N/mm$^2$

$\sigma_y$ = total normal stress in y-direction, in N/mm$^2$

$\tau_{xy}$ = total shear stress in the x-y plane, in N/mm$^2$.

4.3.3 Determination of dynamic stresses and stress summation
The equivalent design waves (EDWs) defined in [4.2.6].1 for A-tanks and the UDWs described in [4.2.6].2 for B-tanks shall be used for determining the dynamic parts of the stress components $\sigma_x$, $\sigma_y$ and $\tau_{xy}$ in any point of the cargo tanks and the supports.
Since all dynamic stresses in a design wave approach are acting simultaneously, i.e. in phase –same time instant, linear summation of static and dynamic components can be made.
In special cases, e.g. when envelope values are used, the methods given in the Guidance below may be used.

Guidance note:
Total stresses, in N/mm$^2$, in given directions in any point of a structure may be calculated according to the following formulae:

$$\sigma_x = \sigma_{xs} \pm \sqrt{\Sigma(\sigma_{x\text{dn}})^2}$$

$$\sigma_y = \sigma_{ys} \pm \sqrt{\Sigma(\sigma_{y\text{dn}})^2}$$
\[ \tau_{xy} = \tau_{yys} + \sqrt{\kappa (\tau_{xydn})^2} \]

\( \sigma_{xs}, \sigma_{ys} \) and \( \tau_{ys} \) are static stresses in N/mm\(^2\).

\( \sigma_{xdn}, \sigma_{ydn} \) and \( \tau_{xydn} \) are dynamic component stresses in N/mm\(^2\), determined separately from acceleration components and hull strain components due to deflection and torsion.

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

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

### 4.3.4 Allowable stress

For cargo tank and support structures subject to static and dynamic loads, the allowable membrane equivalent stress for AC-II is:

\[ \sigma_{m, all} = \frac{R_{eH}}{D} \kappa \]

where:

\[ \kappa = \min \left( \frac{R_{m} D}{R_{eH} C}, 1.0 \right) \]

C and D are given in **Table 2**

The allowable usage factor for AC-II is:

\[ \eta_{S+D} = \frac{\sigma_{m, all}}{R_{eH}} = \frac{\kappa}{D} \]

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

**Table 2 Allowable stress factors for FE analysis (S+D): ULS and ALS design, AC-II**

<table>
<thead>
<tr>
<th>Design condition (Limit State)</th>
<th>Stress factors</th>
<th>Nickel steels and carbon-manganese steels</th>
<th>Austenitic steels</th>
<th>Aluminium alloys</th>
</tr>
</thead>
<tbody>
<tr>
<td>type A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ULS</td>
<td>C</td>
<td>1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALS</td>
<td>C</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>type B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ULS</td>
<td>C</td>
<td>2</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>ALS</td>
<td>C</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Nominal stresses for static load cases (S) shall not exceed 70% of the allowable stresses for the (S+D) load cases.
Allowable stresses in sub-regions and design details will be considered by the Society on a case by case basis.
Thermal stresses shall be considered as given in [1.2.6].

4.3.5 Buckling acceptance criteria
Allowable usage factors for primary members subjected to static and dynamic loads (S+D), AC-II, are given in Table 3 below.

Table 3 Allowable buckling usage factors for cargo tank analysis

<table>
<thead>
<tr>
<th>Design condition (Limit State)</th>
<th>Cargo tanks and tank supports</th>
<th>Hull structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULS</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>ALS</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Acceptable usage factors for static load cases (S), AC-I, shall not exceed 70% of the values given in Table 3.

Guidance note:
Due to the severe consequences of potential damages to the cargo tanks the allowable buckling usage factors in Table 3 have in general been reduced with a factor of 0.9 as compared to general ship standard, see Pt.3 Ch.8 Sec.1 [3.3].

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

5 Local structural strength analysis

5.1 General

5.1.1 Local structural analyses shall be carried out to analyse strength in high stress areas of hull structures and cargo tank/tank supports. Stiffeners subjected to large relative deflections between girders or frames and bulkhead shall be investigated.
Local fine mesh analyses may be omitted if the Society considers low cycle fatigue (LCF) or high cycle fatigue (HCF) to be more relevant for the actual location.

5.2 Locations to be checked

5.2.1 The following areas in the midship cargo region shown in the list below shall be investigated with fine mesh analysis. The need for fine mesh analysis of these areas may be determined based on a screening of the actual geometry and the results from the cargo hold analysis. If considered necessary, the Society will require additional locations to be analysed.

1) hull structures
   — double hull longitudinals subject to large relative deformation
   — top and bottom of side frame ends (conventional A-tank designs)
   — vertical stiffeners on transverse bulkheads to inner bottom.
2) cargo tanks and tank supports including associated hull structures
   — vertical supports
   — upper & lower transverse support
   — upper & lower longitudinal support
— anti-floatation supports
— bottom longitudinals of cargo tanks in way of tank end bulkheads.

5.3 Fine mesh FE models

5.3.1 The principles of sub-modelling and application of loads on sub-models is to follow the procedures in DNVGL-CG-0127, Finite Element Analysis. The procedure is based on the application of 50 mm x 50 mm quadrilateral elements.

5.4 Acceptance criteria

5.4.1 The acceptance criteria given in this sub section apply unless more detail analysis of high cycle and low cycle fatigue strength are carried out. The von Mises equivalent stress is to be calculated based on the membrane axial and shear stresses of the plate element evaluated at the element centroid. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element (membrane stress).

5.4.2 It is required that the resulting von Mises stresses are not exceeding the allowable membrane values specified in Table 4. These criteria apply to regions where stress concentrations occur due to irregular geometries. Nominal stresses shall remain within the limits for cargo hold analysis.

5.4.3 When mesh sizes smaller than 50 mm x 50 mm is used, the average stress is to be calculated based on stresses at the element centroid. Stress averaging is not to be carried across structural discontinuities and abutting structure.

Table 4 Maximum allowable membrane stresses for local fine mesh analysis

<table>
<thead>
<tr>
<th>Element stress</th>
<th>Allowable stresses</th>
</tr>
</thead>
<tbody>
<tr>
<td>acceptance criteria</td>
<td>AC-I</td>
</tr>
<tr>
<td>load components</td>
<td>S</td>
</tr>
<tr>
<td>cargo tanks and tank supports</td>
<td></td>
</tr>
<tr>
<td>element not adjacent to weld (base material)</td>
<td>$1.07 R_{eff} \kappa$</td>
</tr>
<tr>
<td>element adjacent to weld</td>
<td>$0.95 R_{eff} \kappa$</td>
</tr>
<tr>
<td>ship hull structure including double hull with inner hull plating and stiffeners</td>
<td>according to Pt.3 Ch.7 Sec.4 [4.2]</td>
</tr>
</tbody>
</table>

1) The material factor $\kappa$ for cargo tanks and supports is given in [4.3.4]. $R_{eff} \kappa$ accounts for the specified minimum material tensile strength.
2) The maximum allowable stresses are based on the mesh size of 50 mm x 50 mm. Where a smaller mesh size is used, an average von Mises stress calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses.
3) Average von Mises stress is to be calculated according to Pt.3 Ch.7 Sec.4 [4.2.1].

5.5 Acceptance criteria for wood, resin and dam plates

5.5.1 A minimum safety factor of 3 shall be applied for wood and resin. The allowable shear stress for the strength of dam plates is $0.95 R_{eff} \kappa$. 

5.5.2 Material strength data shall be supplied by the designer based on certification of the relevant materials.

6 Thermal analysis

6.1 General

6.1.1 To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for both type A and type B tanks when the cargo temperature is below -10°C, Sec.4 [5.1.1].1.

6.1.2 If not available from similar designs, steady state thermal analysis of the cargo hold area and the cargo tank shall be performed to
— determine steel temperature as basis for material quality selection of the surrounding hull structure and as input to thermal stress analysis, and
— to confirm the structural integrity of the cargo tank, tanks supports and supporting hull structure with respect to yield and buckling in partial and full load conditions.

For type A-tanks reference is made to [1.1.4] and [1.2.6].

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

6.1.4 Thermal expansion coefficient of the material of the cargo tank is to be supplied by/documented by the designer.

6.1.5 Simplified 2-D models and/or 3-D FE models may be used as applicable.

Guidance note:
If a 3-D model is deemed necessary, the integrated cargo hold/tank finite element model specified in [4.1] can be used for the thermal stress analysis.

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6.2 Thermal stress analysis

6.2.1 Load cases should at least be considered as follows;
— full load condition, i.e. 98% filling, to determine maximum cool-down of surrounding hull structure
— partial load condition, filling to each stringer level as relevant to determine stress ranges for low cycle fatigue analysis for the full thermal cycle due to loading and unloading of cargo.

6.2.2 Thermal loads due to the calculated/measured temperature distributions are to be applied over the tank height for each design load case.

6.2.3 For partial load conditions and full load condition, thermal loads, static cargo pressure and minimum design vapour pressure are to be applied.

Deflection of double bottom structure shall be taken into account for all load conditions.
If a tank is divided by longitudinal or/and transverse liquid tight bulkheads in a common tank space, the possible loading patterns of the tank are to be considered.
6.3 Acceptance criteria

6.3.1 The acceptance criteria for the ULS design condition given in [4] and [5] applies for thermal induced stress analysis.

7 Sloshing assessment

7.1 General

7.1.1 For partial tank fillings the risk of significant loads due to sloshing induced by ship motions shall be considered.

7.1.2 Interaction of liquid sloshing motion with the natural ship motion periods should be avoided. Normally, the lowest natural liquid periods should be 20% away from the natural ship motion periods.

The fitting of swash bulkheads can move the liquid resonance periods away from the motion periods of the ship and significantly reduce the risk of sloshing loads inside the tanks.

Guidance note:
Natural periods for liquid motion in prismatic tanks can be estimated as described in Pt.3 Ch.10 Sec.4 [2.4.2]. For a general description of sloshing phenomena, see DNVGL-CG-0158 Sloshing Analysis of LNG Membrane Tanks.

7.1.3 For tanks built without swash bulkheads and/or longitudinal bulkhead the need for documentation by more advanced sloshing analyses, e.g. CFD, and/or model testing will be determined by the Society.

7.2 Sloshing strength analysis

7.2.1 The tank boundary structure including swash bulkheads should be designed to withstand loads caused by liquid sloshing. The design sloshing pressures are to be explicitly considered in the scantling requirements of plates and stiffeners.

7.2.2 As a minimum the tank shall be designed for the sloshing inertia and liquid impact pressure loads given in Pt.3 Ch.10 Sec.4. Based on experience, this will normally be considered sufficient if swash bulkheads are arranged to reduce liquid sloshing resonances in the tanks.

7.2.3 The acceptance criteria for strength analysis shall follow the AC-I and AC-IV criteria for internal sloshing loads and liquid impact loads respectively, see Pt.3 Ch.10 Sec.4, with \( R_{\text{eff}} \) \( \kappa \) representing the specified minimum material strength, i.e. yield equivalent. Where \( \kappa \) is according to [4.3.4].

8 Fatigue analysis

8.1 General

8.1.1 Hull structure
Fatigue strength of hull structures for both type A and type B tanks shall be determined according to Pt.3 Ch.9. Additional requirements may apply for the hull structure depending on class notations, e.g. PLUS, CSA.
8.1.2 A-tanks
Fatigue analysis for proven designs of independent tank type A may normally not be considered for the cargo tanks. With design cargo temperature below -55°C, fatigue analysis shall be carried out. The analysis shall be referred to a minimum of $10^8$ load cycles in North Atlantic environment for tanks and tank supports with damage factor $C_w \leq 1.0$.

8.1.3 B-tanks
For independent tank type B, fatigue life and crack propagation analyses are required for the design of the tank with small leak protection system. The fatigue design shall be based on direct hydrodynamic wave load analysis with a minimum of $10^8$ load cycles in North Atlantic environment.

8.1.4 Construction tolerances
Fatigue analysis shall consider construction tolerances.

8.2 Locations to be considered
8.2.1 The fatigue strength assessment is to be carried out for cargo tank, tank supports and hull structures in the cargo area as specified below. Additional areas may have to be analysed based on specific structural configurations.

1. hull structures
   - hopper knuckles
   - liquid dome opening and liquid dome coaming connection to deck, type B tanks
   - side stringer connections to transverse bulkheads, type B tanks.

2. cargo Tank, see also [1.2.6] and [8.1.2]
   - stiffener end connections
   - tank structure in general
   - tanks in way of supports
   - tank supports.
   - cargo pump/riser support.

8.3 Loading conditions
8.3.1 Fatigue analyses are to be carried out for representative loading conditions according to the ship’s intended operation as given in the loading manual (the trim and stability booklet). The following loading conditions shall be represented as applicable:

8.3.2 hull structure:
   - homogeneous full load condition at design draught (departure)
   - ballast condition at normal ballast draught (arrival). If a normal ballast condition is not defined in the loading manual, minimum ballast draught shall be used.

8.3.3 tank and tank supports:
   - homogeneous full load condition at design draught (departure)
   - partial tank fillings as relevant. Sloshing effects shall be considered
   - ballast condition at normal ballast draught (arrival). If a normal ballast condition is not defined in the loading manual, minimum ballast draught should be used (10% filling in the cargo tank if applicable).

8.3.4 cargo pump/ riser supports or cargo pipe attachment to cargo tank
   - partial fillings: If relevant a minimum of 3 part filling levels are to be used
— ballast condition at normal ballast draught (arrival). If a normal ballast condition is not defined in the loading manual, minimum ballast draught should be used.

8.4 Load cases

8.4.1 Hull structures
The dynamic Equivalent design waves (EDWs) for fatigue assessment (FLS) defined in Pt.3 Ch.4 Sec.2 [3] shall be applied.

8.4.2 Cargo tanks and supports
.1 For novel type A tank type designs, and/or when the cargo temperature is below –55°C all EDWs defined in Pt.3 Ch.4 Sec.2 [3] shall be considered for FLS analysis of tanks and tank supports.
.2 For B-tanks dynamic Fatigue Design Waves (FDWs) shall be determined from linear hydrodynamic analyses, all headings included, maximizing
— vertical acceleration
— transverse acceleration, and
— longitudinal acceleration.
.3 The dynamic stress range is to be determined as the difference between the results from the 1, i.e. HSM-1 and 2, i.e. HSM-2, versions of the rule EDWs and the directly calculated FLS design waves (FDWs) for A- and B type tanks respectively.

Guidance note:
For determining FDWs for B-tanks reference is made to DNVGL-CG-0130 Wave Load Analysis.

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8.5 Acceptance criteria

8.5.1 The fatigue damage ratio may be calculated based on the S-N fatigue approach under the assumption of linear cumulative damage, i.e. the Miner-Palmgren method. Acceptable fatigue damage ratios are specified in Table 5. The table refers to the principle of Leak-Before-Failure (LBF) as defined in Sec.4 [2.2.6].

Table 5 Required fatigue damage ratios, $C_W$

<table>
<thead>
<tr>
<th>Area</th>
<th>Requirement</th>
<th>Environment</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>type B-tanks: primary barrier of cargo tank, i.e., outer tank shell plates, attached stiffeners and adjacent structure</td>
<td>for failures that can be reliably detected by means of leakage detection; — $C_W \leq 0.5$ — predicted remaining failure development time, from the point of detection of leakage till reaching a critical state, shall not be less than 15 days unless different requirements apply for ships engaged in particular voyages</td>
<td>North Atlantic</td>
<td>leak-before-failure (LBF) proven.</td>
</tr>
</tbody>
</table>
### Area

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Environment</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>type B-tanks: primary supporting structures, i.e. girders, stringers, web frames in cargo tanks</td>
<td>for failures that cannot be detected by leakage detection system but can be reliably detected at the time of in-service inspections</td>
<td>North Atlantic</td>
</tr>
<tr>
<td></td>
<td>— $C_w \leq 0.5$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>— predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three (3) times the inspection interval.</td>
<td></td>
</tr>
<tr>
<td>type B-tanks: primary supporting structures, i.e. girders, stringers, web frames in cargo tanks</td>
<td>in particular locations of the tank where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria should be applied as a minimum;</td>
<td>North Atlantic</td>
</tr>
<tr>
<td></td>
<td>— $C_w \leq 0.1$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>— predicted failure development time from the assumed initial defect until reaching a critical state, shall not be less than three (3) times the lifetime of the tank.</td>
<td></td>
</tr>
<tr>
<td>type B-tanks: tank supports and associated hull structure</td>
<td>— $C_w \leq 0.5$</td>
<td>North Atlantic</td>
</tr>
<tr>
<td>type A-tanks: primary barrier, secondary, tertiary structures, tank supports and supporting hull structure</td>
<td>— $C_w \leq 0.5$</td>
<td>North Atlantic</td>
</tr>
<tr>
<td>hull structure in general</td>
<td>— $C_w \leq 1.0$</td>
<td>world wide</td>
</tr>
</tbody>
</table>

### 9 Crack propagation analysis

#### 9.1 General

**9.1.1** For type B tanks fracture mechanics analyses shall be carried out for dynamically loaded weld connections in the tank shell structure and internal girder/frame structure. For details located in the tank shell structure including shell stiffeners and parts of webs/girders adjacent to the shell the analyses shall be used to determine if:

1. a crack penetrates through the plate thickness of the primary barrier and remains stable for at least 15 days from time of detection of leaks in the worst storm conditions, or
2. the crack does not go through the thickness, but grows in length due to dominating bending stress over the plate thickness.
9.2 Initial defects to be used

9.2.1 The size of initial defects to be used in the analysis shall be decided considering the production quality of the builder. Normally, if the Society does not decide otherwise, the following initial defect sizes can be used for failures originating in the primary barrier plate in way of the Heat Affected Zone (HAZ) from welding:

- butt welds: 1.0 mm depth and 5 mm in length
- fillet welds: 0.5 mm depth and 5 mm in length

For failures originating elsewhere, e.g. from end connections of primary barrier stiffeners, the initial crack size in the shell plating shall be determined considering the development of the crack through the stiffener.

9.3 Acceptance criteria

9.3.1 The acceptance criteria described in [8.5.1] shall be satisfied.

9.4 Leak rates

9.4.1 Leak rates through cracks in the outer shell plates (the primary barrier) shall be determined. The requirements to the drip tray and gas venting arrangement to dispose of leakages are given in Sec.4 [2.5].

**Guidance note:**
For details on crack propagation analysis procedures and the determination of leak rates reference is made to DNVGL-CG-0133, Liquefied gas carriers with independent prismatic tanks.

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10 Vibration analysis

10.1 Requirements

10.1.1 For type B tanks 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: \( f \cdot \Delta \geq 1.1 F \)

Turbine-driven ships: \( f \cdot \Delta \geq 1.1 F \) or \( f \cdot \Delta \leq 0.55 F \)

\( f \)  : 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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SECTION 21 DESIGN WITH SPHERICAL INDEPENDENT TANKS OF TYPE-B

1 General

1.1 Design basis

1.1.1 Hull design
The hull design shall be carried out according to main class requirements in Pt.3 of the rules.
In addition, the present rules for Liquefied Gas Carriers, this section give additional design requirements for Liquefied Gas Carriers with independent spherical type B tanks.

1.1.2 Cargo tank design
.1 Spherical tanks are type B independent tanks and are to be designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics.
.2 If the cargo temperature at atmospheric pressure is below -10°C, a partial secondary barrier with a small leak protection system shall be provided as required in Sec.4 [2.3]. The small leak protection system shall be designed according to Sec.4 [2.5].
.3 The design vapour pressure shall be less than 0.07 MPa, but shall not be taken to be less than 0.025 MPa.

1.2 Spherical cargo tank system

1.2.1 Cargo tank
Spherical cargo tanks are normally built in aluminium, Al 5083-0. However, low temperature steel may also be used, e.g. 9% Ni steel. See Sec.6 for material specifications.
Figure 1 shows the arrangement of a conventional spherical tank design. The spherical tank is supported at the equator of the sphere by a cylindrical skirt welded to the foundation deck,

1.2.2 Equator profile
The equator profile is designed to give optimal fatigue life taking the stress and relative movement between tank and hull into consideration.

1.2.3 Cylindrical skirt
The skirt supports the tank and is designed to act as a thermal brake between the tank and the hull structure by reducing the thermal conduction from the tank to the supporting structure. It is built up of three parts, the upper part in which the same material as in the sphere is used, the middle stainless steel part (the thermal brake) and the lower carbon steel part, see Figure 1.

1.2.4 Structural transition joint (STJ)
The STJ joint connects the upper aluminium part and the middle stainless steel part of the skirt for cargo tanks made of aluminium.

1.2.5 Tank insulation
The insulation forms an annular space between the tank and the insulation barrier. The space is to be continuously purged with Nitrogen and supplied with a gas detection system. The nitrogen purging also prevents icing between the tank and the insulation. Any possible leakage is to be led via the annular gap down to the drip pan.

Guidance note:
Insulation is typically provided according to one of the two following principles
extruded polystyrene-foam logs are butt-welded and fed as a long string from platform outside of hold space, also referred to as “Spiral generation”
— studs welded to tank surface support expanded polystyrene panels applied prior or after erection of tank into the hull.

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Figure 1 Spherical tank system and cargo hold configuration

1.2.6 Drip tray
The drip tray is placed below the cargo tank and act as the partial secondary barrier, i.e. the small leak protection system. The drip tray shall be designed to hold the maximum calculated leak during 15 days after leakage detection in the most severe weather conditions in the North Atlantic. The drip tray is to be insulated towards the inner bottom and designed to prevent splashing of the leaked cargo onto the inner bottom, usually achieved by fitting of internal ribs. Evaporation of the leaked cargo is normally achieved by blowing the drip tray with nitrogen.

1.3 Structural analysis of cargo tanks

1.3.1 Design conditions
The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to the following limit state conditions:
ultimately limit state design condition (ULS)
— plastic deformation
— buckling.
fatigue limit state design condition (FLS)
— fatigue failure, and
— crack propagation analysis.

accident limit state design condition (ALS)
— plastic deformation
— buckling.

Finite element analysis and/or prescriptive requirements and fracture mechanics analysis shall be applied.

1.3.2 Structural analyses
A three-dimensional analysis shall be carried out to evaluate stress levels, including interaction with the ship’s hull. The model for this analysis shall include the cargo tank with its supporting structure, as well as a reasonable part of the hull.

1.3.3 Wave load analysis
A direct hydrodynamic analysis of the particular ship accelerations and motions in irregular waves, and of the structural response of the ship and its cargo tanks to these forces and motions shall be performed, unless the data is available from similar ships.

1.3.4 Fracture mechanics analyses
Crack propagation analyses and design against brittle fracture shall be carried out according to recognized standards, e.g. BS7910. A fracture mechanics analysis according to Sec.4 [4.3.3] .6 to Sec.4 [4.3.3] .9 is required.

1.3.5 Model testing
Model tests may be required to determine material properties for yield and fracture mechanics analyses, stress concentration factors and fatigue life of structural elements, Sec.4 [4.3.3] .6 and .7.

2 Cargo tank and hull finite element analysis

2.1 General

2.1.1 For gas carriers with spherical independent tanks, 3D structural analysis shall be carried out for the evaluation of cargo tanks, tank supports and hull structures.

2.1.2 Model extent
Full integrated 3D model of the whole ship hull with cargo tanks and tank covers shall normally be used. However, part ship models may be accepted by the Society.

2.1.3 Static and dynamic interaction forces shall be determined from the global FE model for all relevant loads, i.e. hull girder bending, torsion and external and internal loads. Depending on the particular ship design the size and fineness of the FE models will be determined by the Society.

2.2 Loading conditions and design load cases

2.2.1 The loading conditions shall be reflected in the loading manual and include the following conditions:

a) homogeneous loading conditions for all approved cargoes
b) ballast conditions
c) one or more tanks empty or partially filled
d) harbour condition for which an increased vapour pressure has been approved
Guidance note:
Conditions a), b) and c) above refers to relevant design conditions for the hull and tank structure. Condition d) refers to emergency discharge of the tanks in case of failure of the cargo pumps and is a structural condition for the tanks only. If two cargo pumps are fitted inside each cargo tank emergency discharge need not be considered/designed for, see Sec.5 [6.1.1] and Sec.5 [6.1.2].
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The design load cases are to be selected based on actual loading conditions from vessel’s loading manual.

2.2.2 Selection of loading conditions
The design loading conditions shall include fully loaded condition, alternate conditions, with realistic combinations of full and empty cargo tanks, with sea pressure/tank pressure, giving maximum net loads on cargo tanks, tank supports and double bottom structures. The ship should be able to operate with any tank empty and the others full, if applicable.

The cargo tank and hull stress response shall be maximized when combining internal and external loads with hull girder bending. The worst combination of loads shall be considered.

2.2.3 Accidental loads
The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in Sec.4 [2.1.4].3 and Sec.4 [3.5], as relevant.

2.2.4 Load cases
Design load cases shall be selected to cover all relevant loading conditions for independent spherical tanks. Static (S) and dynamic (D) design loads; bending moments, torsional moments (as applicable), maximum cargo accelerations and sea pressure shall be applied to the cargo hold finite element model and serve as basis for design against yield and buckling of the cargo tank, and the hull structure.

3 Acceptance criteria – hull and cargo tanks

3.1 Ultimate limit state design condition - hull

3.1.1 Yielding
Acceptance criteria are given in Pt.3 Ch.6 Sec.5 and Pt.3 Ch.6 Sec.6 for yield control of the hull structures. The criteria cover prescriptive requirements for primary support members, secondary members (stiffeners) and plate panels. Further, acceptance levels for FE cargo hold analyses and fine mesh analyses are given in Pt.3 Ch.7 Sec.3 and Pt.3 Ch.7 Sec.4.

3.1.2 Buckling
Acceptance criteria is given in Pt.3 Ch.8 Sec.1 for buckling control of the hull structures.

The Buckling check procedures in DNVGL-CG-0128, Buckling analysis, are to be applied. In case of highly irregular geometries and/or boundary conditions, nonlinear FE analyses may have to be carried out in order to determine the buckling strength of specific areas. In such cases, i.e. by using non-linear structural analysis programs, special considerations with respect to modelling, e.g. mesh fineness, imperfection levels/modes and acceptance levels is required and will be considered by the Society.
3.2 Ultimate limit state design condition - cargo tanks

3.2.1 Basic conditions
The analyses shall be based on the conditions in Sec.4 [4.3.2].

3.2.2 Allowable stress for plastic deformation
For Spherical tanks (sphere and skirt) the allowable stresses shall not exceed:

\[
\begin{align*}
\sigma_m & \leq f \\
\sigma_L & \leq 1.5 f \\
\sigma_b & \leq 1.5 F \\
\sigma_L + \sigma_b & \leq 1.5 F \\
\sigma_m + \sigma_b & \leq 1.5 F \\
\sigma_m + \sigma_b + \sigma_g & \leq 3.0 F \\
\sigma_L + \sigma_b + \sigma_g & \leq 3.0 F
\end{align*}
\]

where:

- \(\sigma_m\) = equivalent von Mises primary general membrane stress, in N/mm\(^2\)
- \(\sigma_L\) = equivalent von Mises primary local membrane stress, in N/mm\(^2\)
- \(\sigma_b\) = equivalent von Mises primary bending stress, in N/mm\(^2\)
- \(\sigma_g\) = equivalent von Mises secondary stress, in N/mm\(^2\)

\[
\begin{align*}
f &= \frac{R_{eH}}{B} \kappa_1 \quad \text{where} \quad \kappa_1 = \min\left[\frac{R_mB}{R_{eHA}} : 1.0\right] \\
F &= \frac{R_{eH}}{D} \kappa_2 \quad \text{where} \quad \kappa_2 = \min\left[\frac{R_mD}{R_{eHC}} : 1.0\right]
\end{align*}
\]

where:

- \(R_{eH}\) = minimum specified yield strength in N/mm\(^2\) as defined in Sec.1
- \(R_m\) = minimum specified tensile strength in N/mm\(^2\) as defined in Sec.1

Stress factors to be used for ULS analyses are given in Table 1.
Table 1 Allowable stress factors for ULS design, AC-II

<table>
<thead>
<tr>
<th>Stress factors</th>
<th>Nickel steels and carbon-manganese steels</th>
<th>Austenitic steels</th>
<th>Aluminium alloys</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

3.2.3 Buckling criteria for cargo tanks

.1 Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with .2 and .3. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, lack of straightness or flatness, ovality and deviation from true circular form over a specified arc or chord length, as applicable.

.2 Buckling criteria and acceptance levels for the spherical tanks and the skirts shall be according to DNVGL-CG-0159, Buckling criteria of LNG spherical cargo tank containment systems - skirt and sphere. The acceptance criteria are given in a Partial Safety Factor format with the partial safety factors given in the document.

.3 For the cylindrical skirt other recognised buckling formulations can be applied if considered applicable by the Society. In such cases the safety level (the partial safety factors) shall provide a safety level not lower than the safety level inherent in .2.

3.2.4 Stress categories and stress definitions

Stress categories for interpretation of stress results are defined in Sec.4 [6.1.3].

3.3 Fatigue limit state design condition (FLS) - cargo tanks

3.3.1 Fatigue design conditions

The fatigue and crack propagation analyses shall be carried based on the conditions in Sec.4 [4.3.3].

3.3.2 Design damage ratios and fracture criteria

Acceptable fatigue damage ratios and crack propagation analysis criteria are summarised in Table 2. The table refers to the principle of Leak-Before-Failure (LBF) defined in Sec.4 [2.2.6].

Table 2 Required fatigue damage ratios, $C_W$ and associated crack propagation criteria

<table>
<thead>
<tr>
<th>Area</th>
<th>Requirement</th>
<th>Environment</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>primary barrier</td>
<td>for failures that can be reliably detected by means of leakage detection;</td>
<td>North Atlantic</td>
<td>leak-before-failure (LBF) proven</td>
</tr>
<tr>
<td>— tank shell welds,</td>
<td>— $C_W \leq 0.5$</td>
<td></td>
<td>Sec.4 [2.2.6]</td>
</tr>
<tr>
<td>— tower supports and</td>
<td>— predicted remaining failure development time, from the point of detection of leakage till reaching a critical state, shall not be less than 15 days unless different requirements apply for ships engaged in particular voyages</td>
<td></td>
<td>Sec.4 [4.3.3] .7</td>
</tr>
</tbody>
</table>
### 3.4 Accident design condition - cargo tanks

#### 3.4.1 ALS design conditions

The analyses shall be carried out based on the design conditions in Sec.4 [4.3.4].

#### 3.4.2 Design premises

1. The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in Sec.4 [2.1.4] .3 and Sec.4 [3.5], as applicable.

2. When subjected to the accidental loads specified in Sec.4 [3.5], the stress shall comply with the acceptance criteria specified in [3.2.2] and [3.2.3], modified as appropriate, taking into account their lower probability of occurrence.

#### 3.4.3 Allowable stress factors

1. Due to the low probability of occurrence higher utilisation of the material is in general allowed for the ALS condition than for the ULS condition, [3.4.2] .2.

2. Stress factors for the ALS limit State allowing up to full yield utilisation are shown in Table 3. Based on the severity (consequence) of the actual incident the Society will assess the safety level (stress factors), but will generally not accept lower values than given in Table 3.

<table>
<thead>
<tr>
<th>Area</th>
<th>Requirement</th>
<th>Environment</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>primary barrier — tank shell welds, — equator area and — attachments as applicable</td>
<td>for failures that cannot be detected by leakage but can be reliably be detected at the time of in-service inspections — ( C_w \leq 0.5 ) — predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three (3) times the inspection interval</td>
<td>North Atlantic</td>
<td>no leakage detection, not LBF Sec.4 [4.3.3] .8</td>
</tr>
<tr>
<td>primary barrier — areas with dominating bending stress. — upper horizontal weld to equator profile</td>
<td>in particular locations of the tank where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria should be applied as a minimum — ( C_w \leq 0.1 ) — predicted failure development time from the assumed initial defect until reaching a critical state, shall not be less than three (3) times the lifetime of the tank</td>
<td>North Atlantic</td>
<td>no leakage detection, not LBF Sec.4 [4.3.3] .9</td>
</tr>
<tr>
<td>tank skirt, STJ, foundation deck area and associated hull structure</td>
<td>— ( C_w \leq 0.5 )</td>
<td>North Atlantic</td>
<td>no leakage</td>
</tr>
<tr>
<td>hull structure in general</td>
<td>— ( C_w \leq 1.0 )</td>
<td>world wide</td>
<td>follow procedures in Pt.3 Ch.9 and DNVGL-CG-0129, Fatigue assessment of ship structures</td>
</tr>
</tbody>
</table>
Table 3 Allowable stress factors for ALS design

<table>
<thead>
<tr>
<th>Stress factors</th>
<th>Nickel steels and carbon-manganese steels</th>
<th>Austenitic steels</th>
<th>Aluminium alloys</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>D</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

3.4.4 Allowable buckling utilisation for ALS
The buckling safety factors shall be according to [3.2.3].2.

3.5 Acceptance levels for vibration response
Vibration effects with the potential to damage the containment system shall be considered, Sec.4 [3.3.5]. Vibration levels for the tower and tank structure shall be below 10 mm/s unless it is documented that the risk of fatigue cracking is within acceptable limits with a higher vibration level.

4 Thermal analysis

4.1 Temperature analysis

4.1.1 Stationary analysis
If not available from similar designs, stationary thermal analysis of cargo hold area and the cargo tank shall be performed as required in Sec.4 [3.3.4] and Sec.4 [5.1.1].1 in order to

1. determine steel temperature as basis for material quality selection of the hull structure and as input to thermal stress analysis, and
2. to determine temperature loads/stresses in the tank system for use in the structural integrity analyses of the cargo tanks and support systems with respect to yield and buckling in partial and full load conditions.

**Guidance note:**
Cool-down from ambient temperature to cargo temperature leads to shrinking of the diameter of the spherical tank and the top of the cylindrical skirt. This imposes an extra eccentricity for the meridional forces in the tank and skirt with additional bending stresses in the equator area as a result.

---end---of---guidance---note---

4.1.2 Transient analysis

1. Analysis of transient thermally induced loads during cooling down periods shall be carried out according to Sec.4 [3.3.4].
2. The analysis is to be used to limit the loading rate from warm tank considering spraying rate while avoiding overstressing of critical areas at the tank/equator profile.

**Guidance note:**
Simplified 2-D models and/or 3-D FE models may be used as applicable. If a 3-D model is deemed necessary, an integrated cargo hold/tank finite element model should be used for the temperature - and thermal stress analyses.

---end---of---guidance---note---
4.2 Acceptance criteria
The acceptance criteria for the ULS design condition for yielding and buckling in [3.2.2] and [3.2.3] applies for the combined set of mechanically and thermally induced stress.
5 Sloshing

5.1 Sloshing loads

5.1.1 Effect to be considered

1. Liquid sloshing effects shall be considered as required in Sec.4 [3.4.4].

2. Due to the smooth internal surface spherical tanks are not subject to liquid impact loads, but inertia sloshing loads shall be accounted for in the analysis procedure.

6 Testing

6.1 Requirements

6.1.1 Test acceptance criteria and procedures

Spherical type B independent tanks shall be subjected to a hydrostatic or hydropneumatic test as follows:

1. The maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 0.9 $R_{eh}$ as fabricated at the test temperature.

2. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 0.75 $R_{eh}$, the prototype test shall be monitored by the use of strain gauges or other suitable equipment.

3. During filling up of the tank, prior to applying internal hydropneumatic overpressure, the lower hemisphere shall be monitored for buckling.

Testing shall be carried out for the skirt as well as the spherical tank itself.

Guidance note:

In addition to the general requirements in Pt.3 for the hull structure detailed analysis procedures for spherical carrier hull- and cargo tank structures are given in DNVGL-CG-0134, Liquefied gas carriers with independent spherical tanks.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
SECTION 22 DESIGN WITH CYLINDRICAL TANKS OF TYPE-C

1 General

1.1 Design basis

1.1.1 Hull design
The hull design shall be carried out according to main class requirements in Pt.3 of the rules.
In addition, the present rules for Liquefied Gas Carriers, this section give additional design requirements for
Liquefied Gas Carriers with independent cylindrical type C tanks.

1.1.2 The design basis for type C independent tanks is pressure vessel criteria modified to include fracture
mechanics and crack propagation criteria. The minimum design vapour pressure defined in [1.2.1] is
intended to ensure that dynamic stresses are sufficiently low, so that an initial surface flaw will not propagate
more than half the thickness of the shell during the lifetime of the tank.

1.1.3 The Class may allocate a tank complying with the criteria of type C minimum design pressure as
in [1.2.1], to a type A or type B, dependent on the configuration of the tank and the arrangement of its
supports and attachments.

1.1.4 Structural analysis of cargo tanks
A structural analysis with integrated model including tanks, hull, tank supports and keying structures shall
be performed with direct FE analyses and/or classical methods as relevant. The following limit state design
conditions shall be considered for type-C tanks;
ultimate limit state design condition (ULS)
— plastic deformation
— buckling.
accident limit state design condition (ALS)
— plastic deformation
— buckling.

Guidance note:
Methods for strength analysis of hull structure in liquefied gas carriers with Cylindrical Type-C tanks are given in DNVGL-
CG-0135, Liquefied gas carriers with independent cylindrical tanks.

1.1.5 In special cases, a fatigue analysis according to Sec.4 [4.3.3] may be required.

1.2 Design loads

1.2.1 Design vapour pressure
The vapour pressure, in MPa, used in the design is generally to be taken as given in the specification, and
not to be taken less than the maximum allowable relief valve setting (MARVS). However, for the tank to be
defined as a tank type C, the minimum vapour pressure as described below must be satisfied.

\[ P_0 = 0.2 + AC(p_r)^{1.5} \]
where:

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

with:

- \( \sigma_m \) = design primary membrane stress in N/mm\(^2\)
- \( \Delta \sigma_A \) = allowable dynamic membrane stress range, i.e. double amplitude at probability level \( Q = 10^{-8} \), taken equal to:
  - 55 N/mm\(^2\) for ferritic-perlitic, martensitic and austenitic steels
  - 25 N/mm\(^2\) for aluminium alloy (5083-0)
- \( C \) = characteristic tank dimension in m taken equal to:
  - \( \max(h; 0.75b; 0.45\ell) \)
  - \( h \) = height of tank exclusive dome in m, dimension in ship’s vertical direction
  - \( b \) = width of tank in m, dimension in ship’s transverse direction
  - \( \ell \) = length of tank in m, dimension in ship’s longitudinal direction
- \( \rho_r \) = the relative density of the cargo at the design temperature (\( \rho_r = 1 \) for fresh water)

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

If other materials than those specified above are used, the allowable dynamic membrane stress \( \Delta \sigma_A \) shall be agreed with the society.

The determination of the maximum dynamic membrane stress ranges for other materials should be based on a crack propagation analysis, assuming a defined initial surface flaw, to ensure a suitable low probability for a crack to propagate through thickness of the shell.

**1.2.2** If the carriage of products not covered by Sec.19 is intended, the relative density of which exceeds 1.0, e.g. CO\(_2\), 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 [1.2.1] i.e.:

\[ \Delta \sigma_m \leq \Delta \sigma_A \]

The dynamic pressure differential \( \Delta P \), in MPa, shall be calculated as follows:

\[ \Delta P = \frac{\rho}{1.02 \cdot 10^5} \left( a_{\beta_1} Z_{\beta_1} - a_{\beta_2} Z_{\beta_2} \right) \]

where:

- \( \rho \) is maximum liquid cargo density in kg/m\(^3\) at the design temperature
- \( a_{\beta} \) are as defined in Sec.4 [6.1.1].2, see also Figure 1 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.
1.2.3 Cargo tank pressure

The design liquid pressure defined in Sec.4 [3.3.2] shall be taken into account in the internal pressure calculations. The internal pressure, in MPa, used to determine the thickness of any specific part of the tank is given by:

$$P_{eq} = P_0 + (P_{gd})_{max}$$

where

$P_{eq}$ is determined as detailed in Sec.4 [6.1.1].

For vacuum insulated tanks the vacuum shall be included in the above formula.

1.2.4 External pressure

External overpressure shall be applied to the tank shell for empty and partially filled tank conditions to ensure that the buckling capacity of the tank is sufficient to withstand the maximum pressure difference between the minimum internal pressure (maximum vacuum) and the maximum external pressure to which any portion of the tank may be subjected simultaneously.

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

$$P_{ed} = P_1 + P_2 + P_3 + P_4$$

where:

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

$P_2$ = the set pressure of the pressure relief valves (PRVs), in MPa, for completely closed spaces containing pressure vessels or parts of pressure vessel; elsewhere $P_2 = 0$

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

---

Figure 1 Acceleration ellipse used to evaluate pressure differential
Unless otherwise documented, as a guidance an external pressure of 0.005MPa can be applied. 

\[ P_4 = \text{external pressure, in MPa, due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere } P_4 = 0. \] 
P4 may be calculated using the formulae given in Pt.3 Ch.4 Sec.5.

1.2.5 Sloshing loads
Simplified sloshing requirements as per Pt.3 Ch.10 Sec.4 for inertia sloshing loads and liquid impact loads are to be satisfied as a minimum requirement. In addition, numerical analyses and/or model testing may be required by the Society if found necessary.

Guidance note:
Methods for investigating the sensitivity for sloshing loads are given in the Society's document DNVGL-CG-0135, Liquefied gas carriers with independent cylindrical tanks, 1.4.4.

1.2.6 Thermal loads
Separate thermal analysis may be required if it is assumed that large temperature gradients are present in the tank, or if constraints in the tank impose large stresses in the tank structure due to contraction of the tank. Thermal stresses are normally classified as secondary stresses. For selection of hull material grades stationary temperature analysis need to be carried out for the part of the hull supporting the cargo tank and the adjacent structure. These temperature calculations shall be according to Sec.4 [5.1.1].

1.2.7 Hull interaction loads
Horizontal tanks supported by saddles should preferably be supported by two saddle supports only. In this case, the effect of hull interaction is normally small.

For tanks supported in such a way that the deflection of the hull transfers significant stresses in the tank, the static and wave induced interaction loads are to be included. The interaction loads may in general be found from a cargo hold analysis, where both the local deflections of the double bottom and the deflections due to hull girder bending are assessed. The wave-induced loads shall be calculated as given in Sec.4 [3.4.2].

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 Figure 1. The half axes in the “acceleration ellipse” may be found from the formulae given in Sec.4 [6.1.2].

In cases where hull interaction loads are significant, separate fatigue evaluations shall be carried out.

1.2.8 Tank test load
Tank test shall be done at a pressure of not less than 1.5\( P_0 \). For vacuum insulated tanks the vacuum pressure shall be included, i.e. 1.5 \( (P_0 + P_{\text{vacuum}}) \).

1.2.9 Accidental loads
The accidental loads and design conditions specified in Sec.4 [2.1.4].3 and Sec.4 [3.5] shall be considered, as applicable.

2 Ultimate strength assessment of cargo tanks

2.1 General requirement

2.1.1 For design against excessive plastic deformation, cylindrical and spherical shells, dished ends and openings and their reinforcement shall be calculated according to [2.3] and [2.7] when subjected to internal pressure only and according to membrane strength check in [2.4] when subjected to external pressure.

2.1.2 An analysis of the stresses imposed on the shell from supports is always to be carried out, see [2.5]. Analysis of stresses from other local loads, thermal stresses and stresses in parts not covered by [2.3] may be required to be submitted. For the purpose of these calculations the stress limits given in [2.8.1] apply.
2.1.3 The buckling criteria to be applied shall allow for the actual shape and thickness of the pressure vessels subjected to external pressure and other loads causing compressive stresses. The calculations shall be based on accepted pressure vessel shell buckling theory, e.g. RP-C202 and/or DNVGL-CG-0128, *Buckling analysis*, and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

2.1.4 Minimum thickness
For pressure vessels, the thickness calculated according to [2.3] shall be considered as a minimum thickness after forming, without any negative tolerance.
For pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, shall not be less than 5 mm for carbon-manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys.

2.1.5 Corrosion addition
Corrosion addition to be considered for the cargo tank is in general according to Sec.4 [2.1.5]. For deck tanks exposed to the weather a corrosion addition of 1.0 mm should be added to the calculated thickness.

2.2 Design conditions
2.2.1 For ultimate (ULS) design conditions, accidental (ALS) design conditions and test conditions, the following are to be considered.

Table 1 Design conditions for scantling control of tank structure and support

<table>
<thead>
<tr>
<th>Condition</th>
<th>Location</th>
<th>Reference</th>
<th>Load components</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC 1 yield check</td>
<td>cylindrical shell</td>
<td>Pt.4 Ch.7 Sec.4 [3.2]</td>
<td>— tank system self-weight</td>
</tr>
<tr>
<td></td>
<td>spherical shell</td>
<td>Pt.4 Ch.7 Sec.4 [3.3]</td>
<td>— internal static and dynamic cargo pressure</td>
</tr>
<tr>
<td></td>
<td>dished ends</td>
<td>Pt.4 Ch.7 Sec.4 [4]</td>
<td>— internal vapour pressure</td>
</tr>
<tr>
<td></td>
<td>shell in way of support</td>
<td>As described in [2.3.2]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>openings and reinforcements</td>
<td>Pt.4 Ch.7 Sec.4 [6.3]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>supports</td>
<td>as described in DC 3 below</td>
<td></td>
</tr>
<tr>
<td>ULS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC 2 yield check</td>
<td>swash bulkhead</td>
<td>Pt.3 Ch.10 Sec.2 [2]</td>
<td>— sloshing pressure</td>
</tr>
<tr>
<td>DC 3 yield and buckling check</td>
<td>tank</td>
<td>as for DC 1</td>
<td>— tank system self-weight</td>
</tr>
<tr>
<td></td>
<td>in way of supports</td>
<td>as for DC 1</td>
<td>— max acceleration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>— static cargo pressure at 30 degr. inclination</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>— internal vapour pressure</td>
</tr>
<tr>
<td>DC 4 buckling check</td>
<td>cylindrical shell</td>
<td>[2.4.1]</td>
<td>— design external pressure</td>
</tr>
<tr>
<td></td>
<td>spherical shell</td>
<td>[2.4.2]</td>
<td>— partial filling as relevant</td>
</tr>
<tr>
<td></td>
<td>dished ends</td>
<td>[2.4.3]</td>
<td></td>
</tr>
</tbody>
</table>
### 2.3 Scantling due to internal pressure

#### 2.3.1 Minimum plate thickness calculation based on allowable stress

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: pressure vessel Class I shall apply. The design pressure is given in [1.2.3].

The nominal design allowable stress, \( f \), is given in [2.8.1].

#### 2.3.2 Longitudinal stresses in the cylindrical shell

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

\[
\sigma_z = \frac{P_0}{t} \left( \frac{R}{t} \right) \left( 1 - \frac{R}{2t} \right) + \frac{W}{t} + \frac{M}{t^2}
\]

where:

- \( P_0 \) = internal vapour pressure, in MPa, as defined in [1.2.1]
- \( R \) = inside radius of shell in mm
- \( t \) = minimum net required shell thickness in mm
- \( W \) = axial force (tension is positive) due to static and dynamic weight of cargo in N, excluding \( P_0 \)
- \( M \) = longitudinal bending moment in Nm, e.g. due to:
  - mass loads in a horizontal vessel
  - eccentricities of the centre of working pressure relative to the neutral axis of the vessel
  - friction forces between the vessel and a saddle support.

If applicable, \( \sigma_z \) is also to be checked for \( P_0 = 0 \).

Tank test condition need to be taken into account considering \( p_0 \) the test pressure described in [1.2.8].

The allowable longitudinal stress in the cylindrical tank is given in [2.8.4] against \( P_0 \) and [2.8.5] for tank test load.

The longitudinal stresses are normally to be checked at tank mid-span and at the saddles.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Location</th>
<th>Reference</th>
<th>Load components</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALS DC 5</td>
<td>forward collision</td>
<td>as described in [2.5]</td>
<td>— tank system self-weight&lt;br&gt;— static cargo pressure&lt;br&gt;— longitudinal dynamic cargo pressure of 0.5g in forward direction</td>
</tr>
<tr>
<td>ALS DC 6</td>
<td>aft collision</td>
<td>as described in [2.5]</td>
<td>— tank system self-weight&lt;br&gt;— static cargo pressure&lt;br&gt;— longitudinal dynamic cargo pressure of 0.25g in aftward direction</td>
</tr>
<tr>
<td>ALS DC 7</td>
<td>flooding condition</td>
<td>as described in [2.5]</td>
<td>— empty tank&lt;br&gt;— external liquid height in cargo hold up to design water line</td>
</tr>
<tr>
<td>tank test DC 8</td>
<td>tank test</td>
<td>[7.1]</td>
<td>— full tank filled with fresh water</td>
</tr>
</tbody>
</table>

| Part 5 Chapter 7 Section 22 |
2.4 Scantling due to external pressure

2.4.1 Cylindrical shell
The cylindrical shell shall be checked so that elastic instability or membrane yield does not occur. The allowable design pressure shall be complied with the requirement in [2.8.2].

![Diagram of cylindrical shell](image)

Figure 2 Effective length of cylinders subject to external pressure
— calculation of elastic instability

The pressure $P_c$, in MPa, corresponding to elastic instability of an ideal cylinder, shall be determined from the following formula:

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

where $n$ is chosen to minimise $P_c$ which means that the critical pressure is found by an iteration process over the range $n$, where $n > Z$. The formula is only applicable when $n > Z$.

- $D$ = outside diameter in mm
- $t$ = net thickness of plate, in mm, exclusive of corrosion allowance
- $R_{yH}$ = specified minimum yield stress in N/mm$^2$, as defined in
- $E$ = Young's modulus in N/mm$^2$, as defined in Pt.3 Ch.1 Sec.4
- $n$ = integral number of waves $(\geq 2)$ for elastic instability
\[ Z = \text{coefficient equal to } 0.5nD/L \]
\[ L = \text{effective length between stiffeners in mm, see Figure 2} \]

— calculation of membrane yield

The pressure \( P_y \) in MPa, corresponding to a general membrane yield, shall be determined from the following formula:

\[ P_y = \frac{R e H \cdot t}{R} \]

2.4.2 Spherical shells

The spherical shell shall be checked so that elastic instability or membrane yield does not occur. The allowable design pressure shall be complied with the requirement in [2.8.2].

— calculation of elastic instability

The pressure \( P_c \) in MPa, corresponding to elastic instability of a spherical shell, shall be determined from the following formula:

\[ P_c = 0.24 \cdot E \cdot \left( \frac{t}{R} \right)^2 \]

where

\[ R = \text{outside radius of sphere in mm} \]

— calculation of membrane yield

For membrane check, the external pressure in MPa causing yield in the sphere will be:

\[ P_y = 2 \cdot \frac{R e H \cdot t}{R} \]

2.4.3 Dished ends

Hemispherical ends shall be designed as spherical shells as given in [2.4.2].

Tori spherical ends shall be designed as spherical shells as given in [2.4.2], 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.

Ellipsoidal ends shall be designed as spherical shells as given in [2.4.2], 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.

2.4.4 Stiffening rings

The requirements for scantling of stiffening rings are given in terms of minimum moment of inertia for the member, in mm\(^4\).

\[ I_x = \frac{0.18 \cdot D \cdot P_{ed} \cdot L \cdot D_s^2}{E} \]

where
2.5 Supports

2.5.1 The supporting members shall be arranged in such a way as to provide for the maximum imposed loads given in [1.2].

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 restraints.

2.5.2 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---

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

2.5.4 Calculation of stresses in a cylindrical tank shall include:
— longitudinal stresses at mid-span and at supports
— tangential shear stress at supports and in dished ends, if applicable
— circumferential stresses at supports.

2.5.5 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 Sec.20 [4.3] for tanks type B apply.

2.5.6 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 [1.2].

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:

$$\sigma_{vm} \leq \sigma_{all}$$

where

$$D_s = \text{diameter to the neutral axis of stiffener in mm}$$

$$P_{ed} = \text{external design pressure in MPa defined in [1.2.4]}$$

The length of the shell in mm contributing to the moment of inertia is limited by

$$L_s = 0.75 \sqrt{D t}$$

Stiffening rings shall extent completely around the circumference of the shell.
\[
\sigma_{vm} = \sqrt[3]{(\sigma_n + \sigma_b)^2 + 3\tau^2}
\]

\(\sigma_{vm}\) = von Mises stress
\(\sigma_{all}\) = \(\min(0.57R_m;0.85R_{eff})\)
\(\sigma_n\) = normal stress in N/mm\(^2\) in the circumferential direction of the stiffening ring
\(\sigma_b\) = bending stress in N/mm\(^2\) in the circumferential direction of the stiffening ring
\(\tau\) = shear stress in N/mm\(^2\) in the stiffening ring

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, \(L_{eff}\), not larger than given below may be applied
     \[
     L_{eff} = \frac{1.56\sqrt{Rt}}{1 + 12\frac{t}{R}}
     \]

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

   \(R\) = mean radius of the cylindrical shell in mm
   \(t\) = shell thickness in 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 in 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, e.g. 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.
2.6 Swash bulkheads

2.6.1 The plates and stiffeners of the swash bulkhead shall as far as practicable be calculated according to Pt.3 Ch.10 Sec.4. In cases where the prescriptive formulas do not apply, alternative equivalent methods may be accepted, provided that the capacity formulation reflects the assumed return period of the load.

2.7 Openings and their reinforcement

2.7.1 The requirements to reinforcements of openings and the dimensioning of attachments related to openings are given in Pt.4 Ch.7 Sec.4. This includes openings related to, e.g. tank domes, sumps and manholes, pipe penetrations.

2.7.2 Scantling control of attachments such as domes and sumps should in principle follow the same calculation procedures as for the main shell of the tank, taking into account the actual dimensions. Effects of openings or penetrations should be included.

2.8 Acceptance criteria

2.8.1 Design stresses for allowable code stress assessment

For evaluation of the design stresses in the tank, the design equivalent stress shall not exceed the values given below:

\[
\begin{align*}
\sigma_m & \leq f \\
\sigma_L & \leq 1.5f \\
\sigma_b & \leq 1.5f \\
\sigma_L + \sigma_b & \leq 1.5f \\
\sigma_m + \sigma_b & \leq 1.5f \\
\sigma_m + \sigma_b + \sigma_g & \leq 3.0f \\
\sigma_L + \sigma_b + \sigma_g & \leq 3.0f
\end{align*}
\]

where:

\[
\begin{align*}
\sigma_m &= \text{equivalent von Mises primary general membrane stress, in N/mm}^2; \\
\sigma_L &= \text{equivalent von Mises primary local membrane stress, in N/mm}^2; \\
\sigma_b &= \text{equivalent von Mises primary bending stress, in N/mm}^2; \\
\sigma_g &= \text{equivalent von Mises secondary stress, in N/mm}^2; \\
f &= \text{allowable stress in N/mm}^2 \text{ equal to min } (R_m/A; R_eH/B),
\end{align*}
\]

with \( R_m \) and \( R_eH \) as defined in Sec.1. With regard to the stresses \( \sigma_m, \sigma_L, \sigma_b \) and \( \sigma_g \), the definition of stress categories in Sec.4 [6.1.3] are referred. The values A and B shall have at least the following minimum values:

<table>
<thead>
<tr>
<th></th>
<th>Nickel steels and carbon-manganese steels</th>
<th>Austenitic steels</th>
<th>Aluminium alloys</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

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. However, during pressure testing at
ambient temperature, [7.1], the specified minimum material properties at the test temperature shall be applied.

Allowable stresses for materials other than those referred to in Sec.6, will be subject to approval in each separate case.

2.8.2 Acceptance criteria for buckling strength assessment
A membrane stress check is to be carried out for the cylindrical and spherical shells to ensure that elastic instability or membrane yield do not occur under external pressure. The external pressure shall in general not exceed a critical pressure, $P_c$, which is determined based on an evaluation of the buckling strength of the member, including a general safety factor. The critical pressure, including safety factor, is not allowed to exceed the yield strength of the material. The requirements are given in the following general format:

$$\frac{P_c}{P_{ed}} \geq 4 \quad \text{for cylindrical shell}$$

$$\frac{P_c}{P_{ed}} \geq 3 \quad \text{for spherical shell}$$

$$\frac{P_y}{P_{ed}} \geq 3 \quad \text{for cylindrical and spherical shells}$$

where

$P$ = external pressure in MPa corresponding to elastic instability of cylindrical or spherical shell

$P_y$ = external pressure in MPa corresponding to membrane yield of the material

$P_{ed}$ = external design pressure in MPa as given in [1.2.4]

2.8.3 Acceptance criteria for evaluation of swash bulkhead
The capacity formulations given in Pt.3 Ch.10 Sec.4 [3.1] generally apply for the structural members of the swash bulkheads, provided that the bulkhead is not part of the strength of the tank.

2.8.4 Acceptance criteria for longitudinal stresses in the cylindrical shell
For design against excessive plastic deformation, $\sigma_Z$ according to [2.3.2] shall not exceed 0.8 $f_e$.

where

$e$ = efficiency factor for welded joints, expressed as a fraction

The welded joint efficiency factor to be used in the calculation shall be 0.95 when the inspection and the non-destructive testing referred to in Sec.6 [5.6.5] are carried out. This figure may be increased up to 1.0 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels the Society may accept partial non-destructive examinations, but not less than those of Sec.6 [5.6.5], depending on such factors as the material used, the design temperature, the nil ductility transition temperature of the material as fabricated and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0.85 shall be adopted. For special materials the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.
The value for $f$, shall be based on values for $R_m$ and $R_eH$ in cold worked or tempered condition. For design against buckling, the longitudinal compressive stress, $\sigma_Z$ shall not exceed:

$$\sigma_Z = \frac{0.2 \cdot E \cdot \frac{t}{R}}{1 + 0.004 \cdot \frac{E}{R_eH}}$$

### 2.8.5 Acceptance criteria for tank test condition

In connection with the hydrostatic test described in [7], the membrane stress $\sigma_l$ shall at any point not exceed $\sigma_l \leq 0.9 \cdot R_eH$. It should be ensured that any compression stresses in the tank during filling do not cause any instability of the tank shell.

### 2.8.6 Acceptance criteria for accidental condition

For the accidental load cases, the nominal equivalent von Mises stress in N/mm² shall not be larger than $R_eH$, i.e.:

$$f < R_eH$$

### 3 Cargo tank and hull finite element analysis

#### 3.1 General

**3.1.1** A direct Finite Element strength assessment of the cargo tank is in general not required provided stresses at the supports are properly assessed by other means. For novel designs, large tanks and tank geometries different from the conventional ones such as multi-lobe tanks Finite Element strength assessment may be required by the Society, see also [1.1.4]. In case a finite element strength assessment of the cargo tank is required the procedure and load cases shall be agreed with the Society. With only two supports, the cargo tank can be modelled independently from the hull structures with consideration of the supports and be evaluated separately. However, in case of more than 2 supports the analysis shall be based on an integrated cargo tank/hull Finite Element model in order to determine the interaction forces between the tanks and the supporting ship hull.

Loads given in Sec.4 [3] shall be considered and the evaluation is to be based on acceptance criteria given in [2.8].

**3.1.2** Finite Element analysis of the ship hull and supports shall be carried out according to Pt.3 Ch.7 and as given in this sub-section.

**3.1.3** As a minimum the midship region shall be modelled, but additional analyses for the fore and/or aft cargo hold regions may be required by the society depending on the actual tank/ship design configuration if fore and aft region deviates significantly from the Midship region.

**3.1.4** The structure assessment is to be carried out in accordance with the requirement given in Pt.3 Ch.7 Sec.3 [2] and the Society’s document DNVGL-CG-0127, *Finite element analysis* if not otherwise described in this sub-section.

**3.1.5 Model extent**

The necessary longitudinal extent of the model will depend on the structural arrangement and the loading conditions. The analysis model shall normally extended over three hold lengths (1+1+1), where the middle
tank/hold of the model is used to assess the yield and buckling strength. However, shorter models may be accepted by the Society.

The model shall cover the full breadth of the ship in order to account for asymmetric structural layout of the cargo tank/supporting hull structure and asymmetric design load conditions (heeled or other unsymmetrical loading conditions).

In order to consider the cargo loads, the cargo tank model shall be integrated into the cargo hold model.

3.2 Loading conditions and design load cases

3.2.1 General
Hull girder and local loads according to Pt.3 Ch.4 are to be applied to the model.

3.2.2 Selection of loading conditions
At least the following loading conditions shall be examined:
— maximum draft with any cargo tank(s) empty
— minimum draft with any cargo tank full.
Both harbour and sea-going conditions, inclusive any sequential ballast exchange conditions, are to be reviewed.
Where the loading conditions specified by the designer are not covered by the standard load cases then these additional loading conditions are to be examined.

3.3 Acceptance criteria for cargo hold FE analysis

3.3.1 Evaluation of the analysis shall be made for hull and support structures.

3.3.2 Acceptance criteria for yielding are given in Table 2.

Table 2 Coarse mesh permissible yield utilisation factor

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Coarse mesh permissible yield utilization factor, ( \lambda )perm</th>
</tr>
</thead>
<tbody>
<tr>
<td>ship hull structures</td>
<td>according to Pt.3 Ch.7 Sec.3 [4]</td>
</tr>
<tr>
<td>saddle support structures</td>
<td>0.9 (load combination S+D)</td>
</tr>
<tr>
<td></td>
<td>0.72 (load combination S)</td>
</tr>
</tbody>
</table>

Acceptance criteria for buckling are given in Table 3.

Table 3 Allowable buckling utilisation factor

<table>
<thead>
<tr>
<th>Structural component</th>
<th>( \eta ) allowable buckling utilisation factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ship hull structures</td>
<td>according to Pt.3 Ch.8 Sec.1 [3]</td>
</tr>
<tr>
<td>saddle support structures</td>
<td>0.9 (load combination S+D)</td>
</tr>
<tr>
<td></td>
<td>0.72 (load combination S)</td>
</tr>
</tbody>
</table>
4 Local structure strength analysis

4.1 General

4.1.1 The fine mesh strength assessment is to be carried out in accordance with the Rules Pt.3 Ch.7 Sec.4 and DNVGL-CG-0127, Finite Element Analysis if not otherwise described in this sub section.

4.2 Locations to be checked

4.2.1 The following areas in the midship cargo region shown in the list below are to be investigated with fine mesh analysis. The need for fine mesh analysis of these areas may be determined based on a screening of the actual geometry and the result from the cargo hold analysis. If considered necessary, the Society will require additional locations to be analysed.

4.2.2 Hull structures
   — vertical stiffeners on transverse bulkheads to inner bottom.

4.2.3 Tank support
   — saddle support (when cargo hold model is not sufficient)
   — Anti floating key.

4.3 Acceptance criteria

It is required that the resulting von Mises stresses are not exceeding the allowable membrane values specified in Table 4. These criteria apply to regions where stress concentrations occur due to irregular geometries. Nominal stress shall remain within the limits for cargo hold analysis.

Table 4 Maximum allowable membrane stresses for local fine mesh analysis

<table>
<thead>
<tr>
<th>Element stress</th>
<th>Acceptance criteria</th>
<th>AC-I</th>
<th>AC-II</th>
<th>AC-III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load components</td>
<td></td>
<td>S</td>
<td>S+D</td>
<td>ALS</td>
</tr>
<tr>
<td>tank supports</td>
<td>element not adjacent to weld (base material)</td>
<td>1.07 $R_{eff}$</td>
<td>1.53 $R_{eff}$</td>
<td>1.84 $R_{eff}$</td>
</tr>
<tr>
<td></td>
<td>element adjacent to weld</td>
<td>0.95 $R_{eff}$</td>
<td>1.35 $R_{eff}$</td>
<td>1.62 $R_{eff}$</td>
</tr>
<tr>
<td>ship hull structures</td>
<td></td>
<td>according to Pt.3 Ch.7 Sec.4 [4.2]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) The maximum allowable stresses are based on the mesh size of 50 mm x 50 mm. Where a smaller mesh size is used, an average von Mises stress calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses.

2) Average von Mises stress is to be calculated according to Pt.3 Ch.7 Sec.4 [4.2.1].
5 Fatigue strength assessment

5.1 Hull structure

5.1.1 Design criteria
The fatigue strength assessment is to be carried out in accordance with Pt.3 Ch.9 and the Society’s document DNVGL-CG-0129, Fatigue assessment of ship structure.

5.1.2 Acceptance criteria
The hull structure shall be designed to satisfy a minimum design fatigue life of 25 years operation in worldwide environment according to Pt.3 Ch.9 Sec.1.

5.2 Fatigue of cargo tanks

5.2.1 The Society may, in special cases, require fatigue analyses to be carried out. For tanks where the cargo temperature at atmospheric pressure is below -55°C, verification of compliance with [1.1.2] regarding static and dynamic stress may be required.

5.2.2 The analysis shall be carried out for parent material and welded connections at areas where high dynamic stresses or large stress concentrations may be expected, e.g. at tank supports, penetrations and attachments. Static and dynamic membrane and bending stresses are to be determined for use in the fatigue strength assessment, Sec.4 [4.3.3].9.

5.2.3 The procedure for fatigue analysis shall be in accordance with Sec.4 [4.3.3].

6 Accidental strength assessment

6.1 General

6.1.1 The tanks and the tank supporting structures shall be designed for the accidental loads and design conditions specified in Sec.4 [2.1.4].3 and Sec.4 [3.5], as applicable.

6.1.2 When subjected to the accidental loads specified in Sec.4 [3.5], the stress shall comply with the acceptance criteria specified in [2.8.1] and [2.8.6], modified as appropriate taking into account their lower probability of occurrence.

7 Testing

7.1 Requirements

7.1.1 Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1.5 \( P_o \). In no case during the pressure test shall the calculated primary membrane stress at any point exceed 0.9 \( R_{eh} \). To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times \( R_{eh} \), the prototype test shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

7.1.2 The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.
7.1.3 The pressure shall be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

7.1.4 Where necessary for cargo pressure vessels, and with specific approval of the Society, a hydropneumatic test may be carried out under the conditions prescribed in [7.1.1] to [7.1.3].

7.1.5 Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of [7.1.1] shall be fully complied with.

7.1.6 After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test which may be performed in combination with the pressure testing referred to in [7.1.1].

7.1.7 Pneumatic testing of pressure vessels other than cargo tanks shall only be considered on an individual case basis. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

8 Manufacture and workmanship

8.1 General

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

8.1.2 The workmanship shall comply with the requirements in Pt.4 Ch.7 Sec.7, 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.

8.2 Stress relieving

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

8.2.2 The soaking temperature and holding time shall be as given in Sec.6 [5] and Pt.4 Ch.7 Sec.7 Table 2. For nickel alloy steels and austenitic stainless steel, the requirements for heat treatment will be considered in each case.

8.2.3 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 [7], by applying a higher pressure than the test pressure required by [7]. The pressurizing medium shall be water.

3) for the water temperature, [7] 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 $R_{eh}$
   — equivalent stress composed of primary bending stress plus membrane stress: 1.35 $R_{eh}$
   where $R_{eh}$ 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.

8.3 Manufacture

8.3.1 Out of roundness shall not exceed the limit given in Pt.4 Ch.7 Sec.8 [2.3.4].

8.3.2 Irregularities in profile shall not exceed the limit given in Pt.4 Ch.7 Sec.7 [2.3.5], 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 Figure 3. For spheres, $L$ is one half the outside diameters. For shells under internal pressure, the chord length need not exceed 0.17 $D$. 
Figure 3 Arc length for determining deviation for true form

8.4 Marking

8.4.1 The required marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.
SECTION 23 DESIGN WITH MEMBRANE TANKS

1 General

1.1 Design basis

1.1.1 Hull design
The hull design shall be carried out according to main class requirements in Pt.3 of the rules. In addition, the present rules for Liquefied Gas Carriers, this section give additional design requirements for Liquefied Gas Carriers with membrane tanks.

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

1.1.3 A systematic approach based on analysis and testing shall be used to demonstrate that the system will provide its intended function in consideration of the events identified in service as specified in [1.2.1].

1.1.4 If the cargo temperature at atmospheric pressure is below -10°C a complete secondary barrier shall be provided as required in Sec.4 [2.3]. The secondary barrier shall be designed according to Sec.4 [2.4].

1.1.5 The design vapour pressure $P_o$ shall not normally exceed 0.025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, $P_o$ may be increased to a higher value, but less than 0.07 MPa.

1.1.6 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 into the thermal insulation. Such designs require, however, special consideration by the Society.

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

1.1.8 The circulation of inert gas throughout the primary insulation space and the secondary insulation space, in accordance with Sec.9 [2], shall be sufficient to allow for effective means of gas detection.

1.1.9 The structural analysis of the hull shall be performed in accordance with this section and 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 DNVGL-CG-0136, Liquefied gas carriers with membrane tanks.

1.2 Design considerations

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

.1 ultimate design events:
   .1 tensile failure of membranes;
   .2 compressive collapse of thermal insulation
   .3 thermal ageing
   .4 loss of attachment between thermal insulation and hull structure
.5 loss of attachment of membranes to thermal insulation system
.6 structural integrity of internal structures and their supporting structures, and
.7 failure of the supporting hull structure.

.2 fatigue design events:
.1 fatigue of membranes including joints and attachments to hull structure
.2 fatigue cracking of thermal insulation
.3 fatigue of internal structures and their supporting structures, and
.4 fatigue cracking of inner hull leading to ballast water ingress.

.3 accident design events:
.1 accidental mechanical damage (such as dropped objects inside the tank while in service)
.2 accidental over pressurization of thermal insulation spaces
.3 accidental vacuum in the tank, and
.4 water ingress through the inner hull structure.

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

1.2.2 The necessary physical properties, i.e. mechanical, thermal, chemical, etc. of the materials used in the construction of the cargo containment system shall be established during the design development in accordance with [1.1.3].

1.2.3 As basis for hull material selection temperature analyses shall be carried out as given in Sec.4 [3.3.4], and the hull material selected according to Sec.4 [5.5.1].

1.2.4 For corrosion additions of the hull structure, see Pt.3 Ch.3 Sec.3.

1.3 Arrangement of cargo area

1.3.1 A double bottom, double side, trunk deck and cofferdam bulkhead shall be arranged to facilitate the support of the membrane system. The distance of bottom line to the tank and the distance of shell to the inner side shall comply with Sec.2 [4].
1.3.2 Definition

1.4 Loads

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

1.4.2 Environmental loads
Design loads according to the Rules Pt.3 Ch.4 are applicable for all parts of hull structure including inner hull and transverse bulkhead.

In addition loads from the cargo, as given in Sec.4 [3.3.2], shall be applied when analyzing local strength of plates and stiffeners of the parts of inner hull supporting the membrane tanks as required in [2.2].

For cargo hold FE analysis, dynamic loads defined in Pt.3 Ch.4 shall be applied.

1.4.3 Sloshing loads
When partial tank filling is contemplated, the risk of significant loads due to sloshing induced by any of the ship motions shall be considered.

.1 Inertia sloshing loads as described in the rules, Pt.3 Ch.10 Sec.4, shall be considered as a minimum.
.2 In order to determine liquid impact loads for membrane tanks special tests and/or calculations shall be carried out as described in the Society’s document DNVGL-CG, *Sloshing analysis of LNG membrane tanks*. Result of tests and/or calculations available from previous vessel may be used when the configuration of the tank/ship is considered to be identical.
Guidance note:

In order to avoid insulation system damage from high liquid impact loads the system may either be strengthened (if possible) or be subject to operational limitation in the form of

— tank filling restrictions, or if this is not an option
— maximum operating limits may be specified e.g. in terms of ship headings and significant wave height. Such restrictions are mostly relevant for loading/offloading at offshore export/import terminals.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.5 Structural analysis

1.5.1 Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the cargo containment and associated structures, e.g. structures as defined in Sec.4 [2.7], shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the cargo containment system.

1.5.2 Structural analyses of the hull shall take into account the internal pressure as indicated in Sec.4 [3.3.2]. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

1.5.3 The analyses referred to in [1.5.1] and [1.5.2] shall be based on the particular motions, accelerations and response of ships and cargo containment systems.

2 Ultimate strength assessment

2.1 General

2.1.1 The structural resistance of every critical component, subsystem, or assembly shall be established, in accordance with [1.1.3], for in-service conditions.

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

2.2 Local scantling of inner hull

2.2.1 The scantling of inner hull plates and stiffeners shall meet the requirements described in Pt.3 Ch.6 as minimum. In addition, they shall comply with below requirement taking into account the internal pressure as indicated in Sec.4 [3.3.2] and the specified appropriate requirements for sloshing load as defined in Sec.4 [3.4.4].

— Evaluation against liquid impact loads as described in [1.4.3] is to be carried out based on DNVGL-CG-0158, Sloshing analysis of LNG membrane tanks or equivalent.

2.2.2 Plating

The net local scantlings in mm of inner hull plating supporting the membrane tanks shall satisfy the following:

\[ t = 0.0158 \alpha_p b \left( \frac{P_{eq}}{C_a R_{elH}} \right) \]
where

\[ \alpha_p = \text{correction factor for the panel aspect ratio calculated as follows but not to be taken greater than 1.0} \]

\[ \alpha_p = 1.2 - \frac{b}{2.1a} \]

\[ a = \text{length of plate panel in mm, Pt.3 Ch.3 Sec.7 [2.1.1]} \]
\[ b = \text{breadth of plate panel in mm, Pt.3 Ch.3 Sec.7 [2.1.1]} \]
\[ P_{eq} = \text{cargo tank pressure in kN/mm}^2 \text{ as given in Sec.4 [3.3.2]} \]
\[ C_a = \text{permissible bending stress coefficient for plate taken equal to:} \]

\[ C_a = \beta_a - \alpha_a \frac{\sigma_{hg}}{\sigma_{eq}}, \text{ not to be taken greater than } C_{a\text{-max}} \]

where

\[ \alpha_{ap}, \beta_a \]
\[ C_{a\text{-max}} = \text{maximum permissible bending stress coefficient as defined for AC-II in Pt.3 Ch.6 Sec.4 Table 1} \]
\[ \sigma_{hg} = \text{hull girder bending stress, in N/mm}^2 \text{, calculated at the load calculation point as defined in Pt.3 Ch.3 Sec.7 [2.2]} \]
\[ \sigma_{sw-i} = \text{longitudinal stress, in N/mm}^2, \text{ induced by still water bending moment as defined in Pt.3 Ch.5 Sec.3 [4.1.1]} \]
\[ \sigma_{wv-i} = \text{longitudinal stress, in N/mm}^2, \text{ induced by vertical wave bending moment, sagging or hogging} \]
\[ \sigma_{wh} = \text{longitudinal stress, in N/mm}^2, \text{ induced by horizontal wave bending moment} \]

\[ \sigma_{sw-i} = \frac{M_{wv-i}(z - z_h)10^{-3}}{I_y - n_{50}}, \text{ where vertical wave bending moments, } M_{wv-i} \text{ as defined in Pt.3 Ch.4 Sec.4 [3.1.1]} \]
\[ \sigma_{wh} = \frac{M_{wh}y10^{-3}}{I_z - n_{50}}, \text{ where horizontal wave bending moment, } M_{wh}, \text{ as defined in Pt.3 Ch.4 Sec.4 [3.3.1]} \]

**2.2.3 Section modulus for stiffeners**

The net section modulus in cm$^3$ of stiffeners on inner hull supporting the membrane tanks shall satisfy the following:

\[ Z = \frac{f_{ui}P_{eq}s^2_{bdg}}{f_{bdg}C_3R_{eh}} \]
where

\[ f_u = \text{factor for unsymmetrical profiles, as given in Pt.3 Ch.6 Sec.5 [1.1.2]} \]
\[ l_{bdg} = \text{effective bending span in m as defined in Pt.3 Ch.3 Sec.7} \]
\[ C_s = \text{permissible bending stress coefficient for stiffener taken equal to:} \]

\[ C_s = \beta_s - \alpha_s \frac{\sigma_{hg}}{R_{eH}}, \text{not to be taken greater than } C_{s-max} \]

where

\[ \alpha_s, \beta_s = \text{coefficients as defined for AC-II in Pt.3 Ch.6 Sec.5 Table 4} \]
\[ C_{s-max} = \text{maximum permissible bending stress coefficient as defined for AC-II in Pt.3 Ch.6 Sec.5 Table 4} \]
\[ \sigma_{hg} = \text{hull girder compressive stress, in N/mm}^2, \text{calculated at the load calculation point as defined in Pt.3 Ch.3 Sec.7 [3.2]} \]
\[ = \max[|\sigma_{sw-s} + \sigma_{wv-s}|, |\sigma_{sw-s} + 0.5\sigma_{wv-s} + 0.9\sigma_{wh}|], \text{for } z \geq z_n \]
\[ = \max[|\sigma_{sw-h} + \sigma_{wv-h}|, |\sigma_{sw-h} + 0.5\sigma_{wv-h} + 0.9\sigma_{wh}|], \text{for } z < z_n \]
\[ \sigma_{sw-s}, \sigma_{sw-h} = \text{longitudinal stress, in N/mm}^2, \text{induced by sagging/hogging still water bending moment respectively} \]
\[ = \sigma_{sw-w}, \text{given in [2.2.2]} \]
\[ \sigma_{wv-s}, \sigma_{wv-h} = \text{longitudinal stress, in N/mm}^2, \text{induced by vertical sagging/hogging wave bending moment respectively} \]
\[ = \sigma_{wv-w}, \text{given in [2.2.2]} \]
\[ z_n = \text{vertical distance from BL to horizontal neutral axis, see Pt.3 Ch.1 Sec.4.} \]
\[ \sigma_{wh} \text{ as given in [2.2.2]} \]
\[ s = \text{stiffener spacing in mm} \]
\[ f_{bdg} = \text{bending moment factor as defined in Pt.3 Ch.6 Sec.5 Table 5. For stiffeners with fixity deviating from the ones included in Pt.3 Ch.6 Sec.5 Table 5 with complex load pattern, or being part of a grillage, the requirement in Pt.3 Ch.6 Sec.5 [1.2] applies.} \]

2.2.4 Effect of impact sloshing loads

Sloshing impact loads acting on the containment system inside the cargo tanks have to be transferred into the supporting hull structure, i.e. the inner hull supporting the insulation system. It shall be ensured that the inner hull structure has the sufficient stiffness and strength to carry the sloshing loads. The hull structure assessment shall be carried out in two steps in order to make sure that:

.1 The stiffness of the inner hull plates is sufficient to provide adequate support for the containment system.
.2 The strength of the inner hull longitudinals (stiffeners) is sufficient to carry the sloshing loads without suffering large permanent deformations.

Procedures for such assessments are given in DNVGL-CG-0158, Sloshing analysis of LNG membrane tanks.

Guidance note:
Sloshing impact loads are mostly relevant for localised areas as knuckles and tank corners, e.g. in chamfer knuckles at transverse bulkheads. However, the extent of these areas will be increased if the normal filling restrictions recommended by the system designer have been relaxed.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
2.2.5 Connection area
Connection area of stiffeners shall be according to the rules Pt.3 Ch.6 Sec.7. The design pressure load $p$ may then be taken according to Sec.4 [3.3.2].

3 Finite element strength analysis for hull

3.1 Cargo hold analysis

3.1.1 Model extent
Cargo hold structural strength analysis is mandatory within the cargo area and shall include the aft bulkhead of the aftmost cargo hold and the collision bulkhead, of the forward hold. Longitudinal members and scarfing structures in the deck house between trunk deck and upper deck shall in addition be included in the evaluation along with longitudinal members and scarfing structures in engine room and the cargo area.

3.1.2 Loading conditions
The following loading conditions shall be examined:
— maximum draft with any cargo tank(s) empty
— minimum draft with any cargo tank full.
Both harbour and sea-going conditions, inclusive any sequential ballast exchange conditions, are to be reviewed.
The filling condition of the ballast tank under the considered tank should be taken into account.

3.1.3 Acceptance Criteria
Acceptance criteria for yielding are given in the Rules Pt.3 Ch.7 Sec.3 [4.2].
Acceptance criteria for buckling are given in the Rules Pt.3 Ch.8 Sec.1 [3.3].

3.2 Local fine mesh analysis

3.2.1 Locations to be checked
.1 double hull longitudinals with brackets subjected to large deformations.
   Fine mesh analysis is to be carried out for the connections of side and bottom longitudinal stiffeners and adjoining structures of the cofferdam bulkhead. The adjoining structures at the cofferdam bulkheads include the structural members in way of the bulkhead, the partial double side girders and bottom girders, if any.
   .2 other locations
   Additional locations may be required for fine mesh analysis in case the results of cargo hold analysis is not sufficient to judge the area, i.e due to the poor shape of element.

3.2.2 Acceptance criteria
Acceptance criteria for stress results for local structural analysis are given in Pt.3 Ch.7 Sec.4 [4.2].

4 Fatigue strength assessment

4.1 General

4.1.1 Fatigue analysis shall be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.
4.1.2 The fatigue calculations shall be carried out in accordance with Sec.4 [3.3.3], with relevant requirements depending on:

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

4.2 Fatigue assessment for hull

4.2.1 The ship hull shall be designed to satisfy a minimum design fatigue life of 25 years operation in worldwide environment according to Pt.3 Ch.9 Sec.1 with damage factor $C_W \leq 1.0$.

4.2.2 Plates in inner hull structures acting as supports for the membrane system where cracks along the plate boundaries can cause leakage into the insulation system, i.e. plate welds to stiffeners and frames/girders in the ballast tanks, shall be designed to satisfy a design fatigue life with $10^8$ wave encounters in North Atlantic operation.

4.2.3 Loading conditions
For fatigue assessment, the following two loading conditions shall normally be taken into account:
— fully loaded condition, departure
— normal ballast condition, departure.

4.2.4 Locations to be checked
The fatigue strength calculations shall be carried out for following locations as a minimum. Other locations subject to high dynamic stress and/or high stress concentration may be required for fatigue analysis by the Society.
— lower and upper hopper knuckle connections forming boundary of inner skin amidships
— inner bottom connection to transverse cofferdam bulkhead
— double hull side stringer connection to transverse cofferdam bulkhead
— liquid dome opening and coaming connection to deck, if applicable
— termination of aft end of no.1 inner longitudinal bulkhead, if applicable.

Special consideration regarding specified scope may be given for well proven detail designs.

4.3 Fatigue evaluation of membrane system

4.3.1 For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements in Sec.4 [4.3.3] .7 with $C_W \leq 0.5$.

4.3.2 Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in Sec.4 [4.3.3] .8, with $C_W \leq 0.5$.

4.3.3 Structural element not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in Sec.4 [4.3.3] .9, with $C_W \leq 0.1$.

Guidance note:
All non-inspectable failures that may lead to damage to the primary and secondary barrier, e.g. pump tower supports, should be analysed in accordance with [4.3.3].

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---
5 Accidental strength assessment

5.1 General

5.1.1 The containment system and the supporting hull structure shall be designed for the accidental loads specified in Sec.4 [3.5]. These loads need not be combined with each other or with environmental loads.

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

6 Testing

6.1 Design development testing

6.1.1 The design development testing required in [1.1.3] shall include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. This will culminate in the construction of a prototype scaled model of the complete cargo containment system. Testing conditions considered in the analytical and physical models shall represent the most extreme service conditions the cargo containment system will be likely to encounter over its life. Proposed acceptance criteria for periodic testing of secondary barriers required in Sec.4 [2.4.2] may be based on the results of testing carried out on the prototype-scaled model.

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

6.2 Testing for newbuilding

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

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

6.2.3 Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.
SECTION 24 OTHER CARGO TANK DESIGNS

1 Integral tanks

1.1 Design basis

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

.1 the design vapour pressure $P_0$ as defined in Sec.4 [1.1.2] shall normally not exceed 0.025 MPa. If the hull scantlings are increased accordingly, $P_0$ may be increased to a higher value, but less than 0.07 MPa.

.2 integral tanks may be used for products if the boiling point of the cargo is not below -10°C. A lower temperature may be accepted by the Society subject to special consideration, but in such cases a complete secondary barrier shall be provided.

.3 products required by Sec.19 to be carried in type 1G ships shall not be carried in integral tanks.

1.1.2 Tanks for cargoes with density below 1000 kg/m$^3$ shall as a minimum have scantlings based on the density of seawater.

Tanks for cargoes with density above 1000 kg/m$^3$, see Pt.3 Ch.4 Sec.6.

1.1.3 For materials other than normal strength steel, the minimum thickness requirements will be considered in each case.

1.2 Structural analysis

1.2.1 The structural analysis of integral tanks shall be in accordance with Pt.3 Ch.7.

1.2.2 Ultimate design condition, ULS

.1 The tank boundary scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as given in Sec.4 [3.3.2].

.2 For integral tanks, allowable stresses as given for hull structure in Pt.3 shall be applied.

1.2.3 Accidental design condition, ALS

.1 The tanks and the tank supports shall be designed for the accidental loads specified in Sec.4 [2.1.4].

.2 When subjected to the accidental loads specified in Sec.4 [3.5], the stress shall comply with the acceptance criteria specified in [1.2.2], modified as appropriate, taking into account their lower probability of occurrence.

1.3 Testing

1.3.1 All integral tanks shall be hydrostatically or hydro-pneumatically tested. The test shall be performed so that the stresses approximate, as far as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS.
2 Semi-membrane tanks

2.1 Design basis

2.1.1 Semi-membrane tanks are non-self-supporting tanks when in the loaded condition and consist of a layer, parts of which are supported through thermal insulation by the adjacent hull structure, whereas the rounded parts of this layer connecting the above-mentioned supported parts are designed also to accommodate thermal expansion and/or contraction as well as deformations due to the loads given in Pt.3 Ch.4.

2.1.2 The design vapour pressure $P_o$ shall not normally exceed 0.025 MPa. If the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting thermal insulation, $P_o$ may be increased to a higher value, but less than 0.07 MPa.

2.1.3 For semi-membrane tanks the relevant requirements in this section for independent tanks or for membrane tanks shall be applied as appropriate.

2.1.4 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 Sec.4 [3.3.2].

2.1.5 In the case of semi-membrane tanks that comply in all respects with the requirements applicable to type B independent tanks, except for the type of support, the Society may accept a partial secondary barrier on a case by case basis.

3 Cargo containment systems of novel configuration

3.1 Limit state design for novel concepts

3.1.1 Application
Cargo containment systems that are of a novel configuration that cannot be designed using Sec.20 to [2] shall be designed using this sub section and Sec.4, as applicable. Cargo containment system design according to this sub section shall be based on the principles of limit state design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed using Sec.20 to [2].

3.1.2 Limit states
.1 Limit state designs is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in Sec.4 [2.1.4]. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the requirements.

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

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

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

.3 accident limit states (ALS), which concern the ability of the structure to resist accidental situations.
3.1.3 The procedure and relevant design parameters of the limit state design shall comply with the Standard for the Use of limit state methodologies in the design of cargo containment systems of novel configuration (LSD Standard), as set out in App.B.
APPENDIX A NON-METALLIC MATERIALS

1 General

1.1 General

1.1.1 The guidance given in this appendix is in addition to the requirements of Sec.4 [5.1.1], where applicable to non-metallic materials.

1.1.2 The manufacture, testing, inspection and documentation of non-metallic materials should in general comply with recognized standards, and with the specific requirements in the rules, as applicable.

1.1.3 When selecting a non-metallic material, the designer should ensure that it has properties appropriate to the analysis and specification of the system requirements. A material can be selected to fulfil one or more requirements.

A wide range of non-metallic materials may be considered. Therefore, the section below on material selection criteria cannot cover every possibility and should be considered as guidance.

2 Material selection criteria

2.1 Non-metallic materials

2.1.1 Non-metallic materials may be selected for use in various parts of liquefied gas carrier cargo systems based on consideration of the following basic properties:

- insulation - the ability to limit heat flow
- load bearing - the ability to contribute to the strength of the containment system
- tightness - the ability to provide liquid and vapour tight barriers
- joining - the ability to be joined, e.g. by bonding, welding or fastening.

2.1.2 Additional considerations may apply depending on the specific system design.

3 Property of materials

3.1 General

3.1.1 Flexibility of insulating material is the ability of an insulating material to be bent or shaped easily without damage or breakage.

3.1.2 Loose fill material is a homogeneous solid generally in the form of fine particles, such as a powder or beads, normally used to fill the voids in an inaccessible space to provide an effective insulation.

3.1.3 Nanomaterial is a material with properties derived from its specific microscopic structure.

3.1.4 Cellular material is a material type containing cells that are either open, closed or both and which are dispersed throughout its mass.

3.1.5 Adhesive material is a product that joins or bonds two adjacent surfaces together by an adhesive process.
3.1.6 Other materials are materials that are not characterized in this section of the Code and should be identified and listed. The relevant tests used to evaluate the suitability of material for use in the cargo system should be identified and documented.

4 Material selection and testing requirements

4.1 Material specification

4.1.1 When the initial selection of a material has been made, tests should be conducted to validate the suitability of this material for the use intended.

4.1.2 The material used should clearly be identified and the relevant tests should be fully documented.

4.1.3 Materials should be selected according to their intended use. They should:

1. be compatible with all the products that may be carried
2. not be contaminated by any cargo nor react with it
3. not have any characteristics or properties affected by the cargo, and
4. be capable to withstand thermal shocks within the operating temperature range.

4.2 Material testing

4.2.1 The tests required for a particular material depend on the design analysis, specification and intended duty. The list of tests below is for illustration. Any additional tests required, for example in respect of sliding, damping and galvanic insulation, should be identified clearly and documented. Materials selected according to [4.1] of this appendix should be tested further according to the following:

<table>
<thead>
<tr>
<th>Function</th>
<th>Insulation</th>
<th>Load bearing structural</th>
<th>Tightness</th>
<th>Joining</th>
</tr>
</thead>
<tbody>
<tr>
<td>mechanical tests</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>tightness tests</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>thermal tests</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thermal shock testing should submit the material and/or assembly to the most extreme thermal gradient it will experience when in service.

4.2.2 Inherent properties of materials

1. Tests should be carried out to ensure that the inherent properties of the material selected will not have any negative impact in respect of the use intended.

2. For all selected materials, the following properties should be evaluated:

   1. density - example standard ISO 845
   2. linear coefficient of thermal expansion (LCTE) - example standard ISO 11359 across the widest specified operating temperature range. However, for loose fill material the volumetric coefficient of thermal expansion (VCTE) should be evaluated, as this is more relevant.
   3. Irrespective of its inherent properties and intended duty, all materials selected should be tested for the design service temperature range down to 5°C below the minimum design temperature, but not lower than -196°C.
   4. Each property evaluation test should be performed in accordance with recognized standards. Where there are no such standards, the test procedure proposed should be fully detailed and submitted to the
Society for acceptance. Sampling should be sufficient to ensure a true representation of the properties of the material selected.

4.2.3 Mechanical tests

1. The mechanical tests should be performed in accordance with the following:

<table>
<thead>
<tr>
<th>Mechanical tests</th>
<th>Load bearing structural</th>
</tr>
</thead>
<tbody>
<tr>
<td>tensile</td>
<td>ISO 527</td>
</tr>
<tr>
<td></td>
<td>ISO 1421</td>
</tr>
<tr>
<td></td>
<td>ISO 3346</td>
</tr>
<tr>
<td></td>
<td>ISO 1926</td>
</tr>
<tr>
<td>shearing</td>
<td>ISO 4587</td>
</tr>
<tr>
<td></td>
<td>ISO 3347</td>
</tr>
<tr>
<td></td>
<td>ISO 1922</td>
</tr>
<tr>
<td></td>
<td>ISO 6237</td>
</tr>
<tr>
<td>compressive</td>
<td>ISO 604</td>
</tr>
<tr>
<td></td>
<td>ISO 844</td>
</tr>
<tr>
<td></td>
<td>ISO 3132</td>
</tr>
<tr>
<td>bending</td>
<td>ISO 3133</td>
</tr>
<tr>
<td></td>
<td>ISO 14679</td>
</tr>
<tr>
<td>creep</td>
<td>ISO 7850</td>
</tr>
</tbody>
</table>

2. If the chosen function for a material relies on particular properties such as tensile, compressive and shear strength, yield stress, modulus or elongation, these properties should be tested to a recognized standard. If the properties required are assessed by numerical simulation according to a high order behaviour law, the testing should be performed to the satisfaction of the Society.

3. Creep may be caused by sustained loads, for example cargo pressure or structural loads. Creep testing should be conducted based on the loads expected to be encountered during the design life of the containment system.

4.2.4 Tightness tests

1. The tightness requirement for the material should relate to its operational functionality.

2. Tightness tests should be conducted to give a measurement of the material's permeability in the configuration corresponding to the application envisaged, e.g. thickness and stress conditions using the fluid to be retained, e.g. cargo, water vapour or trace gas.

3. The tightness tests should be based on the tests indicated as examples in the following:

<table>
<thead>
<tr>
<th>Tightness tests</th>
<th>Tightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>porosity/permeability</td>
<td>ISO 15106</td>
</tr>
<tr>
<td></td>
<td>ISO 2528</td>
</tr>
<tr>
<td></td>
<td>ISO 2782</td>
</tr>
</tbody>
</table>

4.2.5 Thermal conductivity tests

1. Thermal conductivity tests should be representative of the lifecycle of the insulation material so its properties over the design life of the cargo system can be assessed. If these properties are likely to deteriorate over time, the material should be aged as best possible in an environment corresponding to its lifecycle, for example operating temperature, light, vapour and installation, e.g. packaging, bags, boxes.
.2 Requirements for the absolute value and acceptable range of thermal conductivity and heat capacity should be chosen taking into account the effect on the operational efficiency of the cargo containment system. Particular attention should also be paid to the sizing of the associated cargo handling system and components such as safety relief valves plus vapour return and handling equipment.

.3 Thermal tests should be based on the tests indicated as examples in the following or their equivalents:

<table>
<thead>
<tr>
<th>Thermal tests</th>
<th>Insulating</th>
</tr>
</thead>
<tbody>
<tr>
<td>thermal conductivity</td>
<td>ISO 8301</td>
</tr>
<tr>
<td></td>
<td>ISO 8302</td>
</tr>
<tr>
<td>heat capacity</td>
<td>x</td>
</tr>
</tbody>
</table>

4.2.6 Physical tests

.1 In addition to the requirements of Sec.4 [5.1.2].3 and Sec.4 [5.1.3].2 guidance and information on some of the additional physical tests that may be considered are listed as follows:

<table>
<thead>
<tr>
<th>Physical tests</th>
<th>Flexible insulating</th>
<th>Loose fill</th>
<th>Nano-material</th>
<th>Cellular</th>
<th>Adhesive</th>
</tr>
</thead>
<tbody>
<tr>
<td>particle size</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>closed cells content</td>
<td></td>
<td></td>
<td>ISO 4590</td>
<td></td>
<td></td>
</tr>
<tr>
<td>absorption/desorption</td>
<td>ISO 12571</td>
<td>X</td>
<td>ISO 2896</td>
<td></td>
<td></td>
</tr>
<tr>
<td>absorption/desorption</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>viscosity</td>
<td></td>
<td>ISO 2555</td>
<td>ISO 2431</td>
<td></td>
<td></td>
</tr>
<tr>
<td>open time</td>
<td></td>
<td></td>
<td>ISO 10364</td>
<td></td>
<td></td>
</tr>
<tr>
<td>thixotropic properties</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>ISO 868</td>
</tr>
</tbody>
</table>

.2 Requirements for loose fill material segregation should be chosen considering its potential adverse effect on the material properties as density and thermal conductivity, when subjected to environmental variations such as thermal cycling and vibration.

.3 Requirements for materials with closed cell structures should be based on its possible impact on gas flow and buffering capacity during transient thermal phases.

.4 Similarly, adsorption and absorption requirements should take into account the potential adverse effect an uncontrolled buffering of liquid or gas may have on the system.

5 Quality assurance and quality control (QA/QC)

5.1 General

5.1.1 Once a material has been selected, after testing as outlined in section 4 of this appendix, a detailed quality assurance/quality control (QA/QC) programme should be applied to ensure the continued conformity of the material during installation and service. This programme should consider the material starting from the manufacturer’s quality manual (QM) and then follow it throughout the construction of the cargo system.

5.1.2 The QA/QC programme should include the procedure for fabrication, storage, handling and preventive actions to guard against exposure of a material to harmful effects. These may include, for example, the effect of sunlight on some insulation materials or the contamination of material surfaces by contact with personal...
products such as hand creams. The sampling methods and the frequency of testing in the QA/QC programme should be specified to ensure the continued conformity of the material selected throughout its production and installation.

5.1.3 Where powder or granulated insulation is produced, arrangements should be made to prevent compacting of the material due to vibrations.

5.2 QA/QC during component manufacture

The QA/QC programme in respect of component manufacture should include, as a minimum but not limited to, the following items.

5.2.1 Component identification

.1 For each material, the manufacturer should implement a marking system to clearly identify the production batch. The marking system should not interfere, in any way, with the properties of the product.

.2 The marking system should ensure complete traceability of the component and should include:

.1 date of production and potential expiry date
.2 manufacturer’s references
.3 reference specification
.4 reference order, and
.5 when necessary, any potential environmental parameters to be maintained during transportation and storage.

5.2.2 Production sampling and audit method

.1 Regular sampling is required during production to ensure the quality level and continued conformity of a selected material.

.2 The frequency, the method and the tests to be performed should be defined in QA/QC programme; for example, these tests will usually cover, inter alia, raw materials, process parameters and component checks.

.3 Process parameters and results of the production QC tests should be in strict accordance with those detailed in the QM for the material selected.

.4 The objective of the audit method as described in the QM is to control the repeatability of the process and the efficacy of the QA/QC programme.

.5 During auditing, auditors should be provided with free access to all production and QC areas. Audit results should be in accordance with the values and tolerances as stated in the relevant QM.

6 Bonding and joining process requirement and testing

6.1 Bonding procedure qualification

6.1.1 The bonding procedure specification and qualification test should be defined in accordance with recognized standards.

6.1.2 The bonding procedures should be fully documented before work commences to ensure the properties of the bond are acceptable.

6.1.3 The following parameters should be considered when developing a bonding procedure specification:

.1 surface preparation
.2 materials storage and handling prior to installation
.3 covering-time
6.1.4 Additional requirements may be included as necessary to ensure acceptable results.

6.1.5 The bonding procedures specification should be validated by an appropriate procedure qualification testing programme.

6.2 Personnel qualifications

6.2.1 Personnel involved in bonding processes should be trained and qualified to recognized standards.

6.2.2 Regular tests should be made to ensure the continued performance of people carrying out bonding operations to ensure a consistent quality of bonding.

7 Production bonding tests and controls

7.1 Destructive testing

During production, representative samples should be taken and tested to check that they correspond to the required level of strength as required for the design.

7.2 Non-destructive testing

7.2.1 During production, tests which are not detrimental to bond integrity should be performed using an appropriate technique such as:

.1 visual examination
.2 internal defects detection, e.g. acoustic, ultrasonic and shear test, and
.3 local tightness testing.

7.2.2 If the bonds have to provide tightness as part of their design function, a global tightness test of the cargo containment system should be completed after the end of the erection in accordance with the designer’s and QA/QC programme.

7.2.3 The QA/QC standards should include acceptance standards for the tightness of the bonded components when built and during the lifecycle of the containment system.
APPENDIX B STANDARD FOR THE USE OF LIMIT STATE METHODOLOGIES IN THE DESIGN OF CARGO CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION

1 General

1.1 General

1.1.1 Purpose
The purpose of this standard is to provide procedures and relevant design parameters of limit state design of cargo containment systems of a novel configuration in accordance with Sec.24 [3].

1.1.2 Limit state design
Limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in Sec.4 [2.1.4]. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the requirements.

1.1.3 Limit states
The limit states are divided into the three following categories:

.1 Ultimate Limit States (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain, deformation or instability in structure resulting from buckling and plastic collapse - under intact (undamaged) conditions

.2 Fatigue Limit States (FLS), which correspond to degradation due to the effect of cyclic loading, and

.3 Accident Limit States (ALS), which concern the ability of the structure to resist accident situations.

1.1.4 Compliance
Sec.4 and Sec.20 through Sec.24 [2] shall be complied with as applicable depending on the cargo containment system concept.

2 Design format

2.1 Design procedure

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

$$L_d \leq R_d$$

A design load $F_{dk}$ is obtained by multiplying the characteristic load by a load factor relevant for the given load category:

$$F_{dk} = \gamma_f \cdot F_k$$

where
γ_f is load factor, and

F_k is the characteristic load as specified in Sec.4 [3] and Sec.4 [4].

A design load effect L_d (e.g., stresses, strains, displacements and vibrations) is the most unfavourable combined load effect derived from the design loads, and may be expressed by:

\[ L_d = q(F_{d1}, F_{d2}, ..., F_{dN}) \]

where q denotes the functional relationship between load and load effect determined by structural analyses.

The design resistance \( R_d \) is determined as follows:

\[ R_d = \frac{R_k}{\gamma_R \cdot \gamma_C} \]

where

- \( R_k \) is the characteristic resistance. In case of materials covered by Chapter 6 of this Code, it may be, but not limited to, specified minimum yield stress, specified minimum tensile strength, plastic resistance of cross sections, and ultimate buckling strength
- \( \gamma_R \) is the resistance factor, defined as \( \gamma_R = \gamma_m \cdot \gamma_s \)
- \( \gamma_m \) is the partial resistance factor to take account of the probabilistic distribution of the material properties (material factor)
- \( \gamma_s \) is the partial resistance factor to take account of the uncertainties on the capacity of the structure, such as the quality of the construction, method considered for determination of the capacity including accuracy of analysis, and
- \( \gamma_C \) is the consequence class factor, which accounts for the potential results of failure with regard to release of cargo and possible human injury.

### 2.1.2 Consequence classes

Cargo containment design shall take into account potential failure consequences. Consequence classes are defined in Table 1, to specify the consequences of failure when the mode of failure is related to the ultimate limit state, the fatigue limit state, or the accident limit state.

<table>
<thead>
<tr>
<th>Consequence class</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>low</td>
<td>failure implies minor release of the cargo</td>
</tr>
<tr>
<td>medium</td>
<td>failure implies release of the cargo and potential for human injury</td>
</tr>
<tr>
<td>high</td>
<td>failure implies significant release of the cargo and high potential for human injury/fatality.</td>
</tr>
</tbody>
</table>
3 Required analyses

3.1 General

3.1.1 Analysis requirements
Three dimensional finite element analyses shall be carried out as an integrated model of the tank and the ship hull, including supports and keying system as applicable. All the failure modes shall be identified to avoid unexpected failures. Hydrodynamic analyses shall be carried out to determine the particular ship accelerations and motions in irregular waves and the response of the ship and its cargo containment systems to these forces and motions.

3.1.2 Buckling strength
Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with Pt.3 Ch.8 or equivalent, e.g. Appendix 4 in CN Spherical. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate out of flatness, plate edge misalignment, straightness, ovality and deviation from true circular form over a specified arc or chord length, as relevant.

3.1.3 Fatigue analysis
Fatigue and crack propagation analysis shall be carried out in accordance with [5] below.

4 Ultimate limit state

4.1 Design procedure for ULS design

4.1.1 Determination of structural resistance
Structural resistance may be established by testing or by complete analysis taking account of both elastic and plastic material properties. Safety margins for ultimate strength shall be introduced by partial factors of safety taking account of the contribution of stochastic nature of loads and resistance considering dynamic loads, pressure loads, gravity loads, material strength, and buckling capacities.

4.1.2 Load combinations and load factors
Appropriate combinations of permanent loads, functional loads and environmental loads including sloshing loads shall be considered in the analysis. At least two load combinations with partial load factors as given in Table 2 shall be used for the assessment of the ultimate limit states.

Table 2 Partial load factors

<table>
<thead>
<tr>
<th>Load combination</th>
<th>Permanent loads</th>
<th>Functional loads</th>
<th>Environmental loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>'a'</td>
<td>1.1</td>
<td>1.1</td>
<td>0.7</td>
</tr>
<tr>
<td>'b'</td>
<td>1.0</td>
<td>1.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

The load factors for permanent and functional loads in load combination 'a' are relevant for the normally well-controlled and/or specified loads applicable to cargo containment systems such as vapour pressure, cargo weight, system self-weight, etc. Higher load factors may be relevant for permanent and functional loads where the inherent variability and/or uncertainties in the prediction models are higher.
4.1.3 Load factors for sloshing
For sloshing loads, depending on the reliability of the estimation method, a larger load factor may be required by the Society.

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

4.1.5 Safety level equivalence
The load factors and the resistance factors used shall be such that the level of safety is equivalent to that of the cargo containment systems as described in Sec.20 through Sec.24[2]. This may be carried out by calibrating the factors against known successful designs.

4.1.6 Material factors
The material factor $\gamma_m$ shall in general reflect the statistical distribution of the mechanical properties of the material, and needs to be interpreted in combination with the specified characteristic mechanical properties. For the materials defined in Sec.6, the material factor $\gamma_m$ may be taken as:

1) when the characteristic mechanical properties specified by the Society typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties, or
2) when the characteristic mechanical properties specified by the Society represents a sufficiently small quantile such that the probability of lower mechanical properties than specified is extremely low and can be neglected.

4.1.7 Resistance factors
The partial resistance factors $\gamma_{sl}$ shall in general be established based on the uncertainties in the capacity of the structure considering construction tolerances, quality of construction, the accuracy of the analysis method applied, etc.

4.1.8 Resistance factors for plastic deformation
For design against excessive plastic deformation using the limit state criteria given in [4.1.9], the partial resistance factors $\gamma_{sl}$ shall be taken as follows:

$$\gamma_{s1} = 0.76 \cdot \frac{B}{\kappa_1}$$

$$\gamma_{s2} = 0.76 \cdot \frac{D}{\kappa_2}$$

$$\kappa_1 = \min \left( \frac{R_m}{R_e \cdot A}, 1.0 \right)$$
\[ \kappa_2 = \text{Min} \left( \frac{R_m}{R_{eH}} \cdot \frac{D}{C} : 1.0 \right) \]

Factors \( A, B, C \) and \( D \) are defined in Sec.20 Table 2 and Sec.21 Table 1. \( R_m \) and \( R_{eH} \) are defined in Sec.1. The partial resistance factors given above are the results of calibration to conventional type B independent tanks.

4.1.9 Design against excessive plastic deformation

.1 Stress response reference

Stress acceptance criteria given below refer to elastic stress analyses.

.2 Parts with predominating membrane response

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

\[ \sigma_m \leq f \]

\[ \sigma_L \leq 1.5f \]

\[ \sigma_b \leq 1.5f \]

\[ \sigma_m + \sigma_b \leq 1.5f \]

\[ \sigma_m + \sigma_b \leq 1.5f \]

\[ \sigma_m + \sigma_b + \sigma_g \leq 3.0f \]

\[ \sigma_L + \sigma_b + \sigma_g \leq 3.0f \]

where

\[ \sigma_m = \text{equivalent von Mises primary general membrane stress in N/mm}^2 \]

\[ \sigma_L = \text{equivalent von Mises primary local membrane stress in N/mm}^2 \]

\[ \sigma_b = \text{equivalent von Mises primary bending stress in N/mm}^2 \]

\[ \sigma_g = \text{equivalent von Mises secondary stress in N/mm}^2 \]

\[ f = \frac{R_{eH}}{\gamma_{s1}'m'y_c} \]
With regard to the stresses $\sigma_m$, $\sigma_L$, $\sigma_b$ and $\sigma_g$, see also the definition of stress categories in Sec.4 [6.1.3].

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

$$
\sigma_L + \sigma_b = \sqrt{(\sigma_{Lx} + \sigma_{bx})^2 - (\sigma_{Lx} + \sigma_{bx})(\sigma_{Ly} + \sigma_{by}) + (\sigma_{Ly} + \sigma_{by})^2 + 3(\tau_{Lxy} + \tau_{bxy})^2}
$$

---end---of---guidance---note---

.3 **Parts with predominating bending response**

Parts of cargo containment systems where loads are primarily carried by bending of girders, stiffeners and plates, shall satisfy the following limit state criteria:

$$
\sigma_{ms} + \sigma_{bp} \leq 1.25F \quad \text{(See note 1, 2)}
$$

$$
\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \leq 1.25F \quad \text{(See note 2)}
$$

$$
\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_g \leq 3F
$$

**Guidance note:**
The sum of equivalent section membrane stress and equivalent membrane stress in primary structure ($\sigma_{ms} + \sigma_{bp}$) will normally be directly available from three-dimensional finite element analyses.

---end---of---guidance---note---

**Guidance note:**
The coefficient, 1.25, may be modified by the Society considering the design concept, configuration of the structure, and the methodology used for calculation of stresses.

---end---of---guidance---note---

where

- $\sigma_{ms} = \text{equivalent von Mises section membrane stress in primary structure in N/mm}^2$
- $\sigma_{bp} = \text{equivalent von Mises membrane stress in primary structure and stress in secondary (stiffener) and tertiary (plating) structure caused by bending of primary structure}$
- $\sigma_{bs} = \text{equivalent von Mises section bending stress in secondary structure (stiffener) and stress in tertiary structure (plating) caused by bending of secondary structure (stiffener) in N/mm}^2$
- $\sigma_{bt} = \text{equivalent von Mises section bending stress in tertiary structure, i.e. plate bending stress in N/mm}^2$
- $\sigma_g = \text{equivalent von Mises secondary stress in N/mm}^2$

$$
f = \frac{R_{eH}}{\gamma_s \gamma_m \gamma_c}
$$
Guidance note:
The stress summation described above should be carried out by summing up each stress component ($\sigma_x, \sigma_y, \tau_{xy}$), and subsequently the equivalent stress shall be calculated based on the resulting stress components.

---end---of---guidance---note---

The stresses $\sigma_{ms}, \sigma_{bp}, \sigma_{bs}$, and $\sigma_{bt}$ are defined in [4.1.9]. For a definition of $\sigma_g$, see Sec.4 [6.1.3].

Skin plates shall be designed in accordance with the requirements of the Administration or recognized organization acting on its behalf. When membrane stress is significant, the effect of the membrane stress on the plate bending capacity shall be appropriately considered in addition.

Section stress categories

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

Equivalent section membrane stress is the component of the normal stress that is uniformly distributed and equal to the average value of the stress across the cross section of the structure under consideration. If this is a simple shell section, the section membrane stress is identical to the membrane stress defined in paragraph [4.1.9].2.

Section bending stress is the component of the normal stress that is linearly distributed over a structural section exposed to bending action, as illustrated in Figure 1.

Figure 1 Definition of the three categories of section stress (Stresses $\sigma_{bp}$ and $\sigma_{bs}$ are normal to the cross section showed)

4.1.10 Resistance factors for buckling

The same factors $\gamma_C$, $\gamma_m$, $\gamma_s$ shall be used for design against buckling unless otherwise stated in the applied recognised buckling standard. In any case the overall level of safety shall not be less than given by these factors.

5 Fatigue limit states
5.1 Design procedure for FLS design

5.1.1 Fatigue design condition as described in Sec.4 [4.3.3] shall be complied with as applicable depending on the cargo containment system concept. Fatigue analysis is required for the cargo containment system designed under Sec.24 [3].

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

5.1.3 Consequence class factor $\gamma_C$ and resistance factor $\gamma_R$ shall be taken as 1.0.

5.1.4 Fatigue damage shall be calculated as described in Sec.4 [4.3.3].2-9 The calculated cumulative fatigue damage ratio for the cargo containment systems shall be less than or equal to the values given in Table 3.

Table 3 Maximum allowable cumulative fatigue damage ratio

<table>
<thead>
<tr>
<th>Cw</th>
<th>low</th>
<th>medium</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

1) Lower value shall be used in accordance with Sec.4 [4.3.3].7 to Sec.4 [4.3.3].9, depending on the detectability of defect or crack, etc.

5.1.5 Lower values may be fixed by the Society, for example for tank structures where effective detection of defect or crack cannot be assured, and for ships carrying more hazardous cargo.

5.1.6 Crack propagation analyses are required in accordance with Sec.4 [4.3.3].6 to Sec.4 [4.3.3].9. The analysis shall be carried out in accordance with methods laid down in a standard recognized by the Society.

6 Accident Limit States

6.1 Design procedure for ALS

6.1.1 Accident design condition as described in Sec.4 [4.3.4] shall be complied with as applicable, depending on the cargo containment system concept.

6.1.2 Load and resistance factors may be relaxed compared to the ultimate limit state considering that damages and deformations can be accepted as long as this does not escalate the accident scenario.

6.1.3 The load factors for ALS shall be taken as 1.0 for permanent loads, functional loads and environmental loads.

6.1.4 Loads mentioned in Sec.4 [3.3.9] (Static heel loads) and Sec.4 [3.5] (Collision and Loads due to flooding on ship) of this Code need not be combined with each other or with environmental loads, as defined in Sec.4 [3.4].

6.1.5 Resistance factor $\gamma_R$ shall in general be taken as 1.0.

6.1.6 Consequence class factors $\gamma_C$ shall in general be taken as defined in [4.1.4], but may be relaxed considering the nature of the accident scenario.
6.1.7 The characteristic resistance $R_k$ shall in general be taken as for the ultimate limit state, but may be relaxed considering the nature of the accident scenario.

6.1.8 Additional relevant accident scenarios shall be determined based on a risk analysis.
7 Testing

7.1 Testing requirements

7.1.1 Cargo containment systems designed according to this standard shall be tested to the same extent as described in Sec.4 [5.2.3], as applicable depending on the cargo containment system concept.
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