

Rules for Classification and Construction

I Ship Technology

1 Seagoing Ships



6 Liquefied Gas Carriers

The following Rules come into force on 1 July 2008.

Alterations to the preceding Edition are marked by beams at the text margin.

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Section 1

General, Character of Classification, Definitions, Surveys and Certification

A. General

1. These Rules apply to ships having their machinery aft and built for the carriage in bulk of liquefied gases and some other products which are listed in [Section 19](#).

2. In addition to these Rules the relevant requirements of Part 0 - Rules for Classification and Surveys and the relevant requirements of Chapter 1 – Hull Structures, Sections 1 through 22 and 24 apply.

3. For the machinery, the electrical plant and the refrigerating installation of these ships, the Chapters 2 – Machinery Installations, 3 – Electrical Installations and 4 – Automation apply.

4. The Rules of this Chapter incorporate the IMO-Resolution MSC.5(48) "International Code for the Construction and Equipment of Ships carrying liquefied Gases in Bulk" (IGC-Code), 1993 edition, as amended.

5. Certain requirements of the IGC-Code that are not within the scope of classification, e.g. para. 6. "Equivalents", [Section 14](#), "Personnel Protection", certain operational requirements in [Section 17](#) "Special Requirements" and [Section 18](#) "Operating Requirements" have been included in these rules.

Except for para. 6. and for operational requirements as mentioned above they will, however, be applied in such instances where

- .1 the Society is authorized by Administrations to issue on their behalf the "Certificate of Fitness for the Carriage of Liquefied Gases in Bulk" or where
- .2 the Society is authorized to carry out investigations and surveys on behalf of Administrations on the basis of which the "Certificate of Fitness for the Carriage of Liquefied Gases in Bulk" will be issued by the Administrations, or where
- .3 the Society is requested to certify compliance with the IGC-Code.

The term "should be" in the respective Paras or Sections is in such cases to be read as "is" or "are to be". Operating Requirements have been included for guidance only and will not be looked at by the Society.

Specific requirements of the Society which are additional to the provisions of the IGC-Code as well as interpretations of some Code requirements have been identified by a special para. No. (e.g. 4.2-0.2) and by a thin vertical line.

Alterations to the preceding Edition are marked by a thicker beam.

Differing from the standard construction of the Rules, which is given in this Section 1, Sections 2 – 19 for direct comparison with the IGC-Code are arranged accordingly.

6. Equivalents

6.4 Where the IGC-Code requires that a particular fitting, material, appliance, apparatus, item of equipment or type thereof should be fitted or carried in a ship, or that any particular provision should be made, or any procedure or arrangement should be complied with, the Administration may allow any other fitting, material, appliance, apparatus, item of equipment or type thereof to be fitted or carried, or any other provision, procedure or arrangement to be made in that ship, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance apparatus, item of equipment or type thereof or that any particular provision, procedure or arrangement is at least as effective as that required by the IGC-Code. However, the Administration may not allow operational methods or procedures to be made an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by the IGC-Code.

6.5 When an Administration so allows any fitting, material, appliance, apparatus, item of equipment, or type thereof, or provision, procedure or arrangement to be substituted, it should communicate to the Organization the particulars thereof together with a report on the evidence submitted, so that the Organization may circulate the same to other Contracting Governments to the **1974 SOLAS Convention** for the information of their officers.

7. Application of the IGC-Code

7.1 The IGC-Code applies to ships regardless of their size, including those of less than 500 gross tonnage, engaged in carriage of liquefied gases having a vapour pressure exceeding 2,8 bar absolute at a tem-

perature of 37,8 °C, and other products as shown in Chapter 19² of the IGC-Code, when carried in bulk.

7.2 Unless expressly provided otherwise, the IGC-Code applies to ships the keels of which are (were) laid or which are (were) at a stage at which:

- .1** construction identifiable with the ship begins; and
- .2** assembly of that ship has commenced comprising at least 50 tonnes or 1 % of the estimated mass of all structural material whichever is less;

on or after 1 July 1998. Ships constructed before 1 July 1998 are to comply with resolution MSC.5 (48) adopted on 17 June 1983 subject to amendments by resolution MSC.30 (61) adopted on 11 December 1992.

7.3 A ship, irrespective of the date of construction, which is converted to a gas carrier on or after July 1st, 1998 shall be treated as a gas carrier constructed on the date on which such conversion commences.

7.4 When cargo tanks contain products for which the IGC-Code requires a type 1G-ship, neither flammable liquids having a flashpoint of 60 °C (closed cup test) or less nor flammable products listed in Chapter 19¹ of the IGC-Code shall be carried in tanks located within the protective zones described in 2.6.1.1.

Similarly, when cargo tanks contain products for which the IGC-Code requires a type 2G/2PG-ship, the above mentioned flammable liquids shall not be carried in tanks located within the protective zones described in 2.6.1.2.

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

The above mentioned flammable liquids and products may be carried within these protective zones, when the quantity retained in the cargo tanks of products for which the IGC-Code requires a type 1G or 2G/2PG-ship is solely used for cooling, circulation or fuelling purposes.

7.5 Except as provided in 7.7.1, when it is intended to carry products covered by the IGC-Code and products covered by the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, IMO-Resolution MSC.4(48), (IBC-Code), as may be amended by the Organization, the ship shall comply with the require-

ments of both Codes appropriate to the products carried.

7.6 Where it is proposed to carry products which may be considered to come within the scope of the Code but are not at present designated in Chapter 19 of the Code², the Administrations and the Port Administrations involved in such carriage shall establish suitable conditions of carriage based on the principles of the Code and notify the Organization of such conditions.

7.7.1 The requirements of the IGC-Code should take precedence when a ship is designed and constructed for the carriage of the following products:

- .1** those listed exclusively in [Section 19](#) of this Chapter¹; and
- .2** one or more of the products which are listed both in Section 19 of this Chapter¹ and in [Section 17 of Chapter 7 – Chemical Tankers](#)². These products are marked with an asterisk (*) in column "a" of Section 19.

7.7.2 When a ship is intended exclusively to carry one or more of the products noted in 7.7.1.2 the requirements of Chapter 7 – Chemical Tankers, i.e. those of the IBC-Code as amended shall apply.

7.8 Compliance of the ship with the requirements of the International Gas Carrier Code shall be shown in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk. Compliance with the amendments to the Code, as appropriate, should also be indicated in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

8. Hazards

Hazards of gases considered in the IGC-Code include fire, toxicity, corrosivity, reactivity, low temperature and pressure.

B. Character of Classification, Entries into the Class Certificate, Documents for Approval

1. Character of Classification

1.1 Ships complying with the requirements of these Rules will have the Notation:

LIQUEFIED GAS CARRIER

affixed to the Character of Classification.

¹ Chapter 19 of the IGC-Code corresponds to Section 19 of this Chapter.

² Chapter 17 of the IBC-Code corresponds to Section 17 of Chapter 7 – Chemical Tankers.

1.2 Liquefied gas carriers will be assigned the symbol $\square$ before the Character of Classification for characterizing proof of damage stability according to the IGC-Code ([Section 2](#)) and after the Character of Classification the relevant ship type notation (Type 1 G, 2 G, 2 PG or 3 G). The following data will be entered into an appendix to the Certificate:

- .1** Five digit code for the specification of the proof of damage stability according to Part 0 – Classification and Surveys, Section 2, C.2.4.2.
- .2** Description of the code.

1.3 Liquefied gas carriers equipped with cargo refrigeration system according to [Section 7.2](#) will have the notation **RI** affixed to the Character of Classification for the machinery plant.

1.4 For liquefied gas carriers a list stating the products permitted to be carried will be issued as an annex to the IMO Certificate of Fitness ³.

2. Documents for approval

2.1 Apart from the documents listed in [Chapter 1 – Hull Structures, Section 1, G.](#), the following documents are to be submitted in triplicate:

- .1** general arrangement plan,
- .2** data on the location and capacity of cargo tanks and products to be carried,
- .3** scantlings and stress analysis of cargo tanks and secondary barrier, if any,
- .4** data of the foundations and the fastening of the cargo tanks and relevant stress analysis,
- .5** calculation of the lowest temperatures of the hull structure considering the insulation according to [4.8](#) with data on the material selection for the hull,
- .6** data on the ship's ballast condition,
- .7** damage stability calculations ⁴ if this Society is acting in accordance with [A.5.1](#) to .3.
- .8** drawings showing the arrangement of access and inspection openings for compliance with the requirements in Section 3.5 (in particular double bottom and double hull)

2.2 Apart from the documents listed in [Chapter 2 – Machinery Installations, Section 15, A.3.](#) the following documents are to be submitted in triplicate:

- .1** plans of cargo piping, arrangement of cargo pumps and their drives,
- .2** plans and calculations of process pressure vessels, valves,
- .3** plans of gas or vapour pipes of the safety relief valves,
- .5** plans and calculation of the safety relief valves,
- .6** plans of fire extinguishing in the cargo area,
- .7** plans of bilge and ballast arrangements in the cargo area,
- .8** data on gas-freeing of the cargo containment system, including data on the inert gas plant with assembly and piping plans,
- .9** plans for the ventilation of spaces within the cargo area,
- .10** data on the gas detection system for the various substances to be transported,
- .11** data on the instrumentation of cargo tanks as per [Section 13](#) and data on the temperature monitoring of the hull structure, if required,
- .12** description of cargo handling operations,
- .13** data on the insulation and proof of its suitability. Proof of sufficient thermal insulation. Calculation of the boil-off rate for the lay-out of the refrigeration plant, if any,
- .14** wiring plan including data on certified safe type equipment in gas dangerous spaces and zones,
- .15** For machinery using gas as fuel:
 - general arrangement plan of the machinery plant,
 - gas piping plans for the machinery plant,
 - complete list of the safety, gas detection and warning equipment,
 - drawings of the internal combustion engines,
 - drawings of the boilers,
 - drawings of the gas turbines,
 - detail drawings of the gas inlet and fuel inlet equipment,

³ This product list will be made available to the Administration whose flag the ship is entitled.

⁴ A GL-computer program may be used for these calculations.

- gas characteristics,
- general arrangement plan of the gas treatment plant, including gas compressors, prime movers and gas preheaters,
- drawings of the gas storage tanks,
- drawings of the gas compressors and preheaters,
- description of the entire plant,

- .16 For Refrigerating Installations the documents listed in [Chapter 4 – Automation, Section 1, A](#) - if applicable - are to be submitted.

C. Definitions

Except where expressly provided otherwise, the following definitions apply. Additional definitions are given in [Section 4](#).

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

2. **"A" Class Divisions** means divisions as defined in SOLAS regulation II-2/3.2.

3.1 **Administration** means the Government of the state whose flag the ship is entitled to fly.

3.2 **Port Administration** means the appropriate authority of the country in the port of which the ship is loading or unloading.

3.3 **Anniversary date** means the day and the month of each year which will correspond to the date of expiry of the Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

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

5. **Breadth B** means the maximum breadth of the ship, measured amidships to the moulded line of the frame in a ship 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**) should be measured in metres.

For scantling purposes the breadth **B** defined in Chapter 1 – Hull Structures, Section 1, H.2.5 applies.

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

7. **Cargo Containment System** is the arrangement for containment of cargo including, where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the hold space.

8. **Cargo Control Room** is a space used in the control of cargo handling operations and complying with the requirements of 3.4.

9. **Cargoes** are products listed in [Section 19](#) carried in bulk by ships subject to the Code.

10. **Cargo Service Spaces** are spaces within the cargo area used for workshops, lockers and store rooms of more than 2 m² in area, used for cargo handling equipment.

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

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

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

14. **Flammable Products** are those identified by an "F" in column "I" in the table of [Section 19](#).

15. **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.

16. **Gas Carrier** is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other substance listed in the table in [Section 19](#).

17. Gas-Dangerous Space or Zone is:

- .1 a space in the cargo area which is not arranged or equipped in an approved manner to ensure that its atmosphere is at all times maintained in a gas-safe condition;
- .2 an enclosed space outside the cargo area through which any piping containing liquid or gaseous products passes, or within which such piping terminates, unless approved arrangements are installed to prevent any escape of product vapour into the atmosphere of that space;
- .3 a cargo containment system and cargo piping;
- .4.1 a hold space where cargo is carried in a cargo containment system requiring a secondary barrier;
- .4.2 a hold space where cargo is carried in a cargo containment system not requiring a secondary barrier;
- .5 a space separated from a hold space described in .4.1 by a single gas-tight steel boundary;
- .6 a cargo pump room and cargo compressor room;
- .7 a zone on the open deck, or semi-enclosed space on the open deck, within 3 m of any cargo tank outlet, gas or vapour outlet, cargo pipe flange or cargo valve or of entrances and ventilation openings to cargo pump rooms and cargo compressor rooms;
- .8 the open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck up to a height of 2,4 m above the weather deck;
- .9 a zone within 2,4 m of the outer surface of a cargo containment system where such surface is exposed to the weather;
- .10 an enclosed or semi-enclosed space in which pipes containing products are located. A space which contains gas detection equipment complying with 13.6.5 and a space utilizing boil-off gas as fuel and complying with [Section 16](#) are not considered gas-dangerous spaces in this context;
- .11 a compartment for cargo hoses; or
- .12 an enclosed or semi-enclosed space having a direct opening into any gas-dangerous space or zone.

18. Gas-Safe Space is a space other than a gas-dangerous space.

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

20. Independent means that a piping or venting system, for example, is in no way connected to another system and there are no provisions available for the potential connection to other systems.

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

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

23. Length (L_C) means 96 % of the total length on a waterline at 85 % of the least moulded depth measured from the top of the keel, or the length from the foreside of the stem to the axis of the rudder stock on that waterline, if that be greater. In ships designed with a rake of keel, the waterline on which this length is measured shall be parallel to the designed waterline. The length (L_C) shall be measured in metres.

For scantling purposes the length **L** defined in [Chapter 1 – Hull Structures, Section 1, H.2.1](#) applies.

24. Machinery Spaces of Category A are those spaces and trunks to such spaces which contain:

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

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

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

27. Oil Fuel Unit is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar.

28. Organization is the International Maritime Organization (IMO).

29. Permeability of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

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

30.2 Secondary Barrier is the liquid-resisting outer element of a cargo containment system designed to afford temporary containment of any envisaged leakage of liquid cargo through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level. Types of secondary barrier are more fully defined in [Section 4](#).

30.3 Recognized Standards are applicable international or national standards acceptable to the Administration or standards laid down and maintained by an organisation which complies with the standard adopted by the Organization⁵ and which is recognized by the Administration. (This definition includes the GL-Rules).

31. Relative Density is the ratio of the mass of a volume of a product to the mass of an equal volume of fresh water.

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

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

33. Service Spaces are those spaces 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.

34. SOLAS means the International Convention for the Safety of Life at Sea, 1974, as amended.

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

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

37. Toxic Products are identified by a "T" in column "f" of the table in [Section 19](#).

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

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

D. Surveys and Certification

1. Surveys for class maintenance

The relevant requirements are given in [Part 0 - Classification and Surveys, Section 4, D](#).

2. Survey and certification according to IGC-Code

The relevant requirements of Section 1.5 of the IGC-Code are given in Part 0 – Classification and Surveys, Section 4, D.

E. Emergency Towing Arrangements

Emergency towing arrangements are to be fitted on liquefied gas carriers of 20,000 tdw and above in accordance with the **1974 SOLAS Convention**, Chapter II-1, Reg. 3-4, see also Chapter 1 – Hull Structures, Section 24, A.10.

F. Safe Access to Tanker Bows

Every liquefied gas carrier shall be equipped with means for safe access to the bow in accordance with

⁵ See Appendix 1 to IMO Resolution a.739(18).

SOLAS, Chapter II-1; Reg. 3-3 and ICLL, Reg. 25 (4), 26 (2), 27 (7) (see also IACS U. I. LL 50).

Section 2

Ship Survival Capability and Location of Cargo Tanks

2.1 General

2.1.1 Ships subject to these Rules shall survive the normal effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the ship and the environment, the cargo tanks should be protected from penetration in the case of minor damage to the ship resulting, for example, from contact with a jetty or tug, and given a measure of protection from damage in the case of collision or stranding, 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 cargo tanks to the ship's shell shall be dependent upon the degree of hazard considered to be presented by the product to be carried.

Guidance

When applying the requirements of this Section attention should be given to IMO-document MSC/Circ 406 of 14.06.1985 "Guidelines for the Uniform Application of the Survival Requirements of the IBC/IGC-Codes".

2.1.2 Ships subject to these Rules shall be designed to one of the following standards.

- .1 A Type 1G Ship** is a gas carrier intended to transport products as indicated in [Section 19](#) which require maximum preventative measures to preclude the escape of such cargo.
- .2 A Type 2G Ship** is a gas carrier intended to transport products as indicated in [Section 19](#) which require significant preventative measures to preclude the escape of such cargo.
- .3 A Type 2PG Ship** is a gas carrier of 150 m in length (L_c) or less intended to transport products as indicated in [Section 19](#) which require significant preventative measures to preclude escape of such cargo, and where the products are carried in independent tanks type C designed (see 4.2.4.4) for a MARVS of at least 7 bar gauge and a cargo containment system design temperature of $-55\text{ }^{\circ}\text{C}$ or above. Note that a ship of this description but 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 products as indicated in [Section 19](#) which require moderate preventative measures to preclude the escape of such cargo.

Thus 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 should be located at the maximum prescribed distance inboard from the shell plating.

2.1.3 The ship type required for individual products is indicated in column "c" in the table of [Section 19](#).

2.1.4 If a ship is intended to carry more than one product listed in [Section 19](#), the standard of damage should correspond to that product having the most stringent ship type requirement. The requirements for the location of individual cargo tanks, however, are those for ship types related to the respective products intended to be carried.

2.2 Freeboard and stability

2.2.1 Ships subject to the Code may be assigned the minimum freeboard permitted by the International Convention on Load Lines, 1966. However, the draught associated with the assignment shall not be greater than the maximum draught otherwise permitted by these Rules.

2.2.2 The stability of the ship in all seagoing conditions and during loading and unloading cargo shall be to a standard which is acceptable to the Administration.

2.2.3 When calculating the effect of free surface 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 and the tank or combination of tanks to be taken into account shall be those where the effect of free surface is the greatest. The free surface effect in undamaged compartments shall be calculated by a method acceptable to the Administration.

2.2.4 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, then its disposition shall be governed by the need to ensure

that the impact loads resulting from a bottom damage are not directly transmitted to the cargo tank structure.

2.2.5 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. In addition, the booklet shall contain sufficient information to enable the master to load and operate the ship in a safe and seaworthy manner.

2.3 Shiplside discharges below the freeboard deck

2.3.1 The provision and control of valves fitted to discharges led through the shell from spaces below the freeboard deck or from within the superstructures and deckhouses on the freeboard deck fitted with weather-tight doors shall comply with the requirements of Regulation 22 of the International Convention on Load Lines 1966, except that the choice of valves in paragraph (1) shall be limited to:

- .1** one automatic non-return valve with a positive means of closing from above the freeboard deck, or
- .2** where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds $0,01 L_c$, two automatic non-return valves without positive means of closing, provided that the inboard valve is always accessible for examination under service conditions, i.e. the valve is to be situated above the tropical or subdivision load line.

2.3.2 For the purpose of this section "summer load waterline" and "freeboard deck", have the meanings as defined in the International Convention on Load Lines, 1966.

2.3.3 The automatic non-return valves referred to in 2.3.1.1 and 2.3.1.2 shall be fully effective in preventing admission of water into the ship, taking into account the sinkage, trim and heel in survival requirements in 2.9 and shall comply with Recognized Standards.

2.3-0.1 For automatic non-return valves see [Chapter 2 – Machinery Installations, Section 11](#).

2.4 Conditions of loading

Damage survival capability shall be investigated on the basis of loading information submitted to the Administration for all anticipated conditions of loading and variations in draught and trim. The survival requirements need not be applied to the ship when in the ballast condition, provided that any cargo retained on board is solely used for cooling, circulation or fuelling purposes.

Guidance

Small independent purge tanks on deck need not be taken into account in the stability calculations for the ballast condition.

2.5 Damage assumptions

2.5.1 The assumed maximum extent of damage shall be in accordance with Table 2.1.

2.5.2 Other damage:

- .1** If any damage of a lesser extent than the maximum specified in 2.5.1 would result in a more severe condition, such damage should be assumed.
- .2** Local side damage anywhere in the cargo area extending inboard 760 mm measured normal to the hull shell should be considered and transverse bulkheads should be assumed damaged when also required by the applicable subparagraph of 2.8.1.

2.5.3 Cargo tanks are to be located at the following minimum distances inboard:

- .1** Type 1G ships: from the side shell plating not less than the transverse extent of damage specified in 2.5.1.1.2 and from the moulded line of the bottom shell plating at centre line not less than the vertical extent of damage specified in 2.5.1.2.3, and nowhere less than 760 mm from the shell plating.
- .2** Types 2G/2PG and 3G ships: from the moulded line of the bottom shell plating at centre line not less than the vertical extent of damage specified in 2.5.1.2.3 and nowhere less than 760 mm from the shell plating.

Table 2.1 Extent of side and bottom damage

2.5.1.1 Side damage		
.1.1 Longitudinal extent		$1/3 L_c^{2/3}$ or 14,5 m whichever is less
.1.2 Transverse extent	measured inboard from the ship's side at right angle to the centre line at the level of the summer load line	$B/5$ or 11,5 m whichever is less
.1.3 Vertical extent	from the moulded line of the bottom shell plating at centre line	upward without limit
2.5.1.2 Bottom damage		
	For $0,3 L_c$ from the forward perpendicular of the ship	Any other part of the ship
.2.1 Longitudinal extent	$1/3 L_c^{2/3}$ or 14,5 m whichever is less	$1/3 L_c^{2/3}$ or 5 m whichever is less
.2.2 Transverse extent	$B/6$ or 10 m whichever is less	$B/6$ or 5 m whichever is less
.2.3 Vertical extent	$B/15$ or 2 m whichever is less, measured from the moulded line of the bottom shell plating at the centre line (see 2.6.3).	$B/15$ or 2 m whichever is less, measured from the moulded line of the bottom shell plating at the centre line (see 2.6.3).

2.6 Location of cargo tanks

2.6.1 For the purpose of tank location, the vertical extent of damage is to 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 damage is to be measured to the longitudinal bulkhead when membrane or semi-membrane tanks are used, otherwise to the side of the cargo tanks (see Fig. 2.1). For internal insulation tanks the extent of damage is to be measured to the supporting tank plating.

2.6.2 Except for Type 1G ships suction wells installed in cargo tanks may protrude into the vertical extent of bottom damage specified in 2.5.1.2.3 provided that such wells are as small as practicable and that the protrusion below the inner bottom plating does not exceed 25 % of the depth of double bottom or 350 mm whichever is less. Where there is no double bottom, the protrusion below the upper limit of bottom damage is not to exceed 350 mm. Suction wells installed in accordance with this paragraph may be ignored in determining the compartments affected by damage.

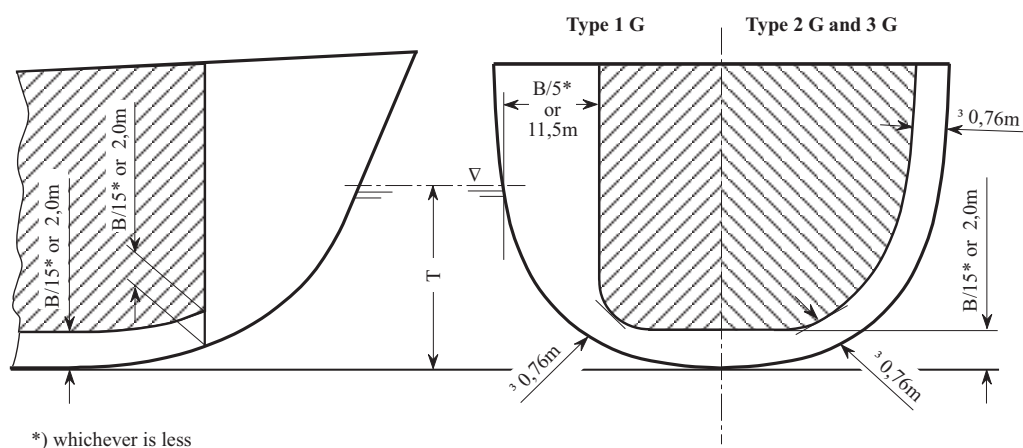


Fig. 2.1 Typical cargo tank location

2.7 Flooding assumptions

2.7.1 The requirements of 2.9 shall be confirmed by calculations which 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.

2.7.2 The permeabilities of spaces assumed to be damaged are to be taken as given in Table 2.2.

Table 2.2 Permeability

Space	Permeability
appropriated to stores	0,60
occupied by accommodation	0,95
occupied by machinery	0,85
voids	0,95
intended for consumable liquids	0 to 0,95 ¹
intended for other liquids	0 to 0,05 ¹
¹ The permeability of partially filled compartments shall be consistent with the amount of liquid carried in the compartment.	

2.7.3 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.

2.7.4 Where the damage between transverse watertight bulkheads is envisaged as specified in 2.8.1.4, .5 and .6, transverse bulkheads shall be spaced at least at a distance equal to the longitudinal extent of damage specified in 2.5.1.1.1 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 2.5. 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 after peak tank top shall not be regarded as a step for the purpose of this paragraph.

2.7.5 The ship shall be so designed as to keep asymmetrical flooding to the minimum consistent with efficient arrangements.

2.7.6 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 2.9.1 and sufficient residual stability shall be maintained during all stages where equalization is used. Spaces which are linked by ducts of large cross-sectional area may be considered to be common.

2.7.7 If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in 2.5 arrangements shall be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.

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

- .1 they are separated from the damaged space by watertight divisions and the requirements of 2.9.1.1 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 2.9.2.1; however, the immersion of any other openings capable of being closed weathertight may be permitted.

2.8 Standard of damage

2.8.1 Ships shall be capable of surviving the damage indicated in 2.5 with the flooding assumptions in 2.7 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;
- .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 2.5.1.1.1;

- .5** A **Type 3G ship** of 125 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 in 2.5.1.1.1;
- .6** A **Type 3G ship** of less than 125 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 2.5.1.1.1 and except damage involving the machinery space when located aft. However, the ability to survive the flooding of the machinery space shall be considered by the Administration.

2.8.2 In the case of small Type 2G/2PG and Type 3G ships which do not comply in all respects with the appropriate requirements of 2.8.1.3, .4 and .6, special dispensations may only be considered by the Administration provided that 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.

2.8-0.1 The longitudinal extent of damage to superstructure (see also 2.7.8) in the instance of side damage to a machinery space aft under 2.8.1 shall be the same as the longitudinal extent of the side damage to the machinery space (see Fig. 2.2).

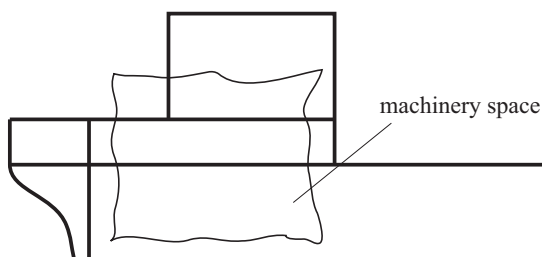


Fig. 2.2 Longitudinal extent of damage to superstructure

2.9 Survival requirements

Ships subject to these Rules shall be capable of surviving the assumed damage specified in 2.5 to the standard provided in 2.8 in a condition of stable equilibrium and shall satisfy the following criteria:

- 2.9.1** 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 or down-flooding may take place. Such openings shall include air pipes and openings which are closed by means of weathertight 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 which 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 be to the satisfaction of the Administration. However, it shall never be significantly less than that required by 2.9.2.1.

2.9.2 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 metre radians. 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 2.9.1.1 and of other openings capable of being closed weathertight may be permitted; and
- .2** the emergency source of power shall be capable of operating.

2.9-0.1 The 20° range may be measured from any angle commencing between the position of equilibrium and the angle of 30°, see Fig. 2.3.

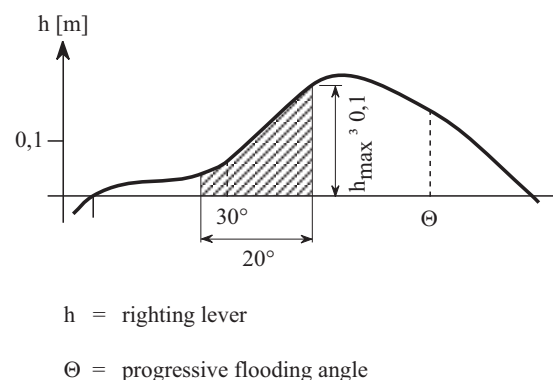


Fig. 2.3 Range of positive stability where the residual stability should be evaluated

Section 3

Ship Arrangements

3.1 Segregation of the cargo area

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

3.1.2 Where cargo is carried in a cargo containment system not requiring a secondary barrier, segregation of hold spaces from spaces referred to in 3.1.1 or spaces either below or outboard of the hold spaces may be effected by cofferdams, fuel oil tanks, or a single gastight bulkhead of all welded construction forming an A-60 class division. A gastight A-O class division is satisfactory if there is no source of ignition or fire hazard in the adjoining spaces.

3.1.3 Where cargo is carried in a cargo containment system requiring a secondary barrier, segregation of hold spaces from spaces referred to in 3.1.1 or spaces either below or outboard of the hold spaces which contain a source of ignition or fire hazard is to be effected by cofferdams or fuel oil tanks. If there is no source of ignition or fire hazard in the adjoining space, segregation may be by a single A-O class division which is gas-tight.

3.1.4 When cargo is carried in a cargo containment system requiring a secondary barrier:

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

3.1.5 Any piping system which may contain cargo or cargo vapour is:

- .1** to be segregated from other piping systems, except where inter-connections are required for cargo related operations, such as purging, gas freeing or inerting. In such cases precautions are to be taken to ensure that cargo or cargo

vapour cannot enter such other piping systems through the interconnections;

- .2** except as provided in [Section 16](#), not to pass through any accommodation space, service space or control station or through a machinery space other than a cargo pump room or cargo compressor space;
- .3** to be connected into the cargo containment system directly from the open deck, except that pipes installed in a vertical trunkway or equivalent may be used to traverse void spaces above a cargo containment system and except that pipes for drainage, venting or purging may traverse cofferdams;
- .4** except for bow or stern loading and unloading arrangements in accordance with [3.8](#), and emergency cargo jettisoning piping systems in accordance with 3.1.6, and except in accordance with [Section 16](#), to be located in the cargo area above the open deck; and
- .5** except for thwartship shore connection piping not subject to internal pressure at sea or emergency cargo jettisoning arrangements, to be located inboard of the transverse tank location requirement of 2.6.1.

3.1.6 Any emergency cargo jettisoning piping system should comply with 3.1.5 as appropriate and may be led aft externally to accommodation spaces, service spaces or control stations or machinery spaces, but are not to pass through them. If an emergency cargo jettisoning piping system is permanently installed a suitable means of isolation from the cargo piping is to be provided within the cargo area.

3.1.7 Arrangements are to be made for sealing the weather decks in way of openings for cargo containment systems.

3.1-0.1 Hold spaces are to be separated from each other by single bulkheads. Due consideration is to be given to the steel selection of the bulkheads considering the lowest temperature they may be exposed to during service. Where cofferdams are used instead of single bulkheads, they may be used as ballast tanks subject to special approval by the Society.

3.2 Accommodation, service and machinery spaces and control stations

3.2.1 No accommodation space, service space or control station is to be located within the cargo area. The bulkhead of accommodation spaces, service spaces or control stations which face the cargo area is to be located so 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.

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

3.2.3 Access through doors, gastight or otherwise, is not permitted from a gas safe space to a gas dangerous space, except for access to service spaces forward of the cargo area through airlocks as permitted by 3.6.1 when accommodation spaces are aft.

3.2.4 Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations shall not face the cargo area. They are to be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse at a distance of at least $L_c/25$ 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. Windows and side scuttles facing the cargo area and on the sides of the superstructures or deckhouses within the distance mentioned above are to be of the fixed (non-opening) type. Wheelhouse windows may be non-fixed and wheelhouse doors may be located within the above limits so long as they are so designed that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured. For ships dedicated to the carriage of cargoes which have neither flammable nor toxic hazards, the Society may approve relaxations from the above requirements.

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

3.2.6 All air intakes and openings into the accommodation, service and control station spaces are to be fitted with closing devices. For toxic gases they are to be operated from inside the space.

3.2-0.1 Compliance with other relevant paragraphs of the Code and in particular with paragraphs 3.2.4, 3.8, 8.2.10 and 12.1.6 where applicable would also ensure compliance with this paragraph.

3.2-0.2 Air outlets are subject to the same requirements as air inlets and air intakes. This interpretation also applies to paragraphs 3.2.2, 3.8.4 and 8.2.10.

3.2-0.3 Doors facing the cargo area or located in prohibited zones in the sides are to be restricted to stores for cargo-related and safety equipment, cargo control stations as well as decontamination showers and eye wash.

3.2-0.4 The requirement for fitting air intakes and openings with closing devices operable from inside the space in ships intended to carry toxic products shall apply to spaces which are used for ships' radio and main navigating equipment, cabins, mess rooms, toilets, hospitals, galleys, etc., but shall not apply to engine room casings, deck stores, steering gear compartments, work shops etc. The requirement does also not apply to forecastle stores and to cargo control rooms located within the cargo areas.

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

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

3.2-0.5 Access to forecastle spaces containing sources of ignition may be permitted through doors facing cargo area provided the doors are located outside hazardous areas as defined in IEC Publication 60092-502.

3.3 Cargo pump-rooms and cargo compressor rooms

3.3.1.1 Cargo pump rooms and cargo compressor rooms are to be situated above the weather deck and located within the cargo area unless specially approved by GL. Cargo compressor rooms are to be treated as cargo pump rooms for the purpose of fire protection according to Chapter 2 – Machinery Installations, Section 12 (SOLAS regulation II-2/9.2.4).

3.3.1.2 When cargo pump rooms and cargo compressor rooms are permitted to be fitted above or below the weather deck at the after end of the aftermost hold space or at the forward end of the foremost hold space, the limits of the cargo area as defined in Section 1, C.1.6 are to be extended to include the cargo pump rooms and cargo compressor rooms for the full breadth and depth of the ship and deck areas above those spaces.

3.3.1.3 Where the limits of the cargo area are extended by 3.3.1.2, the bulkhead which separates the cargo pump rooms and cargo compressor rooms from accommodation and service spaces, control stations

and machinery spaces of category A is to be so located as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.

3.3.2 Where pumps and compressors are driven by shafting passing through a bulkhead or deck, gastight seals with efficient lubrication or other means of ensuring the permanence of the gas seal are to be fitted in way of the bulkhead or deck.

3.3.3 Arrangements of cargo pump rooms and cargo compressor rooms are to be such as to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. All valves necessary for cargo handling are to be readily accessible to personnel wearing protective clothing. Suitable arrangements shall be made to deal with drainage of pump and compressor rooms.

3.3-0.1 When cargo pump rooms or compressor rooms are permitted to be fitted at the after end of the aftermost hold space the bulkhead which separates the cargo pump rooms or compressor rooms from accommodation and service spaces (see 3.3.1.2 and 3.3.1.3), control stations and machinery spaces of category A are to be so located as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead. The same condition is also to be satisfied when cargo pump rooms and compressor rooms, fitted within the cargo area, have a bulkhead in common with accommodation and service spaces, control stations and machinery spaces of category A.

3.4 Cargo control rooms

3.4.1 Any cargo control room is to be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation, service or control station spaces provided the following conditions are complied with:

- .1** the cargo control room is a gas safe space; and
- .2.1** if the entrance complies with 3.2.4, the control room may have access to the spaces described above;
- .2.2** if the entrance does not comply with 3.2.4, the control room shall have no access to the spaces described above and the boundaries to such spaces shall be insulated to "A-60" standard.

3.4.2 If the cargo control room is designed to be a gas safe space, 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 detector

within the cargo control room will not violate the gas safe space if installed in accordance with 13.6.5.

3.4.3 If the cargo control room for ships carrying flammable products is a gas dangerous space, sources of ignition are to be excluded. Consideration is to be paid to the safety characteristics of any electrical installations.

3.5 Access to spaces in the cargo area

3.5.1 Visual inspection shall be possible of at least one side of the inner hull structure without the removal of any fixed structure or fitting. If such a visual inspection, whether combined with those inspections required in 3.5.2, 4.7.7 or 4.10.16 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.

3.5.2 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.

3.5.3 Arrangements for hold spaces, void spaces and other spaces that can be considered gas dangerous and cargo tanks are to be such as to allow entry and inspection of any such space by personnel wearing protective clothing and breathing apparatus and in the event of injury to allow unconscious personnel to be removed from the space and to comply with the following:

- .1** access is to be provided:
 - .1.1** to the cargo tanks direct from the open deck;
 - .1.2** through horizontal openings, hatches or manholes the dimensions of which are to be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction, and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm by 600 mm; and
 - .1.3** through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening of which is to be not less than 600 mm by 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided.
- .2** The dimensions referred to in 3.5.3.1.2 and .1.3 may be decreased if the ability to transverse

such openings or to remove an injured person can be proved to the satisfaction of the Society.

- .3 The requirements of 3.5.3.1.2 and .1.3 do not apply to those spaces described in [Section 1, C.17.5](#). Such spaces are to be provided only with direct or indirect access from the open weather deck not including an enclosed gas safe space.

3.5.4 Access from the open weather deck to gas safe spaces is to be located in a gas safe zone at least 2,4 m above the weather deck unless the access is by means of an airlock in accordance with [3.6](#).

3.5-0.1 Designated passage ways below and above cargo tanks are to have at least the cross sections as required by 3.5.3.1.3.

3.5-0.2 For the purpose of [3.5.1](#) and 3.5.2 the following applies:

- .1 Where the surveyor requires to pass between the surface to be inspected, flat or curved, and structural elements such as deckbeams, stiffeners, frames, girders etc., the distance between that surface and the free edge of the structural elements is to 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 is to be at least 450 mm in case of a curved tank surface (e.g. in case of type C-tank) or 600 mm in case of a flat tank surface (e.g. in case of type A-tank) (see Fig. 3.1).

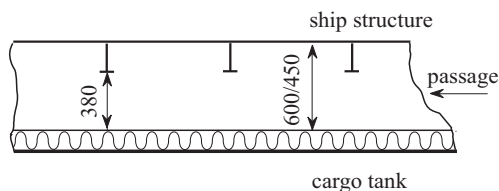


Fig. 3.1

- .2 Where the surveyor does not require to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected is to be at least 50 mm or half the breadth of the structure's face plate, whichever is the larger (see Fig. 3.2).

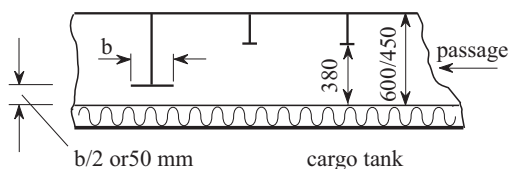


Fig. 3.2

- .3 If for inspection of a curved surface the surveyor requires to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces is to be at least 380 mm (see Fig. 3.3). Where the surveyor does not require to pass between a curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface.

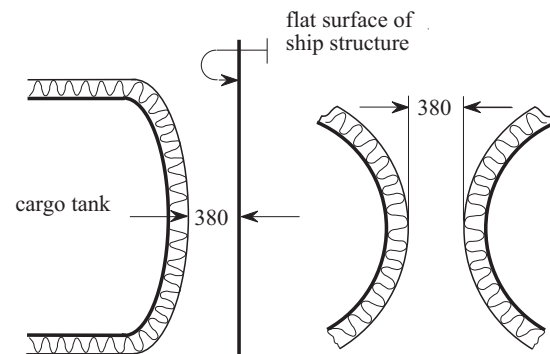


Fig. 3.3

- .4 If for inspection of an approximately flat surface the surveyor requires to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces are to be at least 600 mm (see Fig. 3.4).

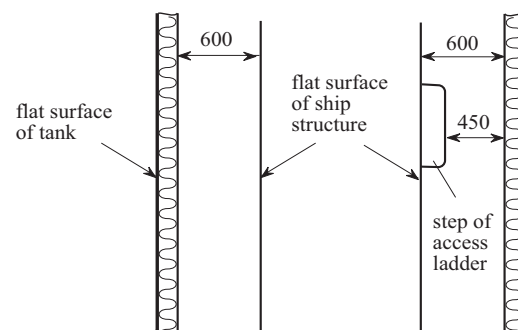


Fig. 3.4

- .5 The minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction wells are not to be less than shown in Fig. 3.5. If there is no section well, the distance between the cargo tank sump and the inner bottom is not to be less than 50 mm.

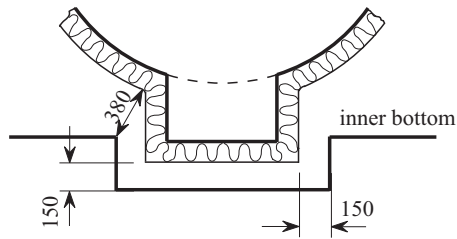


Fig. 3.5

- .6 The distance between a cargo tank dome and deck structures is not to be less than 150 mm (see Fig. 3.6).

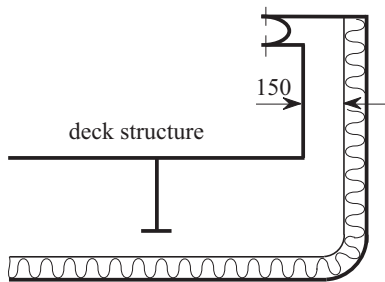
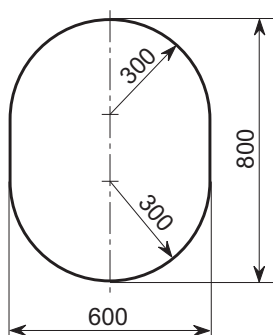


Fig. 3.6

- .7 If necessary for inspection fixed or portable staging is to be installed. This staging is not to impair the distances required under .1 to .4.
- .8 If fixed or portable ventilation ducting has to be fitted in compliance with 12.2 such ducting is not to impair the distances required under .1 to .4.

3.5-0.3 For the purpose of subparagraph 3.5.3.1.2 and .1.3 the following applies:

- .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.
- .2 The term "minimum clear opening of not less than 600×800 mm" includes also an opening of the following size:



- .3 Circular access openings in type C cargo tanks are to have diameters of not less than 600 mm.

3.6 Airlocks

3.6.1 An airlock is permitted only between a gas dangerous zone on the open weather deck and a gas safe space and is to consist of two steel doors substantially gastight spaced at least 1,5 m but not more than 2,5 m apart.

3.6.2 The doors are to be self-closing and without any holding back arrangements.

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

3.6.4 In ships carrying flammable products electrical equipment which is not of the certified safe type in spaces protected by airlocks should be de-energized upon loss of over-pressure in the space (see also 10.1.4).

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

3.6-0.1 The following means for monitoring overpressure in spaces protected by airlocks are considered acceptable alternatives to differential pressure sensing devices in spaces having a ventilation rate not less than 30 air changes per hour:

- .1 monitoring of current or power in the electrical supply to the ventilation motors; or
- .2 air flow sensors in the ventilation ducts.

In spaces where the ventilation rate is less than 30 air changes per hour and where one of the above alternatives is fitted, in addition to the alarms required by 3.6.3, arrangements are to be made to de-energize electrical equipment which is not of the certified safe type, if more than one airlock door is moved from the closed position.

3.6.5 The airlock space is to be mechanically ventilated from a gas safe space and maintained at an over-pressure to the gas dangerous zone on the open weather deck.

3.6.6 The airlock space is to be monitored for cargo vapour.

3.6.7 Subject to the requirements of the International Convention on Load Lines, 1966, the door sill is not to be less than 300 mm in height.

3.7 Bilge, ballast and fuel oil arrangements

3.7.1.1 Where cargo is carried in a cargo containment system not requiring a secondary barrier, hold spaces are to be provided with suitable drainage arrangements not connected with the machinery space. Means of detecting such leakage are to be provided.

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

3.7.2 The hold or interbarrier spaces of Type A independent tanks 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. Such a system shall be provided with removable spool pieces.

3.7.3 In case of internal insulation tanks, means of detecting leakage and drainage arrangements are not required for interbarrier spaces and spaces between the secondary barrier and the inner hull or independent tank structure which are completely filled by insulation material complying with 4.9.7.2.

3.7.4 Ballast spaces, including wet duct keels used as ballast piping, fuel-oil tanks and gas-safe 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 lead directly overboard with no valves or manifolds in either line which could connect the line from the duct keel to lines serving gas-safe spaces. Pump vents shall not be open to machiney spaces.

3.8 Bow or stern loading and unloading arrangements

3.8.1 Subject to the requirements of this Section, cargo piping may be arranged to permit bow or stern loading and unloading.

3.8.1.1 Bow or stern loading and unloading lines which are led past accommodation spaces, service spaces or control stations shall not be used for the transfer of products requiring a Type 1G ship. Bow or

stern loading and unloading lines shall not be used for the transfer of toxic products as specified in [Section 1, C.37](#), unless specifically approved by GL.

3.8.2 Portable arrangements shall not be permitted.

3.8.3 In addition to the requirements of [Section 5](#) the following provisions apply to cargo piping and related piping equipment:

- .1** Cargo piping and related piping equipment outside the cargo area are to have only welded connections. The piping outside the cargo area shall run on the open deck and shall be at least 760 mm in board except for thwartships shore connection piping. Such piping shall be clearly identified and fitted with a shut-off 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.
- .2** The piping is to be full penetration but welded, and fully radiographed regardless of pipe diameter and design temperature. Flange connections in the piping are only permitted within the cargo area and at the shore connection.
- .3** Arrangements are to 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 to be blank-flanged. The vent pipes connected with the purge are to be located in the cargo area.

3.8.4 Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations shall not face the cargo shore connection location of bow or stern loading and unloading arrangements. They shall be located on the outboard side of the superstructure or deckhouse at a distance of at least $L_c/25$ but not less than 3 m from the end of the superstructure or deckhouse facing the cargo shore connection location of the bow or stern loading and unloading arrangements. This distance, however, need not exceed 5 m. Side scuttles facing the shore connection location and on the sides of the superstructure or deckhouse within the distance mentioned above shall be of the fixed (non-opening) type. In addition, during the use of the bow or stern loading and unloading arrangements, all doors, ports and other openings on the corresponding superstructure or decks and deck houses shall be closed. Where in case of small ships compliance with [3.2.4](#) and this paragraph is not possible, the Society may approve relaxations from the above requirements.

3.8.5 Deck openings and air inlets to spaces within distances of 10 m from the cargo shore connection

location shall be kept closed during the use of bow or stern loading or unloading arrangements.

3.8.6 Electrical equipment within a zone of 3 m from the cargo shore connection location shall be in accordance with [Section 10](#).

3.8.7 Fire-fighting arrangements for the bow or stern loading and unloading areas are to be in accordance with 11.3.1.3 and 11.4.7.

3.8.8 Means of communication between the cargo control station and the shore connection location shall be provided and, if necessary, certified safe.

Section 4

Cargo Containment

4.1 General

4.1.1 With regard to this Section reference is made to the Unified Requirements G1 and G2 of the International Association of Classification Societies (IACS).

4.1.2 In addition to the definitions in [Section 1, C.](#), the definitions given in this Section apply throughout this Chapter.

4.2 Definitions

4.2.1 Integral tanks

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

4.2.1.2 The "design vapour pressure" P_0 as defined in [4.2.6](#) is not normally to exceed 0,25 bar. If, however, the hull scantlings are increased accordingly, P_0 may be increased to a higher value but less than 0,7 bar.

4.2.1.3 Integral tanks may be used for products provided the boiling point of the cargo is not below - 10 °C. A lower temperature may be accepted by the Society subject to special consideration.

4.2.2 Membrane tanks

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

4.2.2.2 The design vapour pressure P_0 is not normally to exceed 0,25 bar. If, however, the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting insulation, P_0 may be increased to a higher value but less than 0,7 bar.

4.2.2.3 The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or in which membranes are included or incorporated in the insulation. Such designs require, however, special consideration by the Society.

In any case the thickness of the membranes should normally not exceed 10 mm.

4.2.3 Semi-membrane tanks

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

4.2.3.2 The design vapour pressure P_0 is not normally to exceed 0,25 bar. If, however, the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting insulation, P_0 may be increased to a higher value but less than 0,7 bar.

4.2.4 Independent tanks

4.2.4.1 Independent tanks are self-supporting; they do not form part of the ship's hull and are not essential to the hull strength. There are three categories of independent tanks referred to in 4.2.4.2 - 4.2.4.4.

4.2.4.2 Type A independent tanks are tanks which are designed primarily using classical ship-structural analysis procedures. Where such tanks are primarily constructed of plane surfaces (gravity tanks), the design vapour pressure P_0 is to be less than 0,7 bar.

4.2.4.3 Type B independent tanks are tanks which are designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (gravity tanks) the design vapour pressure P_0 is to be less than 0,7 bar.

4.2.4.4 Type C independent tanks (also referred to as pressure vessels) are tanks meeting pressure vessel criteria and having a design vapour pressure P_0 not less than:

$$P_0 = 2 + A \cdot C(\rho_r)^{1,5} \quad [\text{bar}]$$

$$A = 0,0185 \left(\frac{\sigma_m}{\Delta\sigma_A} \right)^2$$

σ_m = design primary membrane stress

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

$\Delta\sigma_A = 55 \text{ N/mm}^2$ for ferritic-perlitic, martensitic and austenitic steels

$\Delta\sigma_A = 25 \text{ N/mm}^2$ for aluminium alloy (5083-0) (Al Mg 4,5 Mn)

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

$$h, 0,75 b \text{ or } 0,45 \ell$$

h = height of tank (dimension in ship's vertical direction) [m]

b = width of tank (dimension in ship's transverse direction) [m]

ℓ = length of tank (dimension in ship's longitudinal direction) [m]

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

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

4.2-0.1 If the carriage of products not covered by Section 19 is intended, the relative density of which exceeds 1,0, it is to be verified that the double amplitude of the primary membrane stress $\Delta\sigma_m$ created by the maximum dynamic pressure differential Δp does not exceed the allowable double amplitude of the dynamic membrane stress $\Delta\sigma_A$ as specified in 4.2.4.4, i.e.:

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

The dynamic pressure differential Δp is to be calculated as follows:

$$\Delta p = \frac{\rho}{1,02 \cdot 10^4} [a_{\beta 1} \cdot z_{\beta 1} - a_{\beta 2} \cdot z_{\beta 2}] \text{ [bar]}$$

where $a_{\beta 1}$ and $z_{\beta 1}$ are the a_β - and z_β -values giving the maximum liquid pressure $(P_{gd})_{\max}$ as defined in 4.3.2, $a_{\beta 2}$ and $z_{\beta 2}$ are the a_β - and z_β -values giving the minimum liquid pressure, see Fig. 4.1. For ρ see 4.3.2.2.

In order to evaluate the maximum pressure differential Δp , pressure differentials are to be evaluated over the full range of the acceleration ellipse.

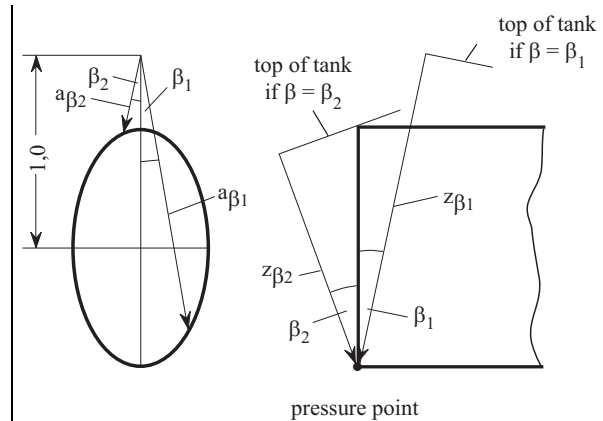


Fig. 4.1 Determination of Δp

4.2.5 Internal insulation tanks

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

4.2.5.2 The two categories of internal insulation tanks are:

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

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

4.2.5.3 Internal insulation tanks are to be of suitable materials enabling the cargo containment system to be designed using model tests and refined analytical methods as required in 4.4.7.

4.2.5.4 The design vapour pressure P_0 shall not normally exceed 0,25 bar. If, however, the cargo containment system is designed for a higher vapour pressure, P_0 may be increased to such higher value, but not exceeding 0,7 bar if the internal insulation tanks are supported by the inner hull structure. However, a design vapour pressure of more than 0,7 bar may be accepted by the Society provided the internal insulation tanks are supported by suitable independent tank structures.

4.2.6 Design vapour pressure

4.2.6.1 The design vapour pressure P_0 is the maximum gauge pressure at the top of the tank which has been used in the design of the tank.

4.2.6.2 For cargo tanks where there is no temperature control and where the pressure of the cargo is dictated only by the ambient temperature, P_0 is not to be less than the gauge vapour pressure of the cargo at a temperature of 45 °C. However, lesser values of this temperature 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 this temperature may be required for ships permanently operating in areas of high ambient temperature.

4.2.6.3 In all cases, including 4.2.6.2, P_0 is not to be less than MARVS.

4.2.6.4 Subject to special consideration by the Society and to the limitations given in 4.2.1 to 4.2.5 for the various tank types, a vapour pressure higher than P_0 may be accepted in harbour conditions, where dynamic loads are reduced.

4.2-0.2 Higher vapour pressures in harbour conditions are to be specified in the operating instructions for the ship's management.

4.2.7 Design temperature

The design temperature for selection of materials is the minimum temperature at which cargo may be loaded or transported in the cargo tanks. Provisions to the satisfaction of the Society are to be made that the tank or cargo temperature cannot be lowered below the design temperature.

4.3 Design loads

4.3.1 General

4.3.1.1 Tanks together with their supports and other fixtures are to be designed taking into account proper combinations of the various loads listed hereafter:

- Internal pressure
- External pressure
- Dynamic loads due to the motion of the ship
- Thermal loads
- Sloshing loads

- Loads corresponding to ship deflection
- Tank and cargo weight with the corresponding reactions in way of supports
- Insulation weight
- Loads in way of towers and other attachments.

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

4.3.1.2 Account is to be taken of the loads corresponding to the pressure test referred to in 4.10.

4.3.1.3 Account is to be taken of an increase of vapour pressure in harbour conditions referred to in 4.2.6.4.

4.3.1.4 The tanks are to be designed for the most unfavourable static heel angle within the range 0° to 30° without exceeding allowable stresses given in 4.5.1.

4.3.2 Internal pressure

4.3.2.1 The internal pressure P_i in bar gauge resulting from the design vapour pressure P_0 and the liquid pressure P_{gd} defined in 4.3.2.2, but not including effects of liquid sloshing, is to be calculated as follows:

$$P_i = P_0 + (P_{gd})_{\max} \quad [\text{bar}]$$

Equivalent calculation procedures may be applied.

4.3.2.2 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 4.3.4.1. The value of the internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamical accelerations is to be calculated as follows:

$$P_{gd} = \frac{a_\beta \cdot z_\beta \cdot \rho}{1,02 \cdot 10^4} \quad [\text{bar}]$$

a_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamical loads, in an arbitrary direction β (see Fig. 4.1).

z_β = largest liquid height [m] above the point where the pressure is to be determined measured from the tank shell in the β direction (see Fig. 4.2). Tank domes considered to be part of the accepted total tank volume are to be taken into account when determining z_β unless the total volume of tank domes V_d does not exceed the following value:

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

V_t = tank volume without any domes

FL = filling limit according to Section 15

ρ = maximum density of the cargo
[kN/m³] at the design temperature.

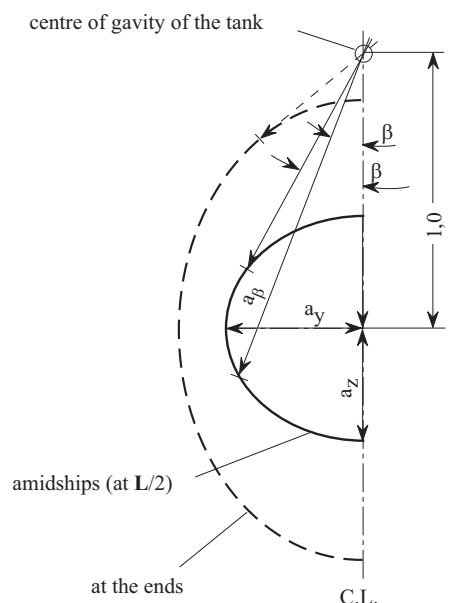
4.3-0.1 Guidance values for the density ρ are given in col. (k) of the list of cargoes in Section 19.

The direction β which gives the maximum value $(P_{gd})_{\max}$ of P_{gd} is to be considered. Where acceleration components in three directions need to be considered, an ellipsoid is to be used instead of the ellipse in Fig. 4.2. The above formula applies only to full tanks.

4.3-0.2 In general, it is sufficient to determine the liquid pressure P_{gd} for the ship's cross section (y-z-plane) and for the ship's longitudinal section (z-x-plane) and to determine the scantlings for the maximum pressure so obtained.

4.3.3 External pressure

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



Resulting acceleration (static + dynamic) a_β in arbitrary direction β . Example is given for the y-z-plane.

a_y = transverse component of acceleration
 a_z = vertical component of acceleration

Fig. 4.2 Acceleration Ellipse

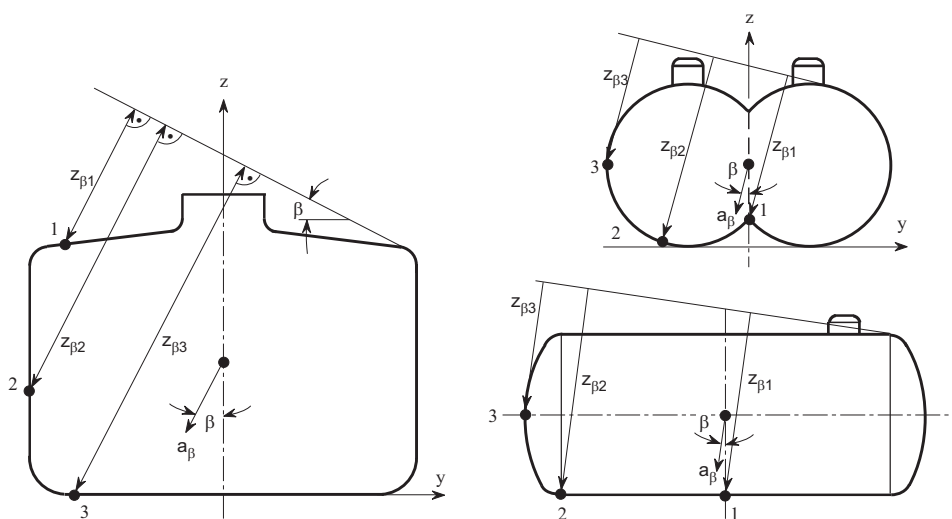


Fig. 4.3a Determination of liquid heights z_β for the pressure points 1; 2; 3

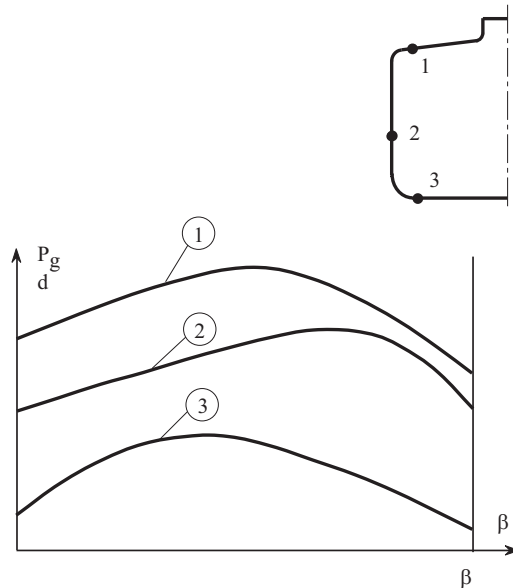


Fig. 4.3b Determination of internal pressure for the pressure points 1; 2; 3

4.3.4 Dynamic loads due to ship motions

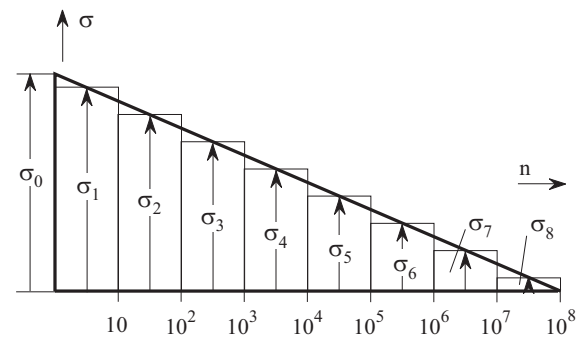
4.3.4.1 The determination of dynamic loads is to take account of the long term distribution of ship motions, including the effects of surge, sway, heave, roll, pitch and yaw on irregular seas which the ship will experience during her operation life (normally taken to correspond to 10^8 wave encounters). Account may be taken of reduction in dynamic loads due to necessary speed reduction and variation of heading when this consideration has also formed part of the hull strength assessment.

4.3.4.2 For design against plastic deformation and buckling the dynamic loads are to be taken as the most probable largest loads the ship will encounter during her operating life (normally taken to correspond to a probability level of 10^{-8}). Guidance formulae for acceleration components are given in 4.12.

4.3.4.3 When design against fatigue is to be considered, the dynamic spectrum is to be determined by long term distribution calculation based on the operating life of the ship (normally taken to correspond to 10^8 wave encounters). If simplified dynamic loading spectra are used for the estimation of the fatigue life, these are to be specially considered by the Society. An example is given in Fig. 4.4.

4.3.4.4 In order to practically apply crack propagation estimates, simplified load distribution over a period of 15 days may be used. Such distributions may be obtained as indicated in Fig. 4.5.

4.3.4.5 Ships for restricted service may be given special consideration.

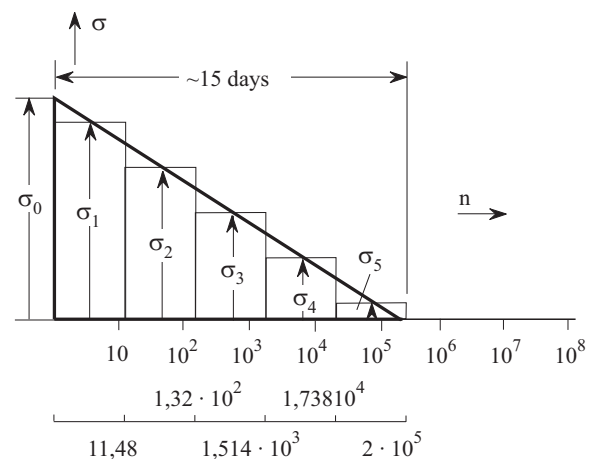


$$\text{Fatigue stress:} \quad \sigma_i = \sigma_0 \left(1,0625 - \frac{i}{8} \right)$$

$$\begin{aligned} \text{related load cycle:} \quad n_i &= 0,9 \cdot 10^i \\ i &= 1, 2, 3, 4, 5, 6, 7, 8 \end{aligned}$$

σ_0 = most probable maximum stress over the life of the ship (probability level $Q = 10^{-8}$)

Fig. 4.4 Long-term wave induced load spectrum (straight line spectrum)



$$\text{Fatigue stress:} \quad \sigma_a = \sigma_0 \left(1,1 - \frac{a}{5,3} \right)$$

$$a = 1,06, 2,12, 3,18, 4,24, 5,30$$

$$\text{related load cycle:} \quad n_a = 0,913 \cdot 10^a$$

The load cycle scale is logarithmic.

Fig. 4.5 Short-term wave induced load spectrum representing the worst period of 15 days ($2 \cdot 10^5$ load cycles) in the long-term spectrum, the value $2 \cdot 10^5$ is an example of estimate

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

Vertical Acceleration:

Motion accelerations of heave, pitch and, possibly roll (normal to the ship base).

Transverse Acceleration:

Motion accelerations of sway, yaw and roll, and gravity component of roll.

Longitudinal Acceleration:

Motion acceleration of surge and pitch, and gravity component of pitch.

4.3-0.3 For the direct calculation of dynamic loads computer programs of GL may be used.

4.3.5 Sloshing loads

4.3.5.1 When partial filling is contemplated, the risk of significant loads due to sloshing induced by any of the ship motions referred to in 4.3.4.6 is to be considered.

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

4.3.6 Thermal loads

4.3.6.1 Transient thermal loads during cooling down periods are to be considered for tanks intended for cargo temperatures below -55°C .

4.3.6.2 Stationary thermal loads are to be considered for tanks where design supporting arrangement and operating temperature may give rise to significant thermal stresses.

4.3.7 Loads on supports

The loads on supports are covered by 4.6.

4.4 Structural analysis

4.4.1 Integral tanks

The structural analysis of integral tanks is to be in accordance with Chapter 1 – Hull Structures, Section 24. The tank boundary scantlings are to meet at least the requirements for deep tanks taking into account the internal pressure as indicated in 4.3.2 but the resulting scantlings are not to be less than normally required by the Society.

4.4.2 Membrane tanks

4.4.2.1 For membrane tanks, the effects of all static and dynamic loads are to be considered to determine the suitability of the membrane and of the associated

insulation with respect to plastic deformation and fatigue.

4.4.2.2 Before approval is given, a model of both the primary and secondary barriers, including corners and joints, is normally to be tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. Test conditions are to represent the most extreme service conditions the cargo containment system will see in its life. Material tests are to ensure that ageing is not liable to prevent the materials from carrying out their intended function.

4.4.2.3 For the purpose of the test referred to in 4.4.2.2, a complete analysis of the particular motions, accelerations and response of ships and cargo containment systems is to be performed, unless these data are available from similar ships.

4.4.2.4 Special attention is to be paid to the possible collapse of the membrane due to an overpressure in the interbarrier space, to a possible vacuum in the cargo tank, to the sloshing effects and to hull vibration effects.

4.4.2.5 The structural analysis of the hull is to be in accordance with Chapter 1 – Hull Structures, Section 24, taking into account the internal pressure as indicated in 4.3.2. Special attention, however, is to be paid to deflections of the hull and their compatibility with the membrane and associated insulation. Inner hull plating thickness is to meet at least the requirements for deep tanks taking into account the internal pressure as indicated in 4.3.2. The allowable stress for the membrane, membrane supporting material and insulation is to be determined in each particular case.

4.4.3 Semi-membrane tanks

A structural analysis is to be performed in accordance with the requirements for membrane tanks or independent tanks as appropriate, taking into account the internal pressure as indicated in 4.3.2.

4.4.4 Type A independent tanks

4.4.4.1 A structural analysis is to be performed in accordance with Chapter 1 – Hull Structures, Section 12, taking into account the internal pressure as indicated in 4.3.2. The cargo tank plating thickness is to meet at least the requirements for deep tanks taking into account the internal pressure as indicated in 4.3.2 and any corrosion allowance required by 4.5.2.

4.4.4.2 For parts, such as structure in way of supports, not otherwise covered by the Rules, stresses are to be determined by direct calculation, taking into account the loads referred to in 4.3 as far as applicable, and the ship deflection in way of supports.

4.4.5 Type B independent tanks

For tanks of this type the following applies:

- .1 The effects of all dynamic and static loads are to be used to determine the suitability of the structure with respect to:
 - plastic deformation
 - buckling
 - fatigue failure
 - crack propagation.

Statistical wave load analysis in accordance with 4.3.4 finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, are to be carried out.
- .2 A three-dimensional analysis is to be carried out to evaluate the stress levels contributed by the ship's hull. The model for this analysis is to include the cargo tank with its supporting and keying system as well as a reasonable part of the hull.
- .3 A complete analysis of the particular ship accelerations and motions in irregular waves and of the response of the ship and its cargo tanks to these forces and motions is to be performed unless these data are available from similar ships.
- .4 A buckling analysis is to consider the maximum construction tolerances.
- .5 Where deemed necessary by the Society, model tests may be required to determine stress concentration factors and fatigue life of structural elements.
- .6 The cumulative effect of the fatigue load is to comply with the following formula:

$$\sum \frac{n_i}{N_i} + \frac{10^3}{N_i} \leq C_w$$

- n_i = number of stress cycles at each stress level during the life of the ship (see Fig. 4.4 and 4.5)
- N_i = number of cycles to fracture for the respective stress level according to the Wöhler (S-N) curve.
- N_j = number of cycles to fracture for the fatigue loads due to loading and unloading
- C_w is to be less than or equal to 0,5 except that the Society may give special consideration to the use of a value greater than 0,5 but not greater than 1,0, de-

pendent on the test procedure and data used to establish the Wöhler (S-N) curve.

4.4-0.1 Guidelines for Fracture Mechanics Analysis

Fracture mechanics analysis shall consider propagation rates in parent material, weld metal and heat-affected zone.

The fracture mechanical properties are to be documented for the various thicknesses of parent material and weld metal alike, possibly by experiment according to ASTM E 399 - 70 T.

It is to be determined to which length an assumed through thickness crack will grow to under dynamic loading.

The calculation is to be based on a stress spectrum as stipulated under 4.3.4.4. The initial length of the existing crack is to be taken equal to the minimum flow size that can be detected by means of a monitoring system (e.g., gas detectors), however, not less than the plate thickness.

4.4.6 Type C independent tanks

4.4.6.1 The pressure vessels of independent tanks are to be calculated as follows:

- .1 The thickness and form of pressure containing parts of pressure vessels under internal pressure, including flanges are to be determined according to a standard acceptable to the Society. These calculations in all cases are to be based on generally accepted pressure vessels design theory. Openings in pressure containing parts of pressure vessels are to be reinforced in accordance with a standard acceptable to the Society. See hereto Chapter 2 – Machinery Installations, Section 8.
- .2 The design liquid pressure defined in 4.3.2 is to be taken into account in the above calculations.
- .3 The welded joint efficiency factor to be used in the calculation according to 4.4.6.1.1 is to be 0,95 when the inspection and the non-destructive testing referred to in 4.10.9 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 4.10.9.2.2 depending on such factors as the material used, the design temperature, the nil ductility transition temperature of the material as fabricated, the type of joint and welding procedure, but in this case an effi-

ciency factor of not more than 0,85 is to be adopted. For special materials, the above mentioned factors are to be reduced depending on the specified mechanical properties of the welded joint.

4.4.6.2 Buckling criteria are to be as follows:

- .1 The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses are to be to a standard acceptable to the Society. These calculations in all cases are to be based on generally accepted pressure vessel buckling theory and are to adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.
- .2 The design external pressure P_e used for verifying the buckling of the pressure vessels is not to be less than that given by the following formula:

$$P_e = P_1 + P_2 + P_3 + P_4 \quad [\text{bar}]$$

P_1 = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves P_1 is to be specially considered, but is not in general be taken as less than 0,25 bar.

P_2 = the set pressure of the pressure relief valves for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere, $P_2 = 0$.

P_3 = compressive actions in the shell due to the weight and contraction of insulation, weight of shell, including corrosion allowance, and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition the local effect of external or internal pressure or both is to be taken into account.

P_4 = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere $P_4 = 0$. (See hereto also [Chapter 1 – Hull Structures, Section 4](#).)

4.4.6.3 Stress analysis in respect of static and dynamic loads is to be performed as follows:

- .1 Pressure vessel scantlings are to be determined in accordance with 4.4.6.1 and .2.
- .2 Calculations of the loads and stresses in way of the supports and the shell attachment of the support are to be made. Loads referred to in [4.3](#) are to be used, as applicable. The permissible stresses in the shell and the stiffening rings in way of supports may be determined according to 4.4-0.2. In special cases a fatigue analysis may be required by the Society.
- .3 If required by the Society, secondary stresses and thermal stresses are to be specially considered.

4.4-0.2 The equivalent stress in the stiffening rings in way of supports shall not exceed one of the following values:

$$\sigma_c = \sqrt{(\sigma_n + \sigma_b)^2 + 3\tau^2} \leq 0,85 R_e \text{ or } 0,57 R_m$$

σ_n = normal stress due to normal fores

σ_b = bending stress

τ = shear stress

R_e, R_m see [4.5.1.7](#)

Guidance for analysis

1. Stiffening rings

1.1 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:

- .1 For cylindrical shells:

$$b_m = 0,78 \sqrt{r \cdot t}$$

on each side of the web

r = mean radius of the cylindrical shell in [mm]

t = shell thickness [mm].

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

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

the effective width may be determined according to Chapter 1 – Hull Structures, Section 3, E. The following value on each side of the web may be taken as a guidance value:

$$b_m = 20 \cdot t_b$$

t_b = bulkhead thickness.

1.2 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 forces of the tank.

1.3 If finite element calculation methods are applied, assumption for calculations are to be specially agreed with GL.

1.4 The buckling strength of the stiffening rings is to be examined in accordance with the requirements of Chapter 1 – Hull Structures, Section 3, F.

2. Supports

2.1 The following factors shall be taken into account:

.1 Elasticity of support material (intermediate layer of wood or similar material)

.2 Change in contact surface between tank and support for the different load cases, and of the relevant reactions, due to:

- thermal shrinkage of tank*
- elastic deformations of tank and support material.*

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

4.4.6.4 For pressure vessels, the thickness calculated according to 4.4.6.1 or the thickness required by 4.4.6.2 plus the corrosion allowance, if any, is to be considered as a minimum without any negative tolerance.

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

4.4-0.3 The calculation procedure of pressure vessels is given in Chapter 2 – Machinery Installations, Section 8.

4.4.7 Internal insulation tanks

4.4.7.1 The effects of all static and dynamic loads are to be considered to determine the suitability of the tank with respect to:

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

Statistical wave load analysis in accordance with 4.3.4, finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach are to be carried out.

4.4.7.2.1 Special attention is to be given to crack resistance and to deflections of the inner hull or independent tank structure and their compatibility with the insulation materials. A three-dimensional structural analysis is to be carried out to the satisfaction of the Society. This analysis is to evaluate the stress levels and deformations contributed either by the inner hull or by the independent tank structure or both and is also to take into account the internal pressure as indicated in 4.3.2. Where water ballast spaces are adjacent to the inner hull forming the supporting structure of the internal insulation tank, the analysis is to take account of the dynamic loads caused by water ballast under the influence of ship motions.

4.4.7.2.2 The allowable stresses and associated deflections for the internal insulation tank and the inner hull structure or independent tank structure are to be determined in each particular case.

4.4.7.2.3 Thicknesses of plating of the inner hull or of an independent tank are to at least comply with the requirements of Chapter 1 – Hull Structures, Sections 12 and/or 24, taking into account the internal pressure as indicated in 4.3.2. Tanks constructed of plane surfaces are at least to comply with the requirements for tank structures given in Chapter 1 – Hull Structures, Section 12.

4.4.7.3 A complete analysis of the response of ship, cargo and any ballast to accelerations and motions in irregular waves of the particular ship is to be performed to the satisfaction of the Society unless such analysis is available for a similar ship.

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

4.4.7.4.2 Test conditions are to represent the most extreme service conditions the cargo containment system will be exposed to during the lifetime of the ship, including thermal cycles. For this purpose, 400 thermal cycles are considered to be a minimum, based upon 19 round voyages per year; where more than 19 round voyages per year are expected, a higher number of thermal cycles will be required. These 400 thermal cycles may be divided into 20 full cycles (cargo temperature to 45 °C) and 380 partial cycles (cargo temperature to that temperature expected to be reached in the ballast voyage).

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

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

4.4.7.4.5 The effects of fatigue loading are to be determined in accordance with 4.4.5.6 or by an equivalent method.

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

4.5 Allowable stresses and corrosion allowance

4.5.1 Allowable stresses

4.5.1.1 For integral tanks, allowable stresses are normally those given for the hull structure in Chapter 1 – Hull Structures, Section 24.

4.5.1.2 For membrane tanks, reference is made to the requirements of 4.4.2.5.

4.5.1.3 For type A independent tanks, primarily constructed of plane surfaces the stresses (equivalent stresses) for primary and secondary members (web frames, stringers, girders, stiffeners) when calculated by classical analysis procedures are not to exceed the lower of $R_m/2,66$ or $R_e/1,33$ for carbon manganese steels and aluminium alloys, where R_m and R_e are defined in 4.5.1.7. However, if detailed calculations are carried out for the primary members, the equivalent stress, σ_e as defined in 4.5.1.8 may be increased over that indicated above to a stress acceptable to the Society; calculations have to 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.

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

$$\sigma_m \leq f$$

$$\sigma_L \leq 1,5 f$$

$$\sigma_b = 1,5 F$$

$$\sigma_L + \sigma_b \leq 1,5 F$$

$$\sigma_m + \sigma_b \leq 1,5 F$$

σ_m = equivalent primary general membrane stress

σ_L = equivalent primary local membrane stress

σ_b = equivalent primary bending stress

f = the lesser of $\frac{R_m}{A}$ or $\frac{R_e}{B}$

F = the lesser of $\frac{R_m}{C}$ or $\frac{R_e}{D}$

with R_m and R_e as defined in 4.5.1.7. With regard to the stresses σ_m , σ_L and σ_b see also the definition of stress categories in 4.13.

The values of A, B, C and D are to be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk provided for in Section 1, D., and are to have at least the following minimum values (Table 4.1).

Table 4.1 Minimum values for A,B,C and D

Nickel steels and carbon manganese steels		Austenitic steels	Aluminium alloys
A	3,0	3,5	4,0
B	2,0	1,6	1,5
C	3,0	3,0	3,0
D	1,5	1,5	1,5

Guidance

For ships trading to the territorial waters of the United States of America the requirements of the US Coast Guard, given in 46 CFR (Code of Federal Register), Part 154, § 154.447 should be observed.

4.5.1.5 For type B independent tanks, primarily constructed of plane surfaces, the equivalent stresses σ_e in primary members (web frames, stringers, girders) are not to exceed the lower of the values resulting from Table 4.2.

Table 4.2 Maximum values for equivalent stresses σ_c

Material	$\frac{\sigma_c}{R_e}$	$\frac{\sigma_c}{R_m}$
C-Mn steels and Ni-Steels	0,75	0,5
Austenitic steels	0,80	0,4
Aluminium alloy	0,75	0,35

Furthermore, the Society may require compliance with additional or other stress criteria.

4.5.1.6 For type C independent tanks, the maximum allowable membrane stress to be used in the calculation according to 4.4.6.1.1 is to be the lower of:

$$\frac{R_m}{A} \text{ or } \frac{R_e}{B}$$

where R_m and R_e are as defined in 4.5.1.7.

The values of A and B are to be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and are to have at least the minimum values indicated in Table 4.1.

4.5.1.7 For the purpose of 4.5.1.3, 4.5.1.4 and 4.5.1.6 the following apply:

- 1** R_e = specified minimum yield stress in $[N/mm^2]$ at room temperature. If the stress-strain curve does not show a defined yield stress, the 0,2 % proof stress applies.

 R_m = specified minimum tensile strength in $[N/mm^2]$ at room temperature. For welded connections in aluminium alloys, the respective values of R_e and R_m in annealed conditions are to be used.
- 2** The above properties are to correspond to the minimum specified mechanical properties of the material, including the weld metal in the as fabricated condition. Subject to special consideration by the Society account may be taken of enhanced yield stress and tensile strength at low temperature. The temperature on which the material properties are based are to be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

4.5.1.8 The equivalent stress σ_c (von Mises, Huber) is to be determined by:

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

σ_x = total normal stress in x-direction

σ_y = total normal stress in y-direction

τ_{xy} = total shear stress in x-y-plane

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

$$\begin{aligned}\sigma_x &= \sigma_{x \text{ st}} \pm \sqrt{\sum (\sigma_{x \text{ dyn}})^2} \\ \sigma_y &= \sigma_{y \text{ st}} \pm \sqrt{\sum (\sigma_{y \text{ dyn}})^2} \\ \tau_{xy} &= \tau_{xy \text{ st}} \pm \sqrt{\sum (\tau_{xy \text{ dyn}})^2}\end{aligned}$$

$\sigma_{x \text{ st}}$, $\sigma_{y \text{ st}}$ and $\sigma_{xy \text{ st}}$ are static stresses.

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

4.5.1.10 For internal insulation tanks, reference is made to the requirements of 4.4.7.2.

4.5.1.11 Allowable stresses for materials other than those covered by Section 6 are to be subject to approval by the Society in each case.

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

4.5.2 Corrosion allowance

4.5.2.1 No corrosion allowance is generally required in addition to the thickness resulting from the structural analysis. However, where there is no environmental control around the cargo tank, such as inerting, or where the cargo is of a corrosive nature, the Society may require a suitable corrosion allowance.

4.5.2.2 For pressure vessels no corrosion allowance is generally required if the contents of the pressure vessel are non-corrosive and the external surface is protected by inert atmosphere or by an appropriate insulation with an approved vapour barrier. Paint or other thin coatings will not be credited as protection. Where special alloys are used with acceptable corrosion resistance, no corrosion allowance is required. If the above conditions are not satisfied, the scantlings calculated according to 4.4.6 are to be increased as appropriate.

4.6 Supports

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

4.6.2 The tanks with supports are also to be designed for a static angle of heel of 30° without exceeding allowable stresses given in 4.5.1.

4.6.3 The supports are to be calculated for the most probable largest resulting acceleration, taking into account rotational as well as translational effects. This acceleration in a given direction may be determined as shown in Fig. 4.2. The half axes of the "Acceleration Ellipse" are to be determined according to 4.3.4.2.

4.6.4 Suitable supports are to be provided to withstand a collision force acting on the tank corresponding to 0,5 g in the forward direction and 0,25 g in the aft direction without deformation likely to endanger the tank structure.

4.6.5 The loads mentioned in 4.6.2 and 4.6.4 need not be combined with each other or with wave induced loads.

4.6.6 For independent tanks and, where appropriate, for membrane and semi-membrane tanks, provisions are to be made to key the tanks against the rotational effects referred to in 4.6.3.

4.6.7 Antiflotation arrangements are to be provided for independent tanks. The antiflotation arrangements are to be suitable to withstand an upward force caused by an empty tank in a hold space flooded to the summer load draught of the ship, without plastic deformation likely to endanger the hull structure.

4.7 Secondary barrier

4.7.1 Where the cargo temperature at atmospheric pressure is below – 10 °C, a secondary barrier is to be provided when required by 4.7.3 to act as a temporary containment for any envisaged leakage of liquid cargo through the primary barrier.

4.7.2 Where the cargo temperature at atmospheric pressure is not below – 55 °C, the hull structure may act as a secondary barrier. In such a case:

.1 the hull material is to be suitable for the cargo temperature at atmospheric pressure as required by 4.9.2; and

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

4.7.3 Secondary barriers in relation to tank types are to be provided in accordance with Table 4.3. For tanks which differ from the basic tank types as defined in 4.2, the secondary barrier requirements are to be decided by the Society in each case.

4.7.4 The secondary barrier is to be designed so that:

.1 It is capable of containing any envisaged leakage of liquid cargo for a period of 15 days, unless different requirements apply for particular voyages, taking into account the load spectrum referred to in 4.3.4.4;

.2 It will prevent lowering of the temperature of the ship structure to an unsafe level in the case of leakage of the primary barrier as indicated in 4.8.2; and

.3 The mechanism of failure for the primary barrier does not also cause the failure of the secondary barrier and vice-versa.

4.7.5 The secondary barrier is to fulfil its functions at a static angle of heel of 30°.

4.7.6.1 Where a partial secondary barrier is required, its extent is to be determined on the basis of cargo leakage corresponding to the extent of failure resulting from load spectrum referred to in 4.3.4.4 after the initial detection of a primary barrier leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors. In all cases, however, the inner bottom adjacent to cargo tanks is to be protected against liquid cargo.

4.7.6.2 Clear of the partial secondary barrier, provision such as a spray shield is to be made to deflect any liquid cargo down into the space between the primary and secondary barriers and to keep the temperature of the hull structure to a safe level.

4.7.7 The secondary barrier is to be capable of being periodically checked for its effectiveness, by means of a pressure vacuum test, a visual inspection or another suitable method acceptable to the Society. The method is to be submitted to the Society for approval.

Table 4.3 Secondary barriers in relation to tank types

Cargo temperature at atmospheric pressure	– 10 °C and above	Below – 10 °C down to – 55 °C	Below – 55 °C
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Integral		Tank type not normally allowed ¹	
Membrane		Complete secondary barrier	
Semi-membrane		Complete secondary barrier ²	
Independent: Type A Type B Type C		Complete secondary barrier Partial secondary barrier No secondary barrier required	
Internal insulation: Type 1 Type 2		Complete secondary barrier	
		Complete secondary barrier is incorporated	

¹ A complete secondary barrier will normally be required if cargoes with a temperature at atmospheric pressure below – 10 °C are permitted in accordance with 4.2.1.3.

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

4.8 Insulation

4.8.1 Where cargo is carried at a temperature below – 10 °C suitable insulation is to be provided to ensure that the temperature of the hull structure does not fall below the minimum allowable design temperature given in Section 6 for the grade of steel concerned, as detailed in 4.9, when the cargo tanks are at their design temperature and the ambient temperatures are 5 °C for air and 0 °C for sea water. These conditions may generally be used for world-wide service. However, higher values of the ambient temperatures may be accepted by the Society for ships operated in restricted areas. Conversely, lesser values of the ambient temperatures may be fixed by the Society for ships trading occasionally or regularly to areas in latitudes where such lower temperatures are expected during the winter months. The ambient temperatures used in the design are to be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

4.8.2 Where a complete or partial secondary barrier is required, calculations are to be made with the assumptions in 4.8.1 to check that the temperature of the hull structure does not fall below the minimum allowable design temperature given for the concerned grade of steel in Section 6 as detailed in 4.9. The complete or partial secondary barrier is to be assumed to be at the cargo temperature at atmospheric pressure.

4.8.3 Calculations required by 4.8.1 and 4.8.2 are to be made assuming still air and still water, and except as permitted by 4.8.4, no credit is to be given for means of heating. In the case referred to in 4.8.2, the cooling effect of the rising boil-off vapour from the leaked cargo is to be considered in the heat transmission studies. For structural members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

4.8.4 In all cases referred to in 4.8.1 and 4.8.2 and for ambient temperature conditions of 5 °C for air and 0 °C for sea water approved means of heating transverse hull structural material may be used to ensure that the temperatures of this material do not fall below the minimum allowable values. If lower ambient temperatures are specified, approved means of heating may also be used for longitudinal hull structural material, provided this material remains suitable for the temperature conditions of 5 °C for air and 0 °C for sea water without heating. Such means of heating are to comply with the following requirements:

- .1** Sufficient heat is to be available to maintain the hull structure above the minimum allowable temperature in the conditions referred to in 4.8.1 and 4.8.2;
- .2** The heating system is to be arranged so that, in the event of a failure in any part of the system, stand-by heating can be maintained equal to not less than 100 % of the theoretical heat load;

- .3 The heating system is to be considered as an essential auxiliary; and
- .4 The design and construction of the heating system is to be to the satisfaction of the Society.

4.8.5 In determining the insulation thickness, due regard is to be paid to the amount of acceptable boil-off in association with the reliquefaction plant on board, main propulsion machinery or other temperature control system.

4.9 Materials

4.9.1 The shell and deck plating of the ship and all stiffeners attached thereto is to be in accordance with Chapter 1 – Hull Structures, Section 2 unless the calculated temperature of the material in the design condition is below -5°C due to the effect of the low temperature cargo, in which case the material is to be in accordance with Table 6.5 assuming the ambient sea and air temperature of 0°C and 5°C respectively. In the design condition the complete or partial secondary barrier is to be assumed to be at the cargo temperature at atmospheric pressure and for tanks without secondary barriers, the primary barrier is to be assumed to be at the cargo temperature.

4.9.2 Hull material forming the secondary barrier is to be in accordance with Table 6.2. Metallic materials used in secondary barriers not forming part of the hull structure are to be in accordance with Table 6.2 or 6.3 as applicable. Insulation materials forming a secondary barrier are to comply with the requirements of 4.9.7. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by Table 6.2 are to be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

4.9.3 Materials used in the construction of cargo tanks are to be in accordance with Tables 6.1, 6.2 or 6.3.

4.9.4 Materials other than those referred to in 4.9.1, 4.9.2 and 4.9.3 used in the construction of the ship which are subject to reduced temperature due to the cargo and which do not form part of the secondary barrier are to be in accordance with Table 6.5 for temperatures as determined by 4.8. This includes inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

Guidance

For ships trading to the territorial waters of the United States of America the material selection re-

quirements of the US Coast Guard, given in 46 CFR (Code of Federal Register), Part 154, § 154.172/178 should be observed.

4.9.5 The insulation materials are to be suitable for loads which may be imposed on them by the adjacent structure.

4.9.6 Where applicable, due to location and/or environmental conditions, insulation materials are to have suitable properties of fire resistance and flame spread and are to be adequately protected against penetration of water vapour and mechanical damage.

4.9.7.1 Materials used for thermal insulation are to be tested for the following properties as applicable, to ensure that they are adequate for the intended service:

- .1 compatibility with the cargo
- .2 solubility in the cargo
- .3 absorption of the cargo
- .4 shrinkage
- .5 ageing
- .6 closed cell content
- .7 density
- .8 mechanical properties
- .9 thermal expansion
- .10 abrasion
- .11 cohesion
- .12 thermal conductivity
- .13 resistance to vibrations
- .14 resistance to fire and flame spread ¹.

4.9.7.2 In addition to the above requirements insulation materials which contribute as cargo containment as defined in 4.2.5 are to be tested for the following properties after simulation of ageing and thermal cycling to ensure that they are adequate for the intended service:

- .1 bonding (adhesive and cohesive strength)
- .2 resistance to cargo pressure

¹ Resistance to fire and flame spread according to DIN 4102 or ASTM D1692.

- .3 fatigue and crack propagation properties
- .4 compatibility with cargo constituencies and any other agent expected to be in contact with the insulation in normal service
- .5 where applicable the influence of presence of water and water pressure on the insulation properties are to be taken into account
- .6 gas de-absorbing.

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

4.9.8 The procedure for fabrication, storage, handling, erection, quality control and control against harmful exposure to sunlight of insulation materials are to be to the satisfaction of the Society.

4.9.9 Where powder or granulated insulation is used, the arrangements are to be such as to prevent compacting of the material due to vibrations. The design is to incorporate means to ensure that the material remains sufficiently buoyant to maintain the required thermal conductivity and also prevent any undue increase of pressure on the cargo containment system.

4.9-0.1 The steel structure has to be properly cleaned prior to the application of the insulation. When the insulation is sprayed or foamed, it has to be observed that the minimum steel temperature at the time of application is not lower than that temperature given in the specification of the insulation.

4.10 Construction and testing

4.10.1.1 All welded joints of the shells of independent tanks are to be of the butt weld, full penetration type. For dome to shell connections, the Society may approve tee welds of the full penetration type. Except for small penetrations on domes, nozzle welds are also generally to be designed with full penetration.

4.10.1.2 Welding joint details for independent tanks type C are to be as follows:

- .1 All longitudinal and circumferential joints of pressure vessels are to be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds are to be obtained by double welding or by the use of backing rings. If used, backing rings are to be removed, unless specifically approved by the Society for very small process pressure vessels. Other edge preparations may be allowed by the Society depending on the results of the tests carried out at the approval of the welding procedure.

- .2 The bevel preparation of the joints between the pressure vessel body and domes and between domes and relevant fittings are to be designed according to a standard for pressure vessels acceptable to the Society. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles are to be full penetration welds extending through the entire thickness of the vessel wall or nozzle wall, unless specially approved by the Society for small nozzle diameters. See hereto also [Rules II – Materials and Welding, Part 3 – Welding, Chapter 3 – Welding in the Various Fields of Application, Section 3](#).

4.10.2 Workmanship is to be to the satisfaction of the Society. Inspection and non-destructive testing of welds for tanks other than independent tanks type C are to be in accordance with the requirements of 6.3.7.

4.10.3 For membrane tanks, quality assurance measures, weld procedure qualification, design details, materials, construction, inspection and production testing of components, are to be to standards developed during the prototype testing programme.

4.10.4 For semi-membrane tanks the relevant requirements in this Section for independent tanks or for membrane tanks are to be applied as appropriate.

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

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

4.10.6 Integral tanks are to be hydrostatically or hydropneumatically tested in accordance with [Chapter 1 – Hull Structures, Section 24, A.15](#). The test in general is to be performed so that the stresses approximate, as far as practicable, the design stresses and so that the pressure at the top of the tank corresponds at least to the MARVS.

4.10.7 In ships fitted with membrane or semimembrane tanks, cofferdams and all spaces which may normally contain liquid and are adjacent to the hull structure supporting the membrane are to be hydrostatically or hydropneumatically tested in accordance with [Chapter 1 – Hull Structures, Section 24, A.15](#). In addition, any other hold structure supporting the mem-

brane is to be tested for tightness. Pipe tunnels and other compartments which do not normally contain liquid need not be hydrostatically tested.

4.10.8.1 In ships fitted with internal insulation tanks where the inner hull is the supporting structure, all inner hull structure is to be hydrostatically or hydropneumatically tested in accordance with Chapter 1 – Hull Structures, Section 24, A.15., taking into account the MARVS.

4.10.8.2 In ships fitted with internal insulation tanks where independent tanks are the supporting structure, the independent tanks are to be tested in accordance with 4.10.10.1.

4.10.8.3 For internal insulation tanks where the inner hull structure or an independent tank structure acts as a secondary barrier, a tightness test of those structures is to be carried out using techniques to the satisfaction of the Society.

4.10.8.4 These tests are to be performed before the application of the materials which will form the internal insulation tank.

4.10.9 For independent tanks type C, inspection and non-destructive testing is to be as follows:

.1 Manufacture and workmanship - The tolerances relating to manufacture and workmanship such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, are to comply with standards acceptable to the Society. The tolerances are also to be related to the buckling analysis referred to in 4.4.6.2. Reference is also made to the [Rules II – Materials and Welding, Part 3 – Welding, Chapter 3 – Welding in the Various Fields of Application, Section 3](#).

.2 Non-destructive testing - As far as completion and extension of non-destructive testing of welded joints are concerned, the extent of non-destructive testing is to be total or partial according to standards acceptable to the Society, but the controls to be carried out are not to be less than the following:

.2.1 Total non-destructive testing referred to in [4.4.6.1.3](#):

Radiography:

butt welds 100 % and

Surface crack detection:

all welds 10 %

reinforcement rings around holes, nozzles, etc. 100 %.

As an alternative ultrasonic testing may be accepted as a partial replacement of the radiographic testing, if specially allowed by the Society. In addition, the Society may require total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc.

.2.2 Partial non-destructive testing referred to in 4.4.6.1.3:

Radiography:

butt welds: all welded crossing joints and at least 10 % of the full length at selected positions uniformly distributed and

Surface crack detection:

reinforcement rings around holes; nozzles, etc. 100 %.

Ultrasonic testing:

as may be required by the Society in each instance.

4.10.10 Each independent tank is to be subjected to a hydrostatic or hydropneumatic test as follows:

.1 For type A independent tanks, this test is to be performed so that the stresses approximate, as far as practicable, the design stresses and so that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed the conditions are to simulate, as far as practicable, the actual loading of the tank and of its supports.

.2 For type B independent tanks, the test is to be performed as required in 4.10.10.1 for type A, independent tanks. In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions are not to exceed 90 % of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75 % of the yield strength the prototype test is to be monitored by the use of strain gauges or other suitable equipment.

.3 Type C independent tanks are to be tested as follows:

.3.1 Each pressure vessel, when completely manufactured, is to be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than $1,5 P_0$, but in no case during the pressure test is the calculated primary membrane stress at any point to exceed 90 % of the yield stress of the material. The definition of P_0 is given in [4.2.6](#). To ensure that this condition is satisfied where calculations indicate

that this stress will exceed 0,75 times the yield strength the prototype test is to be monitored by the use of strain gauges or other suitable equipment in pressure vessels except simple cylindrical and spherical pressure vessels.

- .3.2** The temperature of the water used for the test is to be at least 30 °C above the nil ductility transition temperature of the material as fabricated.
- .3.3** The pressure is to be held for two hours per 25 mm of thickness but in no case less than two hours.
- .3.4** Where necessary for cargo pressure vessels, and with the specific approval of the Society, a hydropneumatic test may be carried out under the conditions prescribed in .3.1, .3.2 and .3.3.
- .3.5** Special consideration may be given by the Society to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of .3.1 are to be fully complied with.
- .3.6** After completion and assembly, each pressure vessel and its related fittings are to be subjected to an adequate tightness test.
- .3.7** Pneumatic testing of pressure vessels other than cargo tanks are to be considered on an individual case basis by the Society. Such testing will be permitted only for these vessels which are so designed and/or supported that they cannot be safely filled with water, or for those vessels which cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

4.10.11 All tanks are to be subjected to a tightness test which may be performed in combination with the pressure test referred to in 4.10.10 or separately.

4.10.12 Requirements with respect to inspection of secondary barriers will be decided by the Society in each case (see also 4.7.7).

4.10.13 In ships fitted with independent tanks type B, at least one tank and its support is to be instrumented to confirm stress levels unless the involved are supported by full scale experience. Similar instrumentation may be required by the Society for independent tanks type C dependent on their configuration and on the arrangement of their supports and attachments.

4.10.14 The overall performance of the cargo containment system is to be verified for compliance with the design parameters during the initial cool down, loading and discharging of the cargo. Records of the performance of the components and equipment essential to verify the design parameters are to be maintained and these records be available to the Society.

4.10.15 Heating arrangements, if fitted in accordance with 4.8.4 are to be tested for required heat output and heat distribution.

4.10.16 The hull is to be inspected for cold spots following the first loaded voyage.

4.10.17 The insulation materials of internal insulation tanks are to be subjected to additional inspection in order to verify their surface conditions after the third loaded voyage of the ship, but not later than the first six months of the ship's service after building or a major repair work is undertaken on the internal insulation tanks.

4.10.18 For independent tanks type C, any required marking of the pressure vessel is to be achieved by a method which does not cause unacceptable local stress raisers.

4.11 Stress relieving for type C independent tanks

4.11.1 For type C independent tanks of carbon and carbon-manganese steel, post-weld heat treatment is to 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 is to be to the satisfaction of the Society. The soaking temperature and holding time is to be to the satisfaction of the Society.

4.11.2 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 are to be heat treated before they are welded to larger parts of the pressure vessel.
- .2** The mechanical stress relieving shall preferably be carried out during the hydrostatic pressure test required in 4.10.10.3 by applying a higher pressure than the test pressure required by 4.10.10.3.1. The pressurizing medium shall be water.
- .3** For the water temperature 4.10.10.3.2 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 distribu-

tion as when supported by its regular saddles or supporting structure.

- .5 The maximum stress relieving pressure shall be held for two hours per 25 mm of thickness but in no case less than two hours.

- .6 The upper limits placed on the calculated stress levels during stress relieving shall be the following:

- equivalent general primary membrane stress:

$$0,9 R_e$$

- equivalent stress composed of primary bending stress plus membrane stress:

$$1,35 R_e$$

R_e = specified 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 4.11.2.14.

- .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 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 point is raised by a method giving high ductility of the steel, slightly higher ratios 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 is to be submitted beforehand to the Society for approval.

4.12 Guidance formulae for acceleration components

The following formulae are given as guidance for the components of acceleration due to ship's motions in the case of ships with a length greater than 50 m. These formulae correspond to a probability level of 10^{-8} in the North Atlantic.

vertical acceleration as defined in 4.3.4.6

$$a_z = \pm a_0 \sqrt{1 + \left[5,3 - \frac{45}{L}\right]^2 \left[\frac{x}{L} + 0,05\right]^2 \left[\frac{0,6}{C_B}\right]^{1,5}}$$

transverse acceleration as defined in 4.3.4.6

$$a_y = \pm a_0 \sqrt{0,6 + 2,5 \left[\frac{x}{L} + 0,05\right]^2 + k \left[1 + 0,6 \cdot k \cdot \frac{z}{B}\right]^2}$$

longitudinal acceleration as defined in 4.3.4.6

$$a_x = \pm a_0 \sqrt{0,06 + A^2 - 0,25 A}$$

$$A = \left[0,7 - \frac{L}{1200} + 5 \frac{z}{L}\right] \left[\frac{0,6}{C_B}\right]$$

L = Length of ship [m] as defined in [Chapter 1 – Hull Structures, Section 1](#).

C_B = block coefficient as defined in Chapter 1 – Hull Structures, Section 1.

B = greatest moulded breadth [m] as defined in Chapter 1 – Hull Structures, Section 1.

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

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

$$a_0 = 0,2 \frac{v}{\sqrt{L}} + \frac{34 - 600/L}{L}$$

v = maximum speed in calm water at full draught in knots.

k = 1,0 in general. For particular loading conditions and hull forms, determination of k according to the formulae below may be necessary.

$$= \frac{13 \cdot \overline{M_B G}}{B}$$

$\geq 1,0$ and

$\overline{M_B G}$ = metacentric height [m]

a_x, a_y, a_z = maximum dimensionless accelerations (i.e. relative to the acceleration of gravity) in the respective directions and they are considered as acting separately for calculation purpose. 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.

4.13 Stress categories

For the purpose of stress evaluation referred to in 4.5.1.4, stress categories are defined in this Section.

4.13.1 Normal stress: the component of stress normal to the plane of reference.

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

4.13.3 Bending stress: the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

4.13.4 Shear stress: the component of the stress acting in the plane of reference.

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

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

4.13.7 Primary local membrane stress: cases arise where a membrane stress produced by pressure or other mechanical loading and associated with a primary and/or a discontinuity effect produces excessive distortion in the transfer of 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:

$$S_1 \leq 0,5 \sqrt{R \cdot t}$$

and

$$S_2 \geq 2,5 \sqrt{R \cdot t}$$

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

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

R = mean radius of the vessel.

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

f = allowable primary general membrane stress.

4.13.8 Secondary stress: a normal stress or shear 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 which cause the stress to occur.

Section 5

Process Pressure Vessels and Liquid, Vapour and Pressure Piping Systems

5.1 General

5.1.1 With regard to this Section, reference is made to the Unified Requirement G3 of the International Association of Classification Societies (IACS). Process pressure vessels and piping systems are to comply also with the relevant Rules of [Chapter 2 – Machinery Installations, Section 8](#) and [11](#).

5.1.2 The requirements for type C independent tanks in Section 4, may also apply to process pressure vessels. The words "pressure vessels" as used in [Section 4](#) cover both independent tanks type C and process pressure vessels.

5.2 Cargo and process piping

5.2.1 General

5.2.1.1 The requirements of 5.2 - 5.5 apply to product and process piping including vapour piping and vent lines of safety valves or similar piping. Instrument piping not containing cargo is exempt from these requirements.

5.2.1.2 Provision is to be made by the use of offsets, loops, bends, mechanical expansion joints such as bellows, slip joints and ball joints or similar suitable means to protect the piping, piping system components and cargo tanks from excessive stresses due to thermal movement and from movements of the tank and the hull structure. Where mechanical expansion joints are used in piping they are to be held to a minimum and, where located outside of cargo tanks, shall be of the bellows type.

5.2.1.3 Low temperature piping is to be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. 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 is to be provided.

5.2.1.4 Where tanks or piping are separated from the ship's structure by thermal isolation, provision is to be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections are to be electrically bonded.

5.2.1.5 Suitable means are to be provided to relieve the pressure and remove liquid contents from cargo loading and discharging crossover headers and cargo hoses to the cargo tanks or other suitable location, prior to disconnecting the cargo hoses.

5.2.1.6 All pipe lines or components which may be isolated in a liquid full condition are to be provided with relief valves.

5.2-0.1 Pipe lines capable of being isolated, and the volume of which does not exceed 0,05 m³, need not be provided with relief valves.

5.2.1.7 Relief valves discharging liquid cargo from the cargo piping system are to discharge into the cargo tanks; alternatively they may discharge to the cargo vent mast if means are provided to detect and dispose of any liquid cargo which may flow into the vent system. Relief valves on cargo pumps are to discharge to the pump suction.

5.2.2 Scantlings based on internal pressure

5.2.2.1 Subject to the conditions stated in 5.2.4 the wall thickness of pipes shall not be less than:

$$t = \frac{t_0 + b + c}{1 - a/100} \quad [\text{mm}]$$

$$t_0 = \frac{p \cdot D}{20 \cdot K \cdot e + p} \quad [\text{mm}]$$

t = minimum thickness

t₀ = theoretical thickness

p = design pressure [bar] referred to in 5.2.3

D = outside diameter [mm]

K = allowable stress [N/mm²] referred to in 5.2.4

e = efficiency factor where e is 1,0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by manufacturers approved for making welded pipes, which are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with the Rules. In other cases an efficiency factor less than 1,0 may be required by the Society depending on the manufacturing process.

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

$$b = \frac{D \cdot t_0}{2,5 \cdot r} \text{ [mm]}$$

r = mean radius of the bend

c = corrosion allowance [mm]. If corrosion or erosion is expected, the wall thickness of the piping is to be increased over that required by other design requirements. This allowance is to be consistent with the expected life of the piping.

a = negative manufacturing tolerance for wall thickness in [%].

5.2.3 Design pressure

5.2.3.1 The design pressure p in the formula for t_0 in 5.2.2.1 is the maximum gauge pressure to which the system may be subjected in service.

5.2.3.2 The greater of the following design conditions is to be used for piping, piping systems and components as appropriate:

- .1 for vapour piping systems or components which may be separated from their relief valves and which may contain some liquid, the saturated vapour pressure at 45 °C, or higher or lower if agreed upon by the Society (see 4.2.6.2); or
- .2 for systems or components which may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45 °C or higher or lower if agreed upon by the Society (see 4.2.6.2), 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; or
- .6 the relief valve setting on a pipe line system.

5.2.3.3 The design pressure is not to be less than 10 bar gauge except for open ended lines where it is not to be less than 5 bar gauge.

5.2.4 Permissible stress

5.2.4.1 For pipes the permissible stress to be considered in the formula for t in 5.2.2.1 is the lower of the following values:

$$K = \frac{R_m}{A} \quad \text{or} \quad K = \frac{R_{eH}}{B}$$

R_m = specified minimum tensile strength at room temperature [N/mm²]

R_{eH} = specified minimum yield stress at room temperature [N/mm²]. If the stress-strain curve does not show a defined yield stress, the 0,2 % proof stress applies.

The values of A and B are to be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and have values of at least:

$$A = 2,7 \quad \text{and} \quad B = 1,8.$$

5.2.4.2 The minimum thickness is to be in accordance with [Chapter 2 – Machinery Installations, Section 11, C.2](#).

5.2.4.3 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads from supports, ship deflection or other causes, the wall thickness is to be increased over that required 5.2.2, or, if this is impracticable or would cause excessive local stresses, these loads are to be reduced, protected against or eliminated by other design methods.

5.2.4.4 Flanges, valves and other fittings are to comply with recognized standards, taking into account the design pressure defined in 5.2.2. For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted.

5.2.4.5 For flanges not complying with a standard the dimensions of flanges and relative bolts are to be to the satisfaction of the Society.

5.2.5 Stress analysis

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

5.2.6 Materials

5.2.6.1 The choice and testing of materials used in piping systems are to comply with the requirements of [Section 6](#) taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of the material of open ended vent piping, provided the temperature of the cargo at the pressure relief valve setting is $-55\text{ }^{\circ}\text{C}$ or greater and provided no liquid discharge to the vent piping can occur. Similar relaxation may be permitted under the same temperature conditions to open ended piping inside cargo tanks, excluding discharge piping and all piping inside of membrane and semi-membrane tanks.

5.2.6.2 Materials having a melting point below $925\text{ }^{\circ}\text{C}$ are not to 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 is to be provided.

5.3 Type tests on piping components

5.3.1 Each type of piping component is to be subjected to type tests as follows:

5.3.2.1 Valves: Each size and type of valves intended to be used at a working temperature below $-55\text{ }^{\circ}\text{C}$ is to be subjected to a tightness test to the minimum design temperature or lower, and to a pressure not lower than the design pressure of the valves. During the test the satisfactory repeated operation of the valve is to be ascertained.

5.3.2.2 Expansion: The following type tests are to be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and, where required, on those expansion bellows installed within the cargo tanks:

- .1** A type element of the bellows, not precompressed, is to be pressure tested at not less than five times the design pressure without bursting. The duration of the test is to be not less than five minutes.
- .2** A pressure test on a type expansion joint complete with all the accessories such as flanges, stays and articulations, at twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation. Depending on the materials used, the Society may require the test to be conducted at the minimum design temperature.
- .3** A cyclic test (thermal movements) is to be performed on a complete expansion joint, which is to successfully 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 room temperature is permitted, when this testing is at least as severe as testing at the service temperature.

- .4** A cyclic fatigue test (ship deformation) is to be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least $2 \cdot 10^6$ cycles at a frequency not higher than 5 cycles/second. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.
- .5** The Society may waive performance of the tests referred to in this paragraph provided that complete documentation is supplied to establish the suitability of the expansion joints to withstand the expected working conditions. When the maximum internal pressure exceeds 1,0 bar gauge this documentation is to include sufficient test data to substantiate the design method used, with particular reference to correlation between calculation and test results.

5.4 Piping fabrication and joining details

5.4.1 The requirements of this paragraph apply to piping inside and outside the cargo tanks. Relaxations from these requirements may be accepted in accordance with recognized standards for piping inside cargo tanks and open ended piping.

5.4.2 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 below $-10\text{ }^{\circ}\text{C}$, butt welds are to be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 10 bar and design temperatures of $-10\text{ }^{\circ}\text{C}$ or lower, backing rings are to be removed.
- .2** Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards are to be used only for open ended lines with external diameter of 50 mm or less and design temperatures not lower than $-55\text{ }^{\circ}\text{C}$.
- .3** Screwed couplings in accordance with recognized standards are only to be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

5.4.3 Flange connections

5.4.3.1 Flanges in flange connections are to be of the welding neck, slip-on or socket welding type.

5.4.3.2 Flanges are to comply with recognized standards as to their type, manufacture and test. In particular, for all piping except open ended, the following restrictions apply:

- .1** For design temperatures lower than $-55\text{ }^{\circ}\text{C}$, only welding neck flanges are to be used.
- .2** For design temperatures lower than $-10\text{ }^{\circ}\text{C}$, slip-on flanges are not to be used in nominal sizes above 100 mm and socket welding flanges are not to be used in nominal sizes above 50 mm.

5.4.4 Piping connections, other than those mentioned in 5.4.2 and .3, may be accepted by the Society in each case.

5.4.5 Bellows and expansion joints are to be provided to allow for expansion of piping.

- .1** If necessary, bellows are to be protected against icing.
- .2** Slip joints are not to be used except within the cargo tanks.

5.4.6 Welding, postweld heat treatment and non-destructive testing:

- .1** Welding is to be carried out in accordance with 6.3.
- .2** Postweld heat treatment are to be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Society may waive the requirement for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.
- .3** 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 are required:
 - .3.1** 100 % radiographic inspection of butt welded joints for piping systems with design temperatures lower than $-10\text{ }^{\circ}\text{C}$ and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm.

When such butt welded joints of piping sections are made by automatic welding procedures in the pipe fabrication shop, upon special approval the extent of radiographic inspection may be progressively reduced but in no case to

less than 10 % of each joint. If defects are revealed the extent of examination shall be increased to 100 % and shall include inspection of previously accepted welds. This special approval can only be granted if well documented quality assurance procedures and records are available to enable the Society to assess the ability of the manufacturer to produce satisfactory welds consistently.

- .3.2** For other butt welded joints not covered by 5.4.6.3.1 of pipes, spot radiographic tests or other non-destructive tests are to 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 are to be radiographed.

5.5 Testing of piping

5.5.1 The requirements of this paragraph apply to piping inside and outside the cargo tanks. However, the Society may accept relaxations from these requirements for piping inside cargo tanks and open ended piping.

5.5.2 After assembly, all cargo and process piping are to be subjected to a hydrostatic test to at least 1,5 times the design pressure. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard ship. Joints welded on board are to be hydrostatically tested to at least 1,5 times the design pressure. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, proposals for alternative testing fluids or testing means are to be submitted to the Society for approval.

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

5.5.4 All piping systems including valves, fittings and associated equipment for handling cargo or vapours are to be tested under normal operating conditions not later than at the first loading operation.

5.6 Cargo system valving requirements

5.6.1 Every cargo piping system and cargo tank is to be provided with the following valves, as applicable:

- .1** For cargo tanks with a MARVS not exceeding 0,7 bar gauge, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, are to have shut-off

valves located as close to the tank as practicable. These valves may be remotely controlled but are to be capable of local manual operation and provide full closure. One or more remotely controlled emergency shut-down valves are to be provided on the ship for shutting down liquid and vapour cargo transfer between ship and shore. Such valves may be arranged to suit the ship's design and may be the same valve as required in 5.6.3 and shall comply with the requirements of 5.6.4.

- .2 For cargo tanks with a MARVS exceeding 0,7 bar, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, are to be equipped with a manually operated stop valve and a remotely controlled emergency shut-down valve. These valves are to be located as close to the tank as practicable. Where the pipe size does not exceed 50 mm in diameter, excess flow valves may be used in lieu of the emergency shut-down valve. A single valve may be substituted for the two separate valves provided the valve complies with the requirements of 5.6.4 is capable of local manual operation and provides full closure of the line.
- .3 Cargo pumps and compressors shall be arranged to shut-down automatically if the emergency shut-down valves required by 5.6.1.1 and .2 of this paragraph are closed by the emergency shut-down system required by 5.6.4.

5.6.2 Cargo tank connections for gauging or measuring devices need not be equipped with excess flow or emergency shut-down 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.

5.6-0.1 The requirements of 5.6.2, providing relaxations for cargo tanks referred to in 5.6.1.2 (type C cargo tanks), do not apply to cargo tank connections for gauging or measuring devices of cargo tanks referred to in 5.6.1.1.

5.6.3 One remote operated, emergency shut-down valve is to be provided at each cargo hose connection in use. Connections not used in transfer operations may be blinded with blank flanges in lieu of valves.

5.6.4 The control system for all required emergency shutdown valves shall be so arranged that all such valves may be operated by single controls situated in at least two remote locations on the ship. One of these locations shall be the control position required by 13.1.3 or cargo control room. The control system shall also be provided with fusible elements designed to melt at temperatures between 98 °C and 104 °C which will cause the emergency shutdown valves to close in the event of fire. Locations for such fusible

elements shall include the tank domes and loading stations. Emergency shutdown valves shall be of the fail-closed (closed on loss of power) type and be capable of local manual closing operation. Emergency shutdown valves in liquid piping shall fully close under all service conditions within 30 s of actuation as measured from the time of manual or automatic initiation to final closure. This is called the total shutdown time and is made up of a signal response time and a valve closure time. The valve closure time should be such as to avoid surge pressures in pipelines. Information about the closing time of the valves and their operating characteristics shall be available on board and the valve closure time should be verifiable and reproducible. Such valves shall close in such a manner as to cut off the flow smoothly.

5.6.5 Excess flow valves shall close automatically at the rated closing flow of vapour or liquid as specified by the manufacturer. The piping, including fittings, valves, and appurtenances protected by an excess flow valve, shall have a greater capacity than the rated closing flow of the excess flow valve. Excess flow valves may be designed with a by-pass not exceeding an area of 1,0 mm diameter circular opening to allow equalization of pressure, after an operating shut-down.

5.7 Ship's cargo hoses

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

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

5.7.3 Cargo hoses supplied on board ships on or after 1 July 2002 shall be prototype tested, complete with end-fittings, at a normal ambient temperature with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test shall demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the extreme service temperature. Hoses used for prototype testing are not to be used for cargo service. Thereafter, before being placed in service, each new length of cargo hose produced is to be hydrostatically tested at ambient temperature to a pressure not less than 1,5 times its specified maximum working pressure nor more than two-fifths its bursting pressure. The hose is to be stencilled or otherwise marked with its specified maximum working pressure, and if used in other than ambient temperature services, its maximum and/or minimum temperature. The specified maximum working pressure shall not be less than 10 bar gauge.

5.8 Cargo transfer methods

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

5.8.2 The procedure for transfer of cargo by gas pressurisation must preclude lifting of the relief valves

during such transfer. Gas pressurisation may be accepted as a means of transfer of cargo for those tanks so designed that the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation.

5.9 Vapour return connections

Connections for vapour return lines to the shore installation are to be provided.

Section 6

Materials of Construction

6.1 General

6.1.1 With regard to this Section reference is made to the Unified Requirement W1 of the International Association of Classification Societies (IACS).

6.1.2 This Section gives the requirements for plates, sections, pipes, forgings, castings and weldments used in the construction of cargo tanks, cargo process pressure vessels, cargo and process piping, secondary barriers and contiguous hull structures associated with the transportation of the products. The requirements for rolled materials, forgings and castings are given in 6.2 and Tables 6.1 to 6.5. The requirements for weldments are given in 6.3.

6.1.3 The manufacture, testing, inspection and documentation are to be in accordance with the Rules II - Materials and Welding, Part 1 – Metallic Materials, and the specific requirements given in this Section.

6.1.4.1 Acceptance tests are to include Charpy V-notch toughness tests, unless otherwise specified by the Society. 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 are to be in accordance with the Rules II - Materials and Welding, Part 1 – Metallic Materials. The testing and requirements for smaller than 5,0 mm size specimens are to be specially considered by the Society. Minimum average values for subsized specimens are to be:

Charpy V-notch specimen size	Minimum energy average of 3 specimens
10 × 10,0 mm	E
10 × 7,5 mm	5/6 E
10 × 5,0 mm	2/3 E

E = the values of energy [J] specified in Tables 6.1 to 6.4.

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

6.1.4.2 In all cases, the largest size Charpy specimens possible for the material thickness shall be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface, (see Fig. 6.1). If the average value of the three initial Charpy V-notch specimens fails to meet the stated requirements, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results combined with those previously obtained to form a new average. If this new average complies with the requirements and if no more than two individual results are lower than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted. At the discretion of the Society other types of toughness tests such as a drop weight test may be used. These may be either in addition to or in lieu of the Charpy V-notch test.

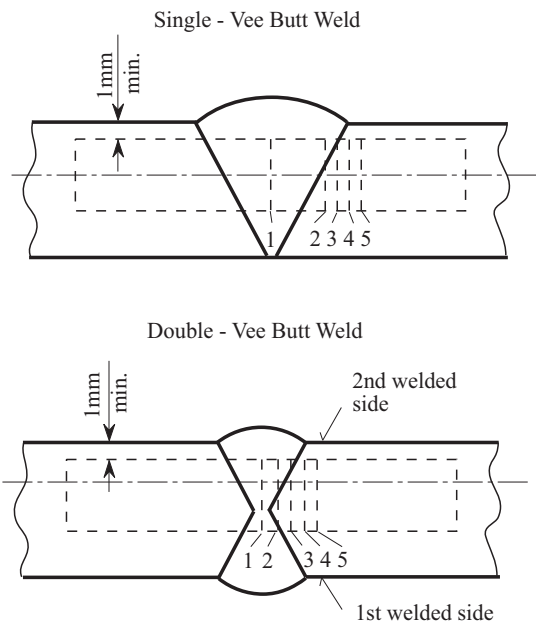
6.1.5 Tensile strength, yield stress and elongation are to be approved by the Society. For carbon-manganese steel and other materials with definitive yield points consideration is to be given to the limitation of the yield to tensile ratio.

6.1.6 The bend test may be omitted as a material acceptance test, but is required for weld tests.

6.1.7 Materials with alternative chemical composition or mechanical properties may be accepted by the Society.

6.1.8 Where postweld heat treatment is specified or required the properties of the base material are to be determined in the heat treated condition in accordance with the applicable Table of this Section and the weld properties are to be determined in the heat treated condition in accordance with 6.3. In cases where a postweld heat treatment is applied, the test requirements may be modified at the discretion of the Society.

6.1.9 Where reference is made in this Chapter to A, B, D, E, AH, DH and EH hull structural steels, these steel grades are hull structural steels according to the Rules II - Materials and Welding, Part 1 – Metallic Materials.



Notch location:

- 1. Centre of weld
 - 2. On fusion line
 - 3. In HAZ, 1 mm from fusion line
 - 4. In HAZ, 3 mm from fusion line
 - 5. In HAZ, 5 mm from fusion line
- HAZ = heat affected zone

The largest Charpy specimens possible for the material thickness are to be machined with the centre of the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases, the distance from the surface of the material to the edge of the specimen is to be approximately 1 mm or greater. In addition for double-vee butt welds, specimens are to be machined closer to the surface of the second welded side.

Fig. 6.1 Orientation of Weld Test Specimen

6.2 Material requirements

The requirements for materials of construction in the Tables are as follows:

Table 6.1: Plates, pipes (seamless and welded), sections and forgings for cargo tanks, and process pressure vessels for design temperatures not lower than 0 °C.

Table 6.2: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0 °C and down to – 55 °C (alloy steels and aluminium alloys).

Table 6.3: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below – 55 °C and down to – 165 °C.

Table 6.4: Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0 °C and down to – 165 °C.

Table 6.5: Plates and sections for hull structures required by 4.9.1 and 4.9.4.

Table 6.1 **Plates, Pipes (seamless and welded) ¹, Sections and Forgings for Cargo Tanks and Process Pressure Vessels for Design Temperatures not lower than 0 °C**

Chemical Composition and Heat Treatment		
Carbon-Manganese Steel	Fully killed	
	Fine grain steel when thickness exceeds 20 mm.	
	Small additions of alloying elements by agreement with the Society	
	Composition limits to be approved by the Society.	
	Normalized, or quenched and tempered. ²	
Tensile and Toughness (Impact) Test Requirements		
Plates	Each "piece" to be tested	
Sections and Forgings	Batch test	
Tensile Properties	Specified minimum yield stress not to exceed 410 N/mm ² ³	
Charpy V-notch Test		
Plates	Transverse test pieces. Minimum average energy value (E) 27 J	
Sections and Forgings	Longitudinal test pieces. Minimum average energy value (E) 41 J	
Test Temperature	Thickness [mm]	Test Temperature [°C]
	t ≤ 20	0
	20 < t ≤ 40	– 20
Notes:		
¹ For seamless pipes and fittings normal practice applies. The use of longitudinally and spirally welded pipes is to be specially approved by the Society.		
² Thermo-mechanically rolled steels may be accepted as an alternative to normalized or quenched and tempered steels subject to special approval by the Society.		
³ Materials with specified minimum yield stress exceeding 410 N/mm ² may be specially approved by the Society. For these materials, particular attention is to be given to the hardness of the weld and heat affected zone.		

Table 6.2 Plates, Sections and Forgings¹ for Cargo Tanks, Secondary Barriers and Process Pressure Vessels for Design Temperatures below 0 °C and down to – 55 °CMaximum Thickness² 25 mm**Chemical Composition and Heat Treatment****Carbon-Manganese Steel** Fully killed Aluminium treated fine grain steel**Chemical composition (ladle analysis):**

C	Mn	Si	S	P
0,16 % max. ³	0,70 – 1,60 %	0,10 – 0,50 %	0,035 % max.	0,035 % max.

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

Ni	Cr	Mo	Cu	Nb	V
0,80 % max.	0,25 % max.	0,08 % max.	0,35 % max.	0,05 % max.	0,10 % max.

Normalized or quenched and tempered⁴.**Tensile and Toughness (Impact) Test Requirements****Plates** Each "piece" to be tested**Sections and Forgings** Batch test**Charpy V-notch Test** Test temperature 5 °C below the design temp. or – 20 °C whichever is lower.**Plates** Transverse test pieces. Minimum average energy value (E) 27 J**Sections and forgings¹** Longitudinal test pieces. Minimum average energy value (E) 41 J.**Notes:**¹ The Charpy V-notch and chemistry requirements for forgings may be specially considered by the Society.² For materials exceeding 25 mm in thickness, Charpy V-notch tests are to be conducted as follows:

Thickness [mm]	Test Temperature [°C]
25 < t ≤ 30	10° below design temperature or – 20° whichever is lower
30 < t ≤ 35	15° below design temperature or – 20° whichever is lower
35 < t ≤ 40	20° below design temperature

The impact energy value is to be in accordance with the table for the applicable type test specimen. For materials exceeding 40 mm in thickness, the Charpy V-notch values are to be specially considered.

Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5 °C below the design temperature or – 20 °C whichever is lower. For thermally stress relieved reinforcements and other fittings, the test temperature is to be the same as that required for the adjacent tank shell thickness.

³ By special agreement with the Society the carbon content may be increased to 0,18 % maximum provided the design temperature is not lower than – 40 °C.⁴ Thermo-mechanically rolled steels may be accepted as an alternative to normalized or quenched and tempered steels subject to special approval by the Society.**Guidance***For materials exceeding 25 mm in thickness for which the test temperature is – 60 °C or lower, the application of specially treated steels or steels in accordance with table 6.3 may be necessary.*

Table 6.3 Plates, Sections and Forgings ¹ for Cargo Tanks, Secondary Barriers and Process Pressure Vessels for Design Temperatures below – 55 °C and down to – 165 °C ².Maximum Thickness ³ 25 mm

Minimum design temperature [°C]	Chemical composition ⁴ and heat treatment	Impact test temperature [°C]
– 60	1,5 % Nickel steel – normalized	– 65
– 65	2,25 % Nickel steel – normalized or normalized and tempered ⁵	– 70
– 90	3,5 % Nickel steel – normalized or normalized and tempered ⁵	– 95
– 105	5 % Nickel steel – normalized or normalized and tempered ^{5, 6}	– 110
– 165	9 % Nickel steel – double normalized and tempered or quenched and tempered	– 196
– 165	Austenitic steels (e.g. type 304, 304L, 316, 316L, 321 and 347) Solution treated ⁷	– 196
– 165	Aluminium alloys; e.g. type 5083 annealed	Not required
– 165	Austenitic Fe-Ni alloy (36 % nickel) heat treatment as agreed	Not required

Tensile and Toughness (Impact) Test Requirements**Plates** Each "piece" to be tested**Sections and Forgings** Batch test**Charpy V-notch Test****Plates** Transverse test pieces. Minimum average energy value (E) 27 J**Sections and forgings** Longitudinal test pieces. Minimum average energy value (E) 41 J.**Notes:**

- ¹ The Impact test requirement for forgings used in critical applications will be subject to special consideration.
- ² The requirements for design temperature below – 165 °C are to be specially agreed with the Society.
- ³ For materials 1,5 % Ni, 2,25 % Ni, 3,5 % Ni and 5 % Ni, with thickness exceeding 25 mm, the impact tests are to be conducted as follows:

Thickness [mm]	Test Temperature [°C]
25 < t ≤ 30	10° below design temperature
30 < t ≤ 35	15° below design temperature
35 < t ≤ 40	20° below design temperature

In no case shall the test temperature be above that indicated in the table.

The energy value is to be in accordance with the table for the applicable type of test specimen. For materials exceeding 40 mm in thickness, the Charpy V-notch values are to be specially considered. For 9 % Ni, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used at the discretion of the Society.

- ⁴ The chemical composition limits are to be approved by the Society.
- ⁵ A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Society.
- ⁶ A specially heat treated 5 % Nickel steel, for example a triple heat treated 5 % Nickel steel may be used down to – 165 °C upon special agreement with the Society, provided that the impact tests are carried out at – 196 °C.
- ⁷ The impact test may be omitted subject to the agreement with the Society.

Minimum design temperature of hull structures [°C]	Maximum thickness [mm] for steel grades in accordance with 6.1.9						
	A	B	D	E	AH	DH	EH
0 and above ¹ – 5 and above ²	In accordance with Chapter 1 – Hull Structures, Section 2						
down to – 5	15	25	30	50	25	45	50
down to – 10	—	20	25	50	20	40	50
down to – 20	—	—	20	50	—	30	50
down to – 30	—	—	—	40	—	20	40
below – 30	In accordance with Table 6.2 except that the thickness limitation given in Table 6.2 and the supplementary requirements for thicker material given in footnote (2) of that table do not apply.						

Notes:

¹ for the purpose of 4.9.4

² for the purpose of 4.9.1

6.3 Welding and non-destructive testing

6.3.1 General

The requirements of this Section are those generally employed for carbon, carbon-manganese, nickel alloy and stainless steels, and may form the basis for acceptance testing of other material. At the discretion of the Society impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests be specially required for any material.

6.3.2 Welding consumables

Welding consumables intended for welding of cargo tanks process pressure vessels and secondary barriers are to be in accordance with the Rules II - Materials and Welding, Part 3 – Welding, unless otherwise agreed with the Society. Deposited weld metal tests and butt weld tests are to be required for all welding consumables, unless otherwise specially agreed with the Society. The results obtained from tensile and Charpy V-notch impact tests are to be in accordance with the Rules II - Materials and Welding, Part 3 – Welding. The chemical composition of the deposited weld metal is to be recorded for information and approval.

6.3.3 Welding procedure tests for cargo tanks, process pressure vessels and secondary barriers

6.3.3.1 Welding procedure tests for cargo tanks, process pressure vessels and secondary barriers are required for all butt welds and the test assemblies are to be representative of:

- each base material
- each type of consumable and welding process
- each welding position

For butt welds in plates, the test assemblies are to be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test is to be approved by the Society. Radiographic or ultrasonic testing may be performed at the option of the manufacturer 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.

6.3.3.2 The following welding procedure tests are required from each test assembly:

- .1** Cross-weld tensile tests
- .2** Transverse bend tests:

These bend tests may be face, root or side bends at the discretion of the Society. However, longitudinal bend tests may be required in

lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

- .3** One set of three Charpy V-notch impact tests is to be made generally at each of the following locations, as shown in Figure 6.1:

Centre line of the welds

Fusion line (F.L.)

1 mm from the F.L.

3 mm from the F.L.

5 mm from the F.L.

- .4** Macrosection, microsection and hardness survey may also be required by the Society.

6.3.4 Test requirements

6.3.4.1 Tensile tests

Generally tensile strength is not to 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 for the weld metal, where the weld metal has a lower tensile strength than that of the parent metal. In every case, the position of fracture is to be reported for information.

6.3.4.2 Bend tests

No fracture is acceptable after a 180° bend over a former of a diameter four times the thickness of the test pieces, unless otherwise specially required by or agreed with the Society.

6.3.4.3 Charpy V-notch impact tests

Charpy tests are to be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (E), are to be not less than 27 J. The weld metal requirements for subsize specimens and single energy values are to be in accordance with 6.1.4. The results of fusion line and heat affected zone impact tests are to have a minimum average energy (E) in accordance with the transverse or longitudinal requirements of the base material, whichever is applicable, and for subsize specimens, the minimum average energy (E) is to be generally in accordance with 6.1.4. If the material thickness does not permit machining either full size or standard specimens, the testing procedure and acceptance standards are to be approved by the Society.

6.3.5 Welding procedure test for piping

Welding procedure tests for piping are to be carried out and are to be similar to those detailed for cargo tanks in 6.3.3. Unless otherwise specially agreed with

the Society, the test requirements are to be in accordance with 6.3.4.

6.3.6 Production weld tests

6.3.6.1 For all cargo tanks and process pressure vessels except integral and membrane tanks, production tests are generally to be performed for approximately each 50 m of butt weld joints and are to be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks are to be performed except that the number of tests may be reduced subject to agreement with the Society. Tests, other than those specified in 6.3.6.2, .3 and .4 may be required for cargo tanks or secondary barriers at the discretion of the Society.

6.3.6.2 The production tests for independent tanks types A and B and semi-membrane tanks are to include the following tests:

- .1** Bend tests, and where required for procedure tests one set of three Charpy V-notch tests is to be made for each 50 m of weld. The specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches are to be in the centre of the weld.
- .2** The test requirements are the same as the applicable test requirements listed in 6.3.4 except that impact tests that do not meet the prescribed energy requirements may still be accepted, upon special consideration of the Society by passing a drop weight test. In such cases, two drop weight specimens are to be tested for each set of Charpy specimens that failed and both must show "no break" performance at the temperature at which the Charpy tests were conducted.

6.3.6.3 In addition to those tests listed in 6.3.6.2.1 for type C independent tank and process pressure vessels, transverse weld tensile tests are required. The test requirements are listed in 6.3.4 except that impact tests that do not meet the prescribed energy requirements may still be accepted upon special consideration by the Society, by passing a drop weight test. In such cases, two drop weight specimens are to be tested for each set of Charpy specimens that failed, and both must show "no break" performance at the temperature at which the Charpy tests were conducted.

6.3.6.4 Production tests for integral and membrane tanks are to be specially agreed with the Society.

6.3.7 Non-destructive testing

6.3.7.1 For type A independent tanks and semi-membrane tanks where the design temperature is -20°C or lower, and for independent tanks type B regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks are to be subjected to 100 % radiographic inspection.

- .1** 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 are to be subjected to radiographic inspection.
- .2** In each case the remaining tank structure including the welding of stiffeners and other fittings and attachments are to be examined by magnetic particle or dye penetrant methods as considered necessary by the Society.
- .3** All testing procedures and acceptance standards are to be approved by the Society. The Society may accept an approved ultrasonic testing procedure in lieu of radiographic inspection, but may in addition require supplementary inspection by radiography at selected locations. Further, the Society may require ultrasonic testing in addition to normal radiographic inspection.

6.3.7.2 Inspection of independent tanks type C and process pressure vessels are to be carried out in accordance with [Section 4.10.9](#).

6.3.7.3 For integral and membrane tanks, special weld inspection procedures and acceptance criteria are to be submitted for approval by the Society.

6.3.7.4 The inspection and non-destructive testing of the inner hull or the independent tank structures supporting internal insulation tanks is to take into account the design criteria as given in 4.4.7. The schedule for inspection and non-destructive testing is to be to the satisfaction of the Society.

6.3.7.5 Inspection of piping is to be carried out in accordance with the requirements of [Section 5](#).

6.3.7.6 The secondary barrier is to be radiographed as considered necessary by the Society. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell are to be tested by radiography.

Section 7

Cargo Pressure / Temperature Control

7.1 General

7.1.1 Unless the entire cargo system is designed to withstand the full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, maintenance of the cargo tank pressure below the MARVS is to be provided by one or more of the following means, except as otherwise provided in this Section.

- .1** A system which regulates the pressure in the cargo tanks by the use of mechanical refrigeration.
- .2** A system whereby the boil-off vapours are utilised as fuel for shipboard use and/or waste heat system subject to the provisions of [Section 16](#). This system may be used at all times, including while in port and while manoeuvring, provided that a means of disposing of excess energy is provided, such as a steam dump system, that is satisfactory to the Society.
- .3** A system allowing the product to warm up and increase in pressure. The insulation or cargo tank design pressure or both is to be adequate to provide for a suitable margin for the operating time and temperatures involved. The system is to be acceptable to the Society in each case.
- .4** Other systems acceptable to the Society.
- .5** In addition to the above means, the Society 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.

Guidance

For ships trading to territorial waters of the United States of America the relevant requirements for cargo temperature/pressure control of the US Coast Guard, given in 46 CFR (Code of Federal Register) Part 154, § 154.702/703 should be observed.

7.1.2 The systems required by 7.1.1 are to be constructed, fitted and tested to the satisfaction of the Society. Materials used in their construction are to be suitable for use with the cargoes to be carried. For normal service, the upper ambient design temperatures shall be:

Sea: 32 °C

Air: 45 °C.

For service in especially hot or cold zones these design temperatures are to be increased or reduced as appropriate by the Society.

7.1.3 For certain highly dangerous cargoes specified in [Section 17](#), the cargo containment system is to 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.

7.2 Refrigeration systems

7.2.1 A refrigeration system shall consist of one or more units capable of maintaining the required cargo pressure/temperature under conditions of the upper ambient design temperatures. Unless an alternative means of controlling the cargo pressure/ temperature is provided to the satisfaction of the Society, a stand-by unit (or units) affording spare capacity at least equal to the largest required single unit is to be provided. A "stand-by unit" shall consist of a compressor with its driving motor, control system and any necessary fittings to permit operation independently of the normal service units. A stand-by heat exchanger is to be provided unless the normal heat exchanger for the unit has an excess capacity of at least 25 % of the largest required capacity. Separate piping systems are not required.

7.2.2.1 Where two or more refrigerated cargoes which may react chemically in a dangerous manner are carried simultaneously, special consideration is to be given to the refrigeration systems to avoid the possibility of mixing cargoes. For the carriage of such cargoes separate refrigeration systems each complete with a stand-by unit as specified in 7.2.1 are to be provided for each cargo. However, where cooling is provided by an indirect or combined system and leakage in the heat exchangers cannot cause mixing of the cargoes under any envisaged condition, separate refrigeration units need not be fitted.

7.2.2.2 Where two or more refrigerated cargoes are not mutually soluble under the conditions of carriage, so that their vapour pressures would be additive on mixing, special consideration is to be given to the refrigeration systems to avoid the possibility of mixing cargoes.

7.2.3 Where cooling water is required in refrigeration systems, an adequate supply is to be provided by a pump or pumps used exclusively for this purpose. This pump or these pumps are to have at least two sea suction lines, where practicable leading from sea-chests one port and one starboard. A spare pump of adequate capacity is to be provided which may be a pump used for other services so long as its use for cooling would not interfere with any other essential service.

7.2.4 The refrigeration system may be arranged in one of the following ways:

- .1** a direct system where evaporated cargo is compressed, condensed and returned to cargo tanks. For certain cargoes specified in [Section 17](#) this system shall not be used;

- .2** an indirect system where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed",

- .3** a combined system where evaporated cargo is compressed and condensed in a cargo/ refrigerant heat exchanger and returned to the cargo tanks. For certain cargoes specified in Section 17 this system shall not be used (see also 17.4).

7.2.5 All primary and secondary refrigerants must be compatible with each other and with the cargo with which they may come into contact. The heat exchange may take place either remotely from the cargo tank or by cooling coils fitted inside or outside the cargo tank.

Section 8

Cargo Vent Systems

8.1 General

All cargo tanks are to be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold spaces, interbarrier spaces and cargo piping which may be subject to pressures beyond their design capabilities are also to be provided with a suitable pressure relief system. The pressure relief system is to be connected to a vent piping system designed so as to minimize the possibility of cargo vapour accumulating about the decks, or entering accommodation spaces, service spaces and control stations, and machinery spaces, or other spaces where it may create a dangerous condition. Pressure control systems specified by [Section 7](#) are to be independent of the pressure relief valves.

8.2 Pressure relief systems

8.2.1 Each cargo tank with a volume exceeding 20 m³ is to be fitted with at least two pressure relief valves of approximately equal capacity, suitably designed and constructed for the prescribed service. For cargo tanks with a volume not exceeding 20 m³, a single relief valve may be fitted.

8.2-0.1 If cargo holds with independent tanks may be completely closed, overpressure/vacuum relief valves are to be provided for in order to avoid pressure variations of more than 0,15 bar above and below atmospheric pressure.

8.2.2 Interbarrier spaces are to be provided with pressure relief devices complying with recognized standards.

8.2-0.2 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:

$$Q_{sa} = 3,4 \cdot A_c \frac{\rho}{\rho_v} \sqrt{h} \quad \left[\text{m}^3/\text{s} \right]$$

Q_{sa} = minimum required discharge rate of air at standard conditions of 273 K and 1,013 bar

A_c = design crack opening area [m²]

$$A_c = \frac{\pi}{4} \delta \cdot \ell \quad \left[\text{m}^2 \right]$$

δ = max. crack opening width [m]

δ = 0,2 · t [m]

t = thickness of tank bottom plating [m]

ℓ = design crack length [m] equal to the diagonal of the largest plate panel of the tank bottom

h = max. liquid height above tank bottom plus 10 · MARVS [m]

ρ = density of product liquid phase [kN/m³] at the set pressure of the interbarrier space relief device

ρ_v = density of product vapour phase [kN/m³] at the set pressure of the interbarrier space relief device and a temperature of 273 K.

8.2.3 In general, the setting of the pressure relief valves shall not be higher than the vapour pressure which has been used in the design of the tank. However, where two or more pressure relief valves are fitted, valves comprising not more than 50 percent of the total relieving capacity may be set at a pressure up to five percent above MARVS.

8.2.4 Pressure relief valves are to be connected to the highest part of the cargo tank above deck level. Pressure relief valves on cargo tanks with a design temperature below 0 °C are to be arranged to prevent their becoming inoperative due to ice formation when they are closed. Due consideration is to be given to the construction and arrangement of pressure relief valves on cargo tanks subject to low ambient temperatures.

Valves are to be constructed of materials with a melting point above 925 °C. Consideration of lower melting point materials for internal parts and seals shall be given if their use provides significant improvement to the general operation of the valve.

8.2.5 Pressure relief valves are to be prototype tested to ensure that the valves have the capacity required. Each valve is to be tested to ensure that it opens at the prescribed pressure setting with an allowance not exceeding:

- ± 10 % for 0 to 1,5 bar,
- ± 6 % for 1,5 to 3,0 bar,
- ± 3 % for 3,0 bar and above.

Pressure relief valves are to be set and sealed by the Society and a record of this action, including the values of set pressure, is to be retained aboard the ship.

8.2-0.3 Prototype testing includes testing at design temperature.

8.2.6 In the case of cargo tanks permitted to have more than one relief valve setting, this may be accomplished by:

- .1** installing two or more properly set and sealed valves and providing means as necessary for isolating the valves not in use from the cargo tank; and
- .2** installing relief valves whose settings may be changed by the insertion of previously approved spacer pieces or alternative springs or by other similar means not requiring pressure testing to verify the new set pressure. All other valve adjustments are to be sealed.

8.2.7 The changing of the set pressure under the provisions of 8.2.6 and the corresponding resetting of the alarms referred to in 13.4.1, shall be carried out under the supervision of the master in accordance with procedures approved by GL and specified in the ship's operating manual. Changes in set pressures are to be recorded in the ship's log and a sign posted in the cargo control room, if provided, and at each relief valve, stating the set pressure.

8.2.8 Stop valves or other means of blanking off pipes between tanks and pressure relief valves to facilitate maintenance are not to be fitted unless all the following arrangements are provided:

- .1** suitable arrangements to prevent more than one pressure relief valve being out of service at the same time;
- .2** a device which automatically and in a clearly visible way indicates which one of the pressure relief valves is out of service; and
- .3** pressure relief valve capacities are such that if one valve is out of service the remaining valves are to have the combined relieving capacity required by 8.5. However, this capacity may be provided by the combined capacity of all valves if a suitably maintained spare valve is carried on board.

8.2.9 Each pressure relief valve installed on a cargo tank is to be connected to a venting system, which is

to be so constructed that the discharge of gas will be unimpeded and directed vertically upwards at the exit and so arranged as to minimize the possibility of water or snow entering the vent system. The height of vent exits is to be not less than $B/3$ or 6 m whichever is greater, above the weather deck and 6 m above the working area and the fore and aft gangway, deck storage tanks and cargo liquid lines.

8.2.10 Cargo tank pressure relief valve vent exits are to be arranged at a distance at least equal to B or 25 m, whichever is less, from the nearest air intake or opening to accommodation, service and control station spaces, or other gas safe spaces. For ships less than 90 m in length, smaller distances may be permitted by the Society. All other vent exits connected to the cargo containment system are to be arranged at a distance of at least 10 m from the nearest air intake or opening to accommodation spaces, service spaces and control stations, or other gas safe spaces.

8.2.11 All other cargo vent exits not dealt with in other Sections are to be arranged in accordance with 8.2.9 and 8.2.10.

8.2.12 If cargoes which react in a hazardous manner with each other are carried simultaneously, a separate pressure relief system is to be fitted for each cargo carried.

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

8.2.14 Suitable protection screens are to be fitted on vent outlets to prevent the ingress of foreign objects.

8.2.15 All vent piping is to be so designed and arranged that it will not be damaged by temperature variations to which it may be exposed, or by the ship's motions.

8.2.16 The back pressure in the vent lines from the pressure relief valves are to be taken into account in determining the flow capacity required by 8.5.

The pressure drop in the vent line from the tank to the pressure relief valve inlet shall not exceed 3 percent of the valve set pressure. For unbalanced pressure relief valves the back pressure in the discharge line shall not exceed 10 percent of the gauge pressure at the relief valve inlet with the vent lines under fire exposure as referred to in 8.5.2.

8.2.17 Pressure relief valves are to be positioned on the cargo tank so that they will remain in the vapour phase under conditions of 15° list and 0,015 L_c trim,

where L_c is as defined in Section 1, C.23, at the maximum allowable filling limit (FL).

8.2.18 The adequacy of the vent system fitted on tanks loaded in accordance with 15.1.5 is to be demonstrated using Guidelines developed by the Organization. A relevant certificate shall be permanently kept on board the vessel. For the purposes of this paragraph, vent system means:

- .1 the tank outlet and the piping to the pressure relief valve;
- .2 the pressure relief valve;
- .3 the piping from the pressure relief valve to the location of discharge to the atmosphere and including any interconnections and piping which joins other tanks.

8.2-0.4 The Guidelines mentioned in 8.2.18 are given in Annex A to this Chapter.

8.3 Additional pressure relieving system for liquid level control

8.3.1 Where required by 15.1.4.2, an additional pressure relieving system to prevent the tank from becoming liquid full at any time during relief under the fire conditions referred to in 8.5 is to be fitted to each tank. This pressure relieving system is to consist of:

- .1 one or more relief valves set at a pressure corresponding to the gauge vapour pressure of the cargo at the reference temperature defined in 15.1.4.2; and
- .2 an over-ride arrangement, whenever necessary, to prevent its normal operation. This arrangement shall include fusible elements designed to melt at temperatures between 98 °C and 104 °C and to cause relief valves specified in 8.3.1.1 to become operable. The fusible elements shall be located, in particular, in the vicinity of the relief valves. The system shall become operable upon loss of system power if provided. The over-ride arrangement shall not be dependent on any source of ship's power.

8.3.2 The total relieving capacity of the additional pressure relieving system at the pressure mentioned in 8.3.1.1 is not to be less than:

$$Q' = F \cdot G' \cdot A^{0.82} \left[m^3/s \right]$$

Q' = minimum required equivalent rate of discharge of air at standard conditions of 273 K and 1,013 bar.

G' = gas factor:

$$= \frac{12,4}{(r + \rho_r \cdot m)D} \sqrt{\frac{Z \cdot T'}{M}}$$

ρ_r = relative density of liquid phase of product at relieving conditions ($\rho_r = 1,0$ for fresh water)

m = $-d i/d \rho_r$ = gradient of decrease of liquid phase enthalpy against increase of liquid phase relative density [kJ/kg] at relieving conditions. For set pressures not higher than 2,0 bar, the values in Table 8.1 may be used. For products not listed in the table and for higher set pressures, the value of m is to be calculated on the basis of the thermodynamic data of the product itself.

i = enthalpy of liquid [kJ/kg]

T' = temperature at relieving conditions [K], i.e. at the pressure at which the additional pressure relieving system is set

F , A , r , D , Z and M are defined in 8.5.2.

8.3.3 Compliance with 8.3.1.1 requires changing of the setting of the relief valves provided for in this section. This is to be accomplished in accordance with the provisions of 8.2.6 and 8.2.7.

Table 8.1 Factor m

Product	$m = -d i/d \rho_r$ [kJ/kg]
Ammonia, anhydrous	3400
Butadiene	1800
Butane	2000
Butylenes	1900
Ethane	2100
Ethylene	1500
Methane	2300
Methyl chloride	816
Nitrogen	400
Propane	2000
Propylene	1600
Propylene oxide	1550
Vinyl chloride	900

8.3.4 Relief valves mentioned under 8.3.1.1 above may be the same as the pressure relief valves mentioned in 8.2, provided the setting pressure and the relieving capacity are in compliance with the requirements of this section.

8.3.5 The exhaust of such pressure relief valves may be led to the venting system referred to in 8.2.9. If separate venting arrangements are fitted these are to be in accordance with the requirements of 8.2.9 to 8.2.15.

8.4 Vacuum protection systems

8.4.1 Cargo tanks designed to withstand a maximum external pressure differential exceeding 0,25 bar and capable of withstanding the maximum external pressure differential which can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operations of a cargo refrigeration system, need no vacuum relief protection.

8.4.2 Cargo tanks designed to withstand a maximum external pressure differential not exceeding 0,25 bar, or tanks which 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 sending boil-off vapour to the machinery spaces, are to be fitted with:

- .1** two independent pressure switches to sequential 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 design 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; or
- .3** other vacuum relief systems approved by the Society.

8.4.3 Subject to the requirements of Section 17, the vacuum relief valves shall admit an inert gas, cargo vapour or air to the cargo tank and are to be arranged to minimize the possibility of the entrance of water or snow. If cargo vapour is admitted, it shall be from a source other than the cargo vapour lines. Air shall not be admitted to the cargo tanks by the vacuum relief valves.

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

8.5 Size of valves

Pressure relief valves are to 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:

$$Q = F \cdot G \cdot A^{0,82} \left[\text{m}^3/\text{s} \right]$$

Q = minimum required equivalent rate of discharge of air at standard conditions of 273 K and 1,013 bar.

F = fire exposure factor for different cargo tank types:

- = 1,0 for 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 an approved fire proofing material, the thermal conductance of insulation, and its stability under fire exposure.);
- = 0,5 for uninsulated independent tanks installed in holds;
- = 0,2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);
- = 0,1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds);
- = 0,1 for membrane and semi-membrane tanks.

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

G = gas factor:

$$= \frac{12,4}{r \cdot D} \sqrt{\frac{Z \cdot T}{M}}$$

T = temperature [K] = (273 + °C) at the relieving conditions, i.e. 120 % of the pressure at which the pressure relief valve is set.

r = latent heat of the material being vaporized at relieving conditions [kJ/kg],

D = constant based on relation of specific heats (k), shown in Table 8.2; if k is not known $D = 0,606$ shall be used. The constant D may also be calculated by the following formula:

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

Z = compressibility factor of the gas at relieving conditions; if not known, $Z = 1,0$ shall be used.

M = molecular weight of the product.

A = external surface area of the tank [m²] for different tank types:

for body of revolution type tanks:

A = external surface area;

for other than bodies of revolution type tanks:

A = external surface area less the projected bottom surface area;

for tanks consisting of an array of pressure vessel tanks:

– insulation on the ship's structure:

A = external surface area of the hold less its projected bottom area;

– insulation on the tank structure:

A = external surface area of the array of pressure vessels excluding insulation, less the projected bottom area as shown in Fig. 8.1.

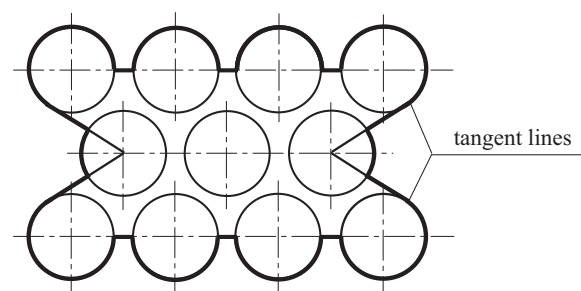


Fig. 8.1 External surface area

Table 8.2 Constant D

k	D	k	D
1,00	0,606	1,52	0,704
1,02	0,611	1,54	0,707
1,04	0,615	1,56	0,710
1,06	0,620	1,58	0,713
1,08	0,624	1,60	0,716
1,10	0,628	1,62	0,719
1,12	0,633	1,64	0,722
1,14	0,637	1,66	0,725
1,16	0,641	1,68	0,728
1,18	0,645	1,70	0,731
1,20	0,649	1,72	0,734
1,22	0,652	1,74	0,736
1,24	0,656	1,76	0,739
1,26	0,660	1,78	0,742
1,28	0,664	1,80	0,745
1,30	0,667	1,82	0,747
1,32	0,671	1,84	0,750
1,34	0,674	1,86	0,752
1,36	0,677	1,88	0,755
1,38	0,681	1,90	0,758
1,40	0,685	1,92	0,760
1,42	0,688	1,94	0,763
1,44	0,691	1,96	0,765
1,46	0,695	1,98	0,767
1,48	0,698	2,00	0,770
1,50	0,701	2,02	0,772
		2,20	0,792

Section 9

Environmental Control

9.1 Environmental control within cargo tanks and cargo piping systems

9.1.1 A piping system is to be provided to enable each cargo tank to be safely gas freed, and to be safely purged with cargo gas from a gas free condition. The system is to be arranged to minimize the possibility of pockets of gas or air remaining after gas freeing or purging.

9.1.2 A sufficient number of gas sampling points is to be provided for each cargo tank in order to adequately monitor the progress of purging and gas freeing. Gas sampling connections are to be valved and capped above the main deck.

9.1.3 For flammable gases, the system is to be arranged to minimize the possibility of a flammable mixture existing in the cargo tank during any part of the gas freeing operation by utilizing an inerting medium as an intermediate step. In addition, the system shall enable the cargo tank to be purged with an inerting medium prior to filling with cargo vapour or liquid, without permitting a flammable mixture to exist at any time within the cargo tank.

9.1.4 Piping systems which may contain cargo shall be capable of being gas freed and purged as provided in 9.1.1 and 9.1.3.

9.1.5 Inert gas utilized in these procedures may be furnished from ashore or from the ship.

9.2 Environmental control within hold spaces (cargo containment systems other than type C independent tanks)

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

9.2.2.1 Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring partial secondary barriers are to be inerted with suitable, dry inert gas and maintained inerted

with make-up gas provided by a shipboard inert gas generation system or by shipboard storage which are to be sufficient for normal consumption for at least thirty days.

9.2.2.2 Except as limited by [Section 17](#), the Society may allow the spaces referred to in 9.2.2.1 to be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces; and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensure that any leakage from the cargo tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand is to be provided.

9.2.3 For non-flammable gases, the spaces referred to in 9.2.1 and 9.2.2.1 may be maintained with a suitable dry air or inert atmosphere.

9.2.4 In case of internal insulation tanks, environmental control arrangements are not required for interbarrier spaces and spaces between the secondary barrier and the inner hull or independent tank structures completely filled with insulation material complying with 4.9.7.2.

9.3 Environmental control of hold spaces surrounding type C independent tanks

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

9.4 Inerting

9.4.1 Inerting refers to the process of providing a non-combustible environment by the addition of compatible gases, which may be carried in storage vessels or manufactured on board the ship or supplied from the shore. The inert gases shall be compatible chemically and operationally, at all temperatures likely to occur within the spaces to be inerted, with the

materials of construction of the spaces and the cargo. The dew points of the gases are to be taken into consideration.

9.4.2 Where inert gas is also stored for fire fighting purposes, it is to be carried in separate containers and shall not be used for cargo services.

9.4.3 Where inert gas is stored at temperatures below 0 °C, either as a liquid or vapour, the storage and supply system is to be so designed that the temperature of the ship's structure is not reduced below the limiting values imposed on it.

9.4.4 Arrangements suitable for the cargo carried are to be provided to prevent the back flow of cargo vapour into the inert gas system.

9.4.5 The arrangements are to be such that each space being inerted can be isolated and the necessary controls and relief valves etc. are to be provided for controlling pressure in these spaces.

9.5 Inert gas production on board

9.5.1 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 [Section 17](#). A continuous reading oxygen content meter is to be fitted to the inert gas supply from the equipment and is to be fitted with an alarm set at a maximum of 5 % oxygen content by volume subject to the requirements of Section 17. Additionally, where inert gas is made by an onboard process of fractional distillation of air which involves the storage of the cryogenic liquefied nitrogen for subsequent release, the liquefied gas entering the storage vessel is to be monitored for traces of oxygen to avoid possible initial high oxygen enrichment of the gas when released for inerting purposes.

9.5.-0.1 Inert gas plants are to comply with GL's requirements for inert gas systems for Tankers as given in [Chapter 2 – Machinery Installations, Section 15, D](#).

9.5.2 An inert gas system shall have pressure controls and monitoring arrangements appropriate to the cargo containment system. A means acceptable to the Society, located in the cargo area, of preventing return of cargo gas is to be provided.

9.5.3 Spaces containing inert gas generating plants shall have no direct access to accommodation, service or control station spaces, but may be located in machinery spaces. If such plants are located in machinery spaces or other spaces outside the cargo area, two non-return valves, or equivalent devices are to be fitted in the inert gas main in the cargo area as required in 9.5.2. Inert gas piping shall not pass through accommodation, service or control station spaces. When not in use, the inert gas system shall be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.

9.5.4 Flame burning equipment for generating inert gas is not to be located within the cargo area. Special consideration may be given to the location of inert gas generating equipment using the catalytic combustion process.

9.6 Inertgas plant for liquefied gas carriers above 20.000 tdw

For liquefied gas carriers intended to carry one or more of the products identified with an asterisk (*) in [Section 19](#) or products covered by [Chapter 7 - Chemical Tankers, Section 18](#) with a flash point ≤ 60 °C or oil products with a flash point ≤ 60 °C the requirements of [Chapter 7 – Chemical Tankers, Section 9.3](#) apply.

Section 10

Electric Installations

10.1 General

10.1.1 The provisions of this Section are applicable to ships carrying flammable products.

10.1.2 Electrical installations are to be such as to minimize the risk of fire and explosion from flammable products.* Electrical installations complying with this Section need not be considered as a source of ignition for the purpose of [Section 3](#).

*Refer to the relevant standards of the International Electrotechnical Commission, in particular publication 60092-502.

10.1.3 The requirements of Chapter 3 – Electrical Installation are to be complied with.

10.1.4 Electrical equipment or wiring is not to be installed in gas-dangerous spaces or zones unless essential for operational purposes. Electrical equipment, cables and wiring should not be installed in hazardous locations unless it conforms with the standards not inferior to those acceptable to the Organization*. However, for locations not covered by such standards, electrical equipment, cables and wiring which do not conform to the standards may be in-

stalled in hazardous locations based on a risk assessment to the satisfaction of the Society, to ensure that an equivalent level of safety is assured.

* Refer to the standards published by the International Electrotechnical Commission, IEC 60092-502:1999 ‘Electrical installations in ships – Tankers’.

10.1.5 Where electrical equipment is installed in gas-dangerous spaces or zones as provided in 10.1.4, it must be to the satisfaction of the Society and approved by the relevant Authorities recognized by the Society for operation in the flammable atmosphere concerned.

10.2 [Deleted]

10.3 Bonding

Independent cargo tanks are to be electrically bonded to the hull. All gasketed cargo pipe joints and hose connections are to be electrically bonded. (See also 5.2.1.4.)

Section 11

Fire Protection and Fire Extinction

11.1 Fire safety requirements

11.1.1 The requirements for tankers in **SOLAS** Chapter II-2 (see [Section 1, C.34](#)) apply to liquefied gas carriers, irrespective of tonnage including ships of less than 500 gross tonnage, except that:

- .1 Regulations 4.5.1.6 and 4.5.10 do not apply;
- .2 Regulation 10.2 as applicable to cargo ships and regulations 10.4 and 10.5 should apply as they would apply to tankers of 2,000 gross tonnage and over;
- .3 Regulation 10.5.6 should apply to ships of 2,000 gross tonnage and over;
- .4 The following Regulations of **SOLAS** Chapter II-2 related to tankers do not apply and are replaced by Sections and paragraphs of this Chapter as detailed below:

Regulation	Replaced by
10.10	11.6
4.5.1.1 and 4.5.1.2	Section 3
4.5.5 and 10.8	11.3 and 11.4
10.9	11.5

- .5 Regulations 13.3.4 and 13.4.3 should apply to ships of 500 gross tonnage and over.

11.1.2 All sources of ignition are to be excluded from spaces where flammable vapour may be present except as otherwise provided in [Sections 10](#) and [16](#).

11.1.3 The provisions of paragraph 11.1 apply in conjunction with [Section 3](#).

11.1.4 For the purposes of fire fighting, any open 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 are to be included in the cargo area.

11.1-0.1 The structural fire protection provisions of Chapter II-2 of the **1974 SOLAS Convention**, applicable to liquefied gas carriers, are given in Chapter 1 – Hull Structures, Section 22, J.

11.2 Fire water main equipment

11.2.1 All ships, irrespective of size, carrying products which are subject to these Rules shall comply with the requirements of **SOLAS** Regulations II-2/10.2, 10.4 and 10.5, 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 the fire pump and fire main are used as part of the water spray system as permitted by [11.3.3](#). In addition, the requirements of Regulation II-2/10.2.1.6 are to be met at a pressure of at least 5,0 bar gauge.

11.2-0.1 Regarding Regulations 4.2.1 and 4.4.1 of Chapter II-2 of the **1974 SOLAS Convention** see Chapter 2 – Machinery Installations, Section 12, E.1 and E.2.

11.2.2 The arrangements are to 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 above the deck. The necessary number of fire hydrants shall be located to satisfy the above arrangements and to comply with the requirements of **SOLAS** Regulations II-2/10.2.1.5.1 and II-2/10.2.3.3, with hose length as specified in regulation II-2/10.2.3.1.1.

11.2-0.2 Regarding Regulations II-2/4.5.1 and II-2/4.8 of the **1974 SOLAS Convention** see also [Chapter 2 – Machinery Installations, Section 12, E.2.3](#) and E.2.5.

11.2.3 Stop valves are to be fitted in any cross-over provided and in the fire main or mains at the poop front and at intervals of not more than 40 m between hydrants on the deck in the cargo area for the purpose of isolating damaged sections of the main.

11.2.4 All water nozzles provided for fire fighting use are to be of an approved dual-purpose type capable of producing either a spray or a jet. All pipes, valves, nozzles and other fittings in the fire-fighting systems shall be resistant to corrosion by sea water, for example by galvanized pipe, and to the effect of fire.

11.2.5 Where the ship's engine room is unattended, arrangements are to be made to start and connect to the fire main at least one fire pump by remote control

from the navigating bridge or other control station outside the cargo area.

11.3 Water spray system

11.3.1 On ships carrying flammable or toxic products or both, a water spray system for cooling, fire prevention and crew protection are to be installed to cover:

- .1 exposed cargo tank domes and any exposed parts of cargo tanks;
- .2 exposed on-deck storage vessels for flammable or toxic products;
- .3 cargo liquid and vapour discharge and loading and any other areas where essential control valves are situated which shall be at least equal to the area of the drip trays provided;
- .4 boundaries of superstructures, deckhouses normally manned, cargo compressor rooms, store-rooms containing high fire risk items and cargo control rooms all facing the cargo area. Boundaries of unmanned forecastle structures not containing high fire risk items do not require water spray protection.

11.3.2 The system is to be capable of covering all areas mentioned in 11.3.1 with a uniformly distributed water spray of at least 10 ℓ/m^2 per minute for horizontal projected surfaces and 4 ℓ/m^2 per minute for vertical surfaces. For structures having not clearly defined horizontal or vertical surfaces, the capacity of the water spray system is to be determined by the greater of the following:

- .1 projected horizontal surface multiplied by 10 ℓ/m^2 per minute;
- .2 actual surface multiplied by 4 ℓ/m^2 per minute.

On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated run-down from higher areas. Stop valves are to be fitted at intervals in the spray main for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections which may be operated independently provided the necessary controls are located together, aft of the cargo area. A section protecting any area included in 11.3.1.1 and .2 is to cover the whole of the athwartship tank grouping which includes that area.

11.3.3 The capacity of the water spray pump shall be sufficient to deliver the required amount of water to

all areas simultaneously or, where the system is divided into sections, the arrangements and capacity shall be such as to simultaneously supply water to any one section and the surfaces specified in 11.3.1.3 and .4. Alternatively, the main fire pumps may be used for this service provided that their total capacity is increased by the amount needed for the spray system. In either case, a connection, through a stop valve, is to be made between the fire main and water spray main outside the cargo area.

11.3.4 Subject to the approval of the Society, water pumps normally used for other services may be arranged to supply the water spray main.

11.3.5 All pipes, valves, nozzles and other fittings in the water spray systems shall be resistant to corrosion by sea water, for example by galvanized pipe, and to the effect of fire.

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

11.4 Dry chemical powder fire extinguishing systems

11.4.1 Ships intending to carry flammable products are to be fitted with a fixed dry chemical powder type extinguishing systems for the purpose of fighting fire on the deck in the cargo area and bow or stern cargo handling areas if applicable. The system and the dry chemical powder shall be adequate for this purpose and satisfactory to the Society.

11.4-0.1 Drawings of the system and details of the dry chemical powder are to be submitted to the Society for approval.

11.4.2 The system is to be capable of delivering powder from at least two hand hose lines or a combination monitor/hand hose line(s) to any part of the above-deck exposed cargo area including above-deck product piping. The system shall be activated by an inert gas, such as nitrogen, used exclusively for this purpose and stored in pressure vessels adjacent to the powder containers.

11.4.3 The system for use in the cargo area shall consist of at least two independent self-contained dry chemical powder units with associated controls, pressurizing medium fixed piping, monitors or hand hose and discharge manifold areas and be capable of actuation and discharge locally and remotely. The monitor is not required to be remotely aimed if it can deliver the necessary powder to all areas of coverage from a single position. All hand hose lines and monitors shall be capable of actuation at the hose storage reel or monitor. At least one hand hose line or monitor is to be situated at the after end of the cargo area.

11.4.4 A fire extinguishing unit having two or more monitors, hand hose lines, or combinations thereof, shall have independent pipes with a manifold at the powder container, unless a suitable alternative means is provided to ensure proper performance as approved by the Society. Where two or more pipes are attached to a unit the arrangement shall be such that any or all of the monitors and hand hose lines are capable of simultaneous or sequential operation at their rated capacities.

11.4.5 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 be such as to allow operation by one man. The length of a hand hose line shall not exceed 33 m. Where fixed piping is provided between the powder container and a hand hose line or monitor, the length of piping shall not exceed that length which is capable of maintaining the powder in a 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.

11.4.6 A sufficient quantity of dry chemical powder is to be stored in each container to provide a minimum 45 seconds discharge time for all monitors and hand hose lines attached to each powder unit. Coverage from fixed monitors shall be in accordance with the following requirements:

capacity of fixed monitors [kg/s] each: 10 25 45
maximum distance of coverage [m]: 10 30 40

Hand hose lines shall be considered to have a maximum effective distance of coverage equal to the length of hose. Special consideration is to be given where areas to be protected are substantially elevated above the monitor or hand hose reel locations.

11.4.7 Ships fitted with bow or stern loading and discharge arrangements are to be provided with an additional dry chemical powder unit complete with at least one monitor and one hand hose line complying with the requirements of 11.4.1 to 11.4.6. This additional unit is to be located to protect the bow or stern

lines. For ships with a cargo capacity of less than 1000 m³ only one such unit need be fitted subject to the approval of the Society. A monitor is to be provided and so arranged as to protect the cargo loading and discharge arrangements. The area of the cargo line forward or aft of the cargo area shall be protected by hand hose lines.

11.5 Cargo compressor and pump-rooms

11.5.1 The cargo compressor and pump-room of any ship is to be provided with a carbon dioxide system as specified in [Chapter 2 – Machinery Installations, Section 12, G](#). A notice is to be exhibited at the controls stating that the system is only to be used for fire-extinguishing and not for inerting purposes, due to the electrostatic ignition hazard. The alarms referred to in [Chapter 2 – Machinery Installations, Section 12, G.7.1](#) are to be certified safe for use in a flammable cargo vapour-air mixture. For the purpose of this requirement, an extinguishing system is to be provided which is suitable for machinery spaces. However, the amount of carbon dioxide gas carried shall be sufficient to provide a quantity of free gas equal to 45 % of the gross volume of the cargo compressor and pump-rooms in all cases.

11.5.2 Cargo compressor and pump-rooms of ships which are dedicated to the carriage of a restricted number of cargoes are to be protected by an appropriate fire-extinguishing system approved by the Society.

11.6 Fire-fighter's outfits¹

11.6.1 Every ship carrying flammable products shall carry fire-fighter's outfits complying with the requirements of SOLAS Regulation II-2/10.10 as follows:

Total cargo capacity	Number of outfits
≤ 5000 m ³	4
> 5000 m ³	5

11.6.2 Additional requirements for safety equipment are given in [Section 14](#).

11.6.3 Any breathing apparatus required as part of a fireman's outfit should be a self-contained airbreathing apparatus having a capacity of at least 1200 ℓ of free air.

¹ See also Section 1, A.5.

Section 12

Mechanical Ventilation in the Cargo Area

The requirements of this Section replace the requirements for ventilation of spaces within the cargo area as required in Chapter 2 – Machinery Installations, Section 15

12.1 Spaces required to be entered during normal cargo handling operations

12.1.1 Electric motor rooms, cargo compressor and pump rooms, other enclosed spaces which contain cargo handling equipment and similar spaces in which cargo handling operations are performed shall be fitted with mechanical ventilation systems capable of being controlled from outside such spaces. Provision is to be made to ventilate such spaces prior to entering the compartment and operating the equipment and a warning notice requiring the use of such ventilation is to be placed outside the compartment.

12.1.2 Mechanical ventilation inlets and outlets shall be arranged to ensure sufficient air movement through the space to avoid the accumulation of flammable or toxic vapours and to ensure a safe working environment, but in no case shall the ventilation system have a capacity of less than 30 changes of air per hour based upon the total volume of the space. As an exception, gas safe cargo control rooms may have 8 changes of air per hour.

12.1.3 Ventilation systems are to be fixed and if of the negative pressure type, permit extraction from either or both upper and lower parts of the spaces dependent on the density of the vapours of the products carried.

12.1.4 In rooms housing electric motors driving cargo compressors or pumps, spaces except machinery spaces containing inert gas generators, cargo control rooms if considered as gas safe spaces and other gas safe spaces within the cargo area, the ventilation has to be of the positive pressure type.

12.1.5 In cargo compressor and pump rooms and in cargo control rooms if considered gas dangerous, the ventilation is to be of the negative pressure type.

12.1.6 Ventilation exhaust ducts from gas dangerous spaces shall discharge upwards in locations at least 10 m in the horizontal direction from ventilation intakes and openings to accommodation, service and control station spaces and other gas safe spaces.

12.1-0.1 The height of ventilation outlets is not to be less than 3 m above the weather deck or 2 m above the working area or fore and aft gangway if fitted within 3 m of the working area or gangway.

12.1-0.2 Gas dangerous spaces for the purpose of this para. are spaces mentioned in 12.1.5. For other spaces, which are "gas dangerous spaces" only due to their position, relaxations may be granted.

12.1.7 Ventilation intakes are to be so arranged as to minimize the possibility of re-cycling hazardous vapours from any ventilation discharge opening.

12.1-0.3 The ventilation intakes are to be fitted in locations at least 3 m in the horizontal direction from ventilation intakes and openings to accommodation service and machinery spaces and control stations and other spaces outside the cargo area. The height of ventilation intakes is not to be less than 3 m above the weatherdeck.

12.1.8 Ventilation ducts from gas dangerous spaces are not to be led through accommodation, service and machinery spaces or control stations, except as allowed in [Section 16](#).

12.1.9 Electric motors driving fans are to be placed outside the ventilation ducts if the carriage of flammable products is intended. Ventilation fans shall not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, for gas dangerous spaces shall be of non-sparking construction defined as:

- .1** Impellers or housing of non-metallic construction, due regard being paid to the elimination of static electricity;
- .2** Impellers and housing of non-ferrous materials;
- .3** Ferrous impellers and housing including those made of austenitic (stainless) steel with not less than 13 mm design tip clearance.

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.

12.1.10 Spare parts are to be carried for each type of fan on board referred to in this Section.

12.1.11 Protection screens of not more than 13 mm square mesh are to be fitted in outside openings of ventilation ducts.

12.2 Spaces not normally entered

Hold spaces, interbarrier spaces, void spaces, cofferdams, spaces containing cargo piping and other spaces where cargo vapours may accumulate, shall be capable of being ventilated to ensure a safe environment when entry into the spaces is necessary. Where a permanent ventilation system is not provided for such

spaces, approved means of portable mechanical ventilation is to be provided. Where necessary owing to the arrangement of spaces, such as hold spaces and interbarrier spaces, essential ducting for such ventilation shall be permanently installed. Fans or blowers are to be clear of personnel access openings, and are to comply with [12.1.9](#).

12.2-0.1 The capacity of the ventilation system should normally be 8 air changes per hour. A lower capacity may be accepted for hold spaces surrounding independent tanks after special consideration.

12.2-0.2 A dry air generation plant, if installed in accordance with [Section 9](#), may also be used for ventilation purposes, provided the plant is equipped with an appropriate system.

Section 13

Instrumentation (Gauging, Gas Detection)

13.1 General

13.1.1 Each cargo tank is to be provided with means for indicating level, pressure and temperature of the cargo. Pressure gauges and temperature indicating devices shall be installed in the liquid and vapour piping systems, in cargo refrigerating installations and in the inert gas system as detailed in this Section.

13.1.2 Where a secondary barrier is required, permanently installed instrumentation shall be provided to detect when the primary barrier fails to be liquid-tight at any location or when liquid cargo is in contact with the secondary barrier at any location. This instrumentation shall be appropriate gas detecting devices according to 13.6. 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.

13.1-0.1 Upon special approval appropriate temperature indicating devices may be accepted by the Society instead of gas detecting devices when the cargo temperature is not lower than -55°C .

13.1.3 If the 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.

13.1.4 Instruments are to be tested to ensure reliability in the working conditions and recalibrated at regular intervals. Testing procedures for instruments and the intervals between recalibration are to be approved by the Society.

13.2 Level indicators for cargo tanks

13.2.1 Each cargo tank shall be fitted with at least one liquid level gauging device, designed to operate at pressures not less than the MARVS of the cargo tank and at temperatures within the cargo operating temperature range. Where only one liquid level gauge is fitted it is to be arranged so that any necessary maintenance can be carried out while the cargo tank is in service.

13.2-0.1 In order to assess whether or not one level gauge is acceptable in relation to 13.2.1 "any neces-

sary maintenance" means that any part of the level gauge can be overhauled while the cargo tank is in service.

13.2.2 Cargo tank liquid level gauges shall be of the following types subject to any special requirement for particular cargoes shown in column "g" in the table of [Section 19](#):

- .1** indirect devices, which determine the amount of cargo by means such as weighing or pipe flow meters;
- .2** closed devices, which do not penetrate the cargo tank, such as devices using 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 on the tank it is to be provided with a shut-off valve located as close as possible to the tank;
- .4** restricted devices, which penetrate the tank and when in use permit a small quantity of cargo vapour or liquid to escape to the atmosphere, such as fixed tube and slip tube gauges. When not in use, the devices shall be kept completely closed. The design and installation must 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.

13.2.3 Sighting ports with a suitable protective cover and situated above the liquid level with an internal scale may be allowed by the Society as a secondary means of gauging for cargo tanks which are designed for a design vapour pressure P_0 not higher than 0,7 bar.

13.2.4 Tubular gauge glasses shall not be fitted. Gauge glasses of the robust type as fitted on high pressure boilers and fitted with excess flow valves may be allowed by the Society for deck tanks, subject to any provisions of [Section 17](#).

13.3 Overflow control

13.3.1 Except as provided in 13.3.2, each cargo tank is to be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated. Another sensor operating independently of the high liquid level alarm is to automatically actuate a shut-off in a manner which will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full. The emergency shutdown valve referred to in 5.6.1 and 5.6.3 may be used for this purpose. If another valve is used for this purpose, the same information as referred to in 5.6.4 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, GL and the Port State Authority may agree to alternative arrangements such as limiting the loading rate, etc.

13.3-0.1 The closing time of the closing valve is to be changeable.

13.3-0.2 The sensor for automatic closing of the loading valve for overflow control as required in 13.3.1 may be combined with the liquid level indicators required by 13.2.1.

13.3.2 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 m³; or
- .2** is designed to withstand the maximum possible pressure during the loading operation and such pressure is below that of the start-to-discharge pressure of the cargo tank relief valve.

13.3.3 Electrical circuits, if any, of level alarms are to be capable of being tested prior to loading.

13.4 Pressure gauges

13.4.1 The vapour space of each cargo tank is to be provided with a pressure gauge which shall incorporate an indicator in the cargo control position required by 13.1.3. In addition, a high pressure alarm and, if vacuum protection is required, a low pressure alarm, are to be provided on the navigating bridge and at the cargo control position. Maximum and minimum allowable pressures are to be marked on the indicators. For cargo tanks fitted with pressure relief valves, which can be set at more than one set pressure in accordance with 8.2.6, high pressure alarms are to be provided for each set pressure.

13.4-0.1 Common read-outs of the pressure sensors on the bridge are acceptable.

13.4.2 Each cargo pump discharge line and each liquid and vapour cargo manifold is to be provided with at least one pressure gauge.

13.4.3 Local reading manifold pressure gauges are to be provided to indicate the pressure between stop valves and hose connections to the shore.

13.4.4 Hold spaces and interbarrier spaces without open connection to the atmosphere are to be provided with pressure gauges.

13.5 Temperature indicating devices

13.5.1 Each cargo tank is to be provided with at least two devices for indicating cargo temperatures, one placed at the bottom of the cargo tank and the second near the top of the tank, below the highest allowable liquid level. The temperature indicating devices are to be marked to show the lowest temperature for which the cargo tank has been approved by the Society.

13.5.2 When cargo is carried in a cargo containment system with a secondary barrier at a temperature lower than – 55 °C, temperature indicating devices are to be provided within the insulation or on the hull structure adjacent to cargo containment systems. The devices shall give readings at regular intervals and, where applicable, audible warning of temperatures approaching the lowest for which the hull steel is suitable.

13.5-0.1 These alarms are to be at the cargo control position according to 13.1.3 and on the navigating bridge.

13.5.3 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 temperature indicating devices as follows:

- .1** A sufficient number of devices to establish that an unsatisfactory temperature gradient does not occur.
- .2** On one tank a number of devices in excess of those required in .1 of this paragraph in order to verify that the initial cool down procedure is satisfactory.

These devices may be either temporary or permanent. When a series of similar ships are built, the second and successive ships need not

comply with the requirements of this subparagraph.

13.5.4 The number and position of temperature indicating devices shall be to the satisfaction of the Society.

13.5-0.2 Common read-outs of the temperature sensors on the navigating bridge are acceptable.

13.6 Gas detection requirements

13.6.1 Gas detection equipment acceptable to the Society and suitable for the products to be carried shall be provided in accordance with column "f" in the table of [Section 19](#).

13.6.2 In every installation, the positions of fixed sampling heads are to be determined with due regard to the density of the vapours of the products intended to be carried and the dilution resulting from compartment purging or ventilation.

13.6.3 Pipe runs from sampling heads shall not be lead through gas safe spaces except as permitted by 13.6.5.

13.6.4 Audible and visual alarms from the gas detection equipment, if required by this Section, are to be located on the navigating bridge, in the cargo control position required by [13.1.3](#), and at the gas detector readout location.

13.6.5 Gas detection equipment may be located in the cargo control station required by [13.1.3](#), on the navigating bridge or at other suitable locations. When such equipment is located in a gas safe space the following conditions shall be met:

- .1** gas-sampling lines shall have shut-off valves or an equivalent arrangement to prevent cross-communication with gas-dangerous spaces; and
- .2** exhaust gas from the detector is to be discharged to the atmosphere in a safe location.

13.6.6 Gas detection equipment is to be so designed that it may readily be tested. Testing and calibration shall be carried out at regular intervals. Suitable equipment and span gas for this purpose is to be carried on board. Where practicable, permanent connections for such equipment are to be fitted.

13.6.7 A permanently installed system of gas detection and audible and visual alarms shall be provided for:

- .1** cargo pump rooms;
- .2** cargo compressor rooms;
- .3** motor rooms for cargo handling machinery;
- .4** cargo control rooms unless designated as gas safe;
- .5** other enclosed spaces in the cargo area where vapour may accumulate including hold spaces and interbarrier spaces for independent tanks other than type C;
- .6** ventilation hoods and gas ducts where required by [Section 16](#); and
- .7** air locks.

13.6-0.1 Also for hold spaces containing type C cargo tanks a permanently installed gas detection system is recommended.

13.6.8 The gas detection equipment shall be capable of sampling and analysing from each sampling head location sequentially at intervals not exceeding 30 minutes, except that in the case of gas detection for the ventilation hoods and gas ducts referred to in [13.6.7.6](#) sampling is to be continuous. Common sampling lines to the detection equipment shall not be fitted.

13.6.9 In the case of products which are toxic or toxic and flammable, the Administration may authorize the use of portable equipment except when column "i" in the table of [Section 19](#) refers to [17.9](#) for toxic detection as an alternative to a permanently installed system if used before entry of the spaces listed in [13.6.7](#) by personnel and thereafter at 30 minute intervals while they remain therein ¹.

13.6.10 For the spaces listed in [13.6.7](#), alarms are to be activated for flammable products when the vapour concentration reaches 30 % of the lower flammable limit.

13.6.11 In the case of flammable products, where cargo containment systems other than independent tanks are used, hold spaces and/or interbarrier spaces are to be provided with a permanently installed system of gas detection capable of measuring gas concentrations of 0 to 100 % by volume. The detection equipment, equipped with audible and visual alarms, shall be capable of monitoring from each sampling head location sequentially at intervals not exceeding 30 minutes. Alarms should be activated when the vapour concentration reaches the equivalent of 30 % of the lower flammable limit in air or such other limit as may be approved by the Society in the light of particular

¹ See also [Section 1, A.5](#).

cargo containment arrangements. Common sampling lines to the detection equipment shall not be fitted.

13.6-0.2 With reference to the requirements of [13.6.8](#) and 13.6.11 commutation of sampling shall be carried out close to the detection cell.

13.6.12 In the case of toxic gases, hold spaces and/or interbarrier spaces are to 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 loca-

tion by means of fixed or portable equipment at intervals not exceeding 4 hours and in any event before personnel enter the space and at 30 minute intervals whilst they remain therein.

13.6.13 Every ship should be provided with at least two sets of portable gas detection equipment acceptable to the Administration and suitable for the products to be carried ¹.

13.6.14 A suitable instrument for the measurement of oxygen levels in inert atmospheres is to be provided.

Section 14

Personnel Protection

14.1 Protective equipment

For protection of crew members engaged in loading and discharging operations, suitable protective equipment including eye protection should be provided taking into account the character of the products.

14.2 Safety equipment

14.2.1 Sufficient, but not less than two complete sets of safety equipment in addition to the firemen's outfits required by 11.6.1 each permitting personnel to enter and work in a gas-filled space, should be provided.

14.2.2 One complete set of safety equipment should consist of:

- .1 one self-contained air-breathing apparatus not using stored oxygen, having a capacity of at least 1200 ℓ of free air;
- .2 protective clothing, boots, gloves and tight-fitting goggles;
- .3 fire proof life line with belt; and
- .4 explosion-proof lamp.

14.2.3 An adequate supply of compressed air should consist either of:

- .1 one set of fully charged spare air-bottles for each breathing apparatus required by 14.2.1; a special air compressor suitable for the supply of high pressure air of the required purity; and a charging manifold capable of dealing with sufficient spare breathing apparatus air-bottles for the breathing apparatus required by 14.2.1; or
- .2 fully charged spare air-bottles with a total free air capacity of at least 6000 litres for each breathing apparatus required by 14.2.1.

14.2.4 Alternatively, the Administration may accept a low pressure air line system with hose connexions suitable for use with the breathing apparatus required by 14.3. This system should provide sufficient high pressure air capacity to supply, through pressure reduction devices, enough low pressure air to enable two

men to work in a gas dangerous space for at least one hour without using the air-bottles of the breathing apparatus. Means should be provided for recharging the fixed air-bottles and the breathing apparatus air-bottles from a special air compressor suitable for the supply of high pressure air of the required purity.

14.2.5 Protective equipment required in 14.1 and safety equipment as required in 14.2.1 should be kept in suitable, clearly marked lockers in readily accessible places.

14.2.6 The compressed air equipment should be inspected at least once a month by a responsible officer and the inspection recorded in the ship's log book, and inspected and tested by an expert at least once a year.

14.3 First aid equipment

14.3.1 A stretcher which is suitable for hoisting an injured person from spaces below deck, should be kept in a readily accessible location.

14.3.2 The ship should have on board medical first-aid equipment, including oxygen resuscitation equipment and antidotes for cargoes to be carried.¹

14.4 Personnel protection requirements for individual products

14.4.1 Provisions of 14.4 are applicable to ships carrying products for which those paragraphs are listed in column "i" in the table of [Section 19](#).

14.4.2 Respiratory and eye protection suitable for emergency escape purposes should be provided for every person on board subject to the following:

¹ Reference is made to the Medical First Aid guide for Use in Accidents Involving Dangerous Goods (MFAG), which provides advice on the treatment of casualties in accordance with the symptoms exhibited as well as equipment and antidotes that may be appropriate for treating the casualty. MFAG numbers related to products covered by the IGC Code are given in the table of minimum requirements (Section 19).

- .1.1 filter type respiratory protection is unacceptable;
- .1.2 self-contained breathing apparatus should normally have a duration of service of at least 15 minutes;
- .2 emergency escape respiratory protection should not be used for fire-fighting or cargo handling purposes and should be marked to that effect;
- .3 two additional sets of the above respiratory and eye protection should be permanently located in the navigating bridge.

Guidance

For ships subject to the requirements of the See-Berufsgenossenschaft only type approved emergency escape respiratory protection is to be used.

14.4.3 Suitably marked decontamination showers and an eye wash should be available on deck in convenient locations. The showers and eye wash should be operable at all ambient conditions (i. e. also below 0 °C).

14.4.4 In ships of a cargo capacity of 2000 m³ and over two complete sets of safety equipment should be provided in addition to the equipment required by 11.6.1 and 14.2.1. At least three charged spare air-bottles should be provided for each self-contained air-breathing apparatus required in this paragraph.

14.4.5 Personnel should be protected against the effects of a major cargo release by the provision of a space within the accommodation area designed and equipped to the satisfaction of the Administration.

14.4.6 For certain highly dangerous products, cargo control rooms should be of the gas-safe type only.

Section 15

Filling Limits for Cargo Tanks

15.1 General

15.1.1 No cargo tanks shall have a higher filling limit (FL) than 98 % at the reference temperature, except as permitted by 15.1.3.

15.1.2 The maximum loading limit (LL) to which a cargo tank may be loaded shall be determined by the following formula:

$$LL = FL \left(\frac{\rho_R}{\rho_L} \right)$$

LL = loading limit expressed in percent which means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded

FL = filling limit as specified in 15.1.1 or 15.1.3

ρ_R = relative density of cargo at the reference temperature

ρ_L = relative density of cargo at the loading temperature and pressure.

15.1.3 The society may allow a greater filling limit (FL) than 98 % in 15.1.1 and 15.1.2 at the reference temperature, taking into account the shape of the tank, arrangements of pressure relief valves, accuracy of level and temperature gauging and the difference between the loading temperature and the temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valves, provided the conditions of 8.2.17 are maintained.

15.1.4 For the purpose of this Section only, “reference temperature” means:

- .1 The temperature corresponding to the vapour pressure of the cargo at the set pressure relief valves when no cargo vapour pressure/temperature control as referred to in [Section 7](#) is provided.
- .2 The temperature of the cargo upon termination of loading, during transport, or at unloading, whichever is the greater, when a cargo vapour

pressure/temperature control as referred to in Section 7 is provided. If this reference temperature would result in the cargo tank becoming liquid full before the cargo reaches a temperature corresponding to the vapour pressure of the cargo at the set pressure of the relief valves required in 8.2, an additional pressure relieving system complying with 8.3 is to be fitted.

15.1.5 The Society may allow type C tanks to be loaded according to the following formula provided that the tank vent system has been approved in accordance with 8.2.18:

$$LL = FL \left(\frac{\rho_R}{\rho_L} \right)$$

LL = loading limit as specified in 15.1.2

FL = filling limit as specified in 15.1.1 or 15.1.3

ρ_R = relative density of cargo at the highest temperature which the cargo may reach upon termination of loading, during transport, or at unloading, under the ambient design temperature conditions described in 7.1.2

ρ_L = as specified in 15.1.2.

This paragraph does not apply to products requiring a type 1G ship.

Regardless of the date of construction of the ship, Type C cargo tanks can be loaded in accordance with the provisions of paragraph 15.1.5 or, alternatively, to the provisions of paragraph 15.1.2.

15.2 Information to be provided to the master

The maximum allowable loading limits for each cargo tank shall be indicated for each product which may be carried, for each loading temperature which may be applied and for the applicable maximum reference temperature, on a list to be approved by the Society. Pressures at which the pressure relief valves, including those valves required by [8.3](#), have been set shall be stated on the list. A copy of the list shall be permanently kept on board by the Master.

Section 16

Use of Cargo as Fuel

16.1 General

16.1.1 Methane (LNG) is the only cargo whose vapour or boil-off gas may be utilized in machinery spaces of Category A and in such spaces may be utilized only in boilers, inert gas generators, combustion engines and gas turbines.

16.1.2 These provisions do not preclude the use of gas fuel for auxiliary services in other locations, provided that such other services and locations should be subject to special consideration by the Administration.

16.2 Arrangement of machinery spaces of Category A

16.2.1 Spaces in which gas fuel is utilized are to be fitted with a mechanical ventilation system and are to be arranged in such a way as to prevent the formation of dead spaces. Such ventilation is to be particularly effective in the vicinity of electrical equipment and machinery or of other equipment and machinery which may generate sparks. Such a ventilation system is to be separated from those intended for other spaces.

16.2.2 Gas detectors are to be fitted in these spaces, particularly in the zones where air circulation is reduced. the gas detection system shall comply with the requirements of [Section 13](#).

16.2.3 Electrical equipment located in the double wall pipe or duct specified in 16.3.1 is to be of the intrinsically safe type.

16.3 Gas fuel supply

16.3.1 Gas fuel piping shall not pass through accommodation spaces, services spaces, or control stations. Gas fuel piping may pass through or extend into other spaces provided they fulfil one of the following:

- .1** the gas fuel piping shall be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes shall be pressurized with inert gas at a

pressure greater than the gas fuel pressure. Suitable alarms are to be provided to indicate a loss of inert gas pressure between the pipes; or

- .2** the gas fuel piping shall be installed within a ventilated pipe or duct. The air space between the gas fuel piping and inner wall of this pipe or duct is to be equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour. the ventilation system is to be arranged to maintain a pressure less than the atmospheric pressure. The fan motors are to be placed outside the ventilated pipe or duct. The ventilation outlet is to be placed in a position where no flammable gas-air mixture may be ignited. The ventilation shall always be in operation when there is gas fuel in the piping. Continuous gas detection is to be provided to indicate leaks and to shut down the gas fuel supply to the machinery space in accordance with [16.3.10](#). The master gas fuel valve required by [16.3.7](#) shall close automatically, if the required air flow is not established and maintained by the exhaust ventilation system.

16.3-0.1 The gas piping system is to be designed in accordance with [Chapter 2, Section 11, C.](#), as far as applicable.

16.3-0.2 Installation of gas piping

- .1** Gas piping must be independent of other systems and may exclusively be used for the conveyance of gas. It is to be ensured by their arrangement that they are protected against external damages.
- .2** The main gas line between the gas make up station and the machinery space shall be as short as possible. This applies also to the gas pipes to gas injection valves and burners. The gas piping has to be installed as high in the space as possible and at the greatest possible distance from the ship's hull.

16.3.2 If a gas leak occurs, the gas fuel supply shall not be restored until the leak has been found and repaired. Instructions to this effect are to be placed in a prominent position in the machinery spaces.

16.3.3 The double wall piping system or the ventilated pipe or duct provided for the gas fuel piping shall terminate at the ventilation hood or casing required by 16.3.4.

16.3.4 A ventilation hood or casing is to be provided for the areas occupied by flanges, valves, etc., and for the gas fuel piping, at the gas fuel utilization units, such as boilers, diesel engines or gas turbines. If this ventilation hood or casing is not served by the exhaust ventilation fan serving the ventilated pipe or duct as specified in 16.3.1.2, then it is to be equipped with an exhaust ventilation system and continuous gas detection is to be provided to indicate leaks and to shut down the gas fuel supply to the machinery space in accordance with 16.3.10. The master gas fuel valve required by 16.3.7 shall close automatically if the required air flow is not established and maintained by the exhaust ventilation system. The ventilation hood or casing is to be installed or mounted to permit the ventilating air to sweep across the gas utilization unit and be exhausted at the tip of the ventilation hood or casing.

16.3.5 The ventilation inlet and discharge for the required ventilation systems is to be respectively from and to a safe location.

16.3.6 Each gas utilization unit is to be provided with a set of three automatically operated valves. Two of these valves shall be in series in the gas fuel pipe to the consuming equipment. The third valve shall be in a pipe that vents, to a safe location in the open air, that portion of the gas fuel piping that is between the two valves in series. These valves are to be arranged so that failure of the necessary forced draught, loss of flame on boiler burners, abnormal pressure in the gas fuel supply line, or failure of the valve control actuating medium will cause the two gas fuel valves which are in series to close automatically and the vent valve to open automatically. Alternatively, the function of one of the valves in series and the vent valve can be incorporated into one valve body so arranged that, when one of the above conditions occurs, flow to the gas utilization unit will be blocked and the vent opened. The three shut-off valves are to be arranged for manual reset.

16.3-0.3 It must be possible to operate the shut-off devices locally and from each control platform. They must close automatically under the following service conditions:

- .1** Whenever the gas pressure varies by more than 10 % or, in the case of supercharged engines, if the differential pressure between gas and charging air is no longer constant.
- .2** If fault situations as described in 16.5-0.2 and 16.6-0.10 arise.

16.3.7 A master gas fuel valve that can be closed from within the machinery space is to be provided within the cargo area. The valve is to be arranged so as to close automatically if leakage of gas is detected, or loss of ventilation for the duct or casing or loss of pressurization of the double wall gas fuel piping occurs.

16.3-0.4 High-pressure gas piping, which according to 16.3.1.2 is installed in a ventilated pipe or duct, is to be subdivided into sections between master gas fuel valve and gas utilization unit by quick-closing valves, if a major volume of gas may penetrate into the duct or pipe in the event of pipe burst. The number of quick-closing valves is to be agreed with the Society, taking into account the gas pressure and the volume of the gas piping. Under the same criteria the quick-closing valves must close automatically like the master gas fuel valves mentioned in 16.3.7.

16.3.8 Gas fuel piping in machinery spaces shall comply with sections 5.2 - 5.5 as far as found applicable. The piping shall as far as practicable, have welded joints. Those parts of the gas fuel piping, which are not enclosed in a ventilated pipe or duct according to 16.3.1 and are on the open deck outside the cargo area shall have full penetration butt welded joints and shall be fully radiographed.

16.3.9 Provisions are to be made for inerting and gas-freeing that portion of the gas fuel piping system located in the machinery space.

16.3.10 Gas detection systems provided in accordance with the requirements of 16.3.1 and 16.3.4 are to comply with 13.6.2 and 13.6.4 through to 13.6.8 as applicable; they shall activate the alarm at 30 % of the lower flammable limit and shut down the master gas fuel valve referred to in 16.3.7 before the gas concentration reaches 60 % of the a lower flammable limit.

16.3-0.5 Gas detectors are to be arranged at all points where gas must be expected to gather.

16.4 Gas make-up plant and related storage tanks

16.4.1 All equipment (heaters, compressors, filters, etc.) for making-up the gas for its use as fuel, and the related storage tanks shall be located in the cargo area in accordance with paragraph 3.1.5.4. If the equipment is in an enclosed space the space shall be ventilated according to [Section 12.1](#) and be equipped with a fixed fire extinguishing system according to [Section 11.5](#) and with a gas detection system according to [Section 13.6](#) as applicable.

16.4.2 The compressors are to be capable of being remotely stopped from a position which is always and easily accessible and also from the engine room. In addition, the compressors are to be capable of automatically stopping when the suction pressure reaches a certain value depending on the set pressure of the vacuum relief valves of the cargo tanks. The automatic shut-down device of the compressors are to have a manual resetting. Volumetric compressors are to be fitted with pressure relief valves discharging into the suction line of the compressor. The size of the pressure relief valves is to be determined in such a way that, with the delivery valve kept closed, the maximum pressure does not exceed by more than 10 % the maximum working pressure. The requirements of 5.6.1.3 apply to these compressors.

16.4.3 If the heating medium for the gas fuel evaporator or heater is returned to spaces outside the cargo area it shall first go through a degassing tank. The degassing tank is to be located in the cargo area. Provisions are to be made to detect and alarm the presence of gas in the tank. The vent outlet is to be in a safe position and fitted with a flame screen.

16.4.4 Piping and pressure vessels in the gas fuel conditioning system are to comply with [Section 5](#).

16.5 Requirements for gas fired main boilers

16.5.1 Each boiler is to have a separate uptake.

16.5.2 A system suitable to ensure the forced draught in the boilers is to be provided. The particulars of such a system are to be to the satisfaction of the Society.

16.5.3 Combustion chambers of boilers are to be of suitable form such as not to present pockets where gas may accumulate.

16.5.4 The burner system is to be of dual type, suitable to burn either oil fuel or gas fuel alone or oil and gas fuel simultaneously. Only oil fuel is to be used during manoeuvring and port operations unless automatic transfer from gas to oil burning is provided in which case the burning of a combination of oil and gas or gas alone may be permitted provided the system is demonstrated to the satisfaction of the Society. It shall be possible to change over easily and quickly from gas fuel operation to oil fuel operation. Gas nozzles are to be fitted in such a way that gas fuel is ignited by the flame of the oil fuel burner. A flame scanner is to be installed and arranged to assure that gas flow to the burner is cut off unless satisfactory ignition has been established and maintained. On the pipe of each gas burner a manually operated shut-off valve is to be fitted. An installation is to be provided

for purging the gas supply piping to the burners by means of inert gas or steam, after the extinguishing of these burners.

16.5-0.1 For fuel oil and air supply to the pilot burner see Chapter 2 – Machinery Installations, Section 9, B.3.1.

16.5-0.2 The gas supply must be automatically stopped by the shut-off devices specified in 16.3.6, if:

- .1** the air supply is insufficient for complete combustion of the gas,
- .2** the pilot burner for an operating burner extinguishes, unless the gas supply line to every individual burner is equipped with a quick-closing valve that automatically cuts off the gas,
- .3** the pressure in the fuel oil admission line drops to an inadmissibly low level.

16.5.5 Alarm devices are to be fitted in order to monitor a possible decrease in liquid fuel oil pressure or a possible failure of the related pumps.

16.5.6 Arrangements are to be made that, in case of flame failure of all operating burners for gas or oil or for a combination thereof, the combustion chambers of the boilers are automatically purged before relighting. Arrangements are to also be made to enable the boilers to be manually purged.

16.6 Special requirements for diesel/gas engines and gas turbines

16.6-0.1 As main engines only dual fuel engines will be approved, which are designed either for combined dual fuel operation by ignition-ray process or for fuel oil operation only.

16.6-0.2 The gas is to be conveyed close to the cylinder inlet valves through gas inlet valves, without prior mixing with combustion air, or else blown directly into the cylinders.

16.6-0.3 Also, in case of sudden shut-off of the gas supply, the engines must be capable of continuous operation by fuel oil exclusively.

16.6-0.4 Starting and reversing of the engines is admissible during operation by diesel fuel only.

16.6-0.5 For protection against the effects of misfiring, blow-off safety devices capable of blow-off without risk are to be in the exhaust gas manifold and in the charge air/air inlet duct.

16.6-0.6 The exhaust-gas pipes from multi-engine plants are to be arranged such as to lead to the open air separately. Combination of these pipes is not admissible.

16.6-0.7 In the starting-air lines, in front of each cylinder non-return valves and flame arresters are to be arranged.

16.6-0.8 The crankcases of trunk piston engines are to be continuously vented. In the case of ventilation by induced draught fans the negative pressure in the crankcase must not exceed a water head of 25 mm. Vent lines have to extend to the open deck at a safe point. A gas detecting device is to be fitted in the vent line between crankcase and fan.

16.6-0.9 For safety equipment see [Chaper 2 – Machinery Installations, Section 2, F](#).

16.6-0.10 The gas supply must be stopped automatically by the shut-off valves specified in [16.3.6](#), if:

- .1** the pilot fuel injection pump or the supply of pilot fuel fails,

- .2** the engine speed drops below the lowest service speed,

- .3** the gas detector in the crankcase vent line indicates a gas concentration approaching the lower explosion limit.

16.6-0.11 Requirements for gas turbines are to be agreed with the Society in each individual case.

16.7 Testing of pipings

16.7-0.1 Before being put into operation, the gas piping system is to be subjected to a hydrostatic pressure test to 1,5 times the working pressure, but at least to a pressure of 5 bar, and to a pneumatic tightness test. Additionally, all shut off devices are to be pneumatically tested to tightness of their sealing faces, to 1,1 times the working pressure.

16.7-0.2 Safety, quick-closing or automatic stop valves, level indicators, temperature meters, pressure gauges, gas detection and warning systems are to be subjected to function test.

Section 17

Special Requirements

17.1 General

The provisions of this Section are applicable where reference is made in column "i" in the table of [Section 19](#).

These are requirements additional to the general requirements of this Chapter.

17.2 Materials of construction

Materials which may be exposed to cargo during normal operations are to 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 are not to be used for certain products as specified in column "i" in the table of Section 19 by referring to this paragraph:

- .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.
- .6 Copper and copper bearing alloys with greater than 1 % copper.

17.3 Independent tanks

17.3.1 Products should be carried in independent tanks only.

17.3.2 Products should be carried in type C independent tanks and the provisions of 7.1.3 apply. The design pressure of the cargo tank shall take into account any padding pressure and/or vapour discharge unloading pressure.

17.4 Refrigeration systems

17.4.1 Only the indirect system described in [7.2.4.2](#) is to be used.

17.4.2 For ships engaged in the carriage of products which readily form dangerous peroxides, recondensed cargo is not to be allowed to form stagnant pockets of uninhibited liquid. This may be achieved either by:

- .1 using the indirect system described in [7.2.4.2](#) with the condenser inside the cargo tank, or
- .2 using the direct system or combined system described in [7.2.4.1](#) and .3 respectively or the indirect system described in [7.2.4.2](#) 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 is to be added upstream of such a place.

17.4.3 If the ship is to carry consecutively products specified in [17.4.2](#) with a ballast passage between, all uninhibited liquid should be removed prior to the ballast voyage. If a second cargo is to be carried between such consecutive cargoes the reliquefaction system should be thoroughly drained and purged before loading the second cargo. Purging should be carried out using either inert gas or vapour from the second cargo, if compatible. Practical steps should be taken to ensure that polymers or peroxides do not accumulate in the cargo system.

17.5 Deck cargo piping

100 % radiography of all butt welded joints in cargo piping exceeding 75 mm in diameter is required.

17.6 Exclusion of air from vapour spaces

Air is to be removed from the cargo tanks and associated piping before loading and then subsequently excluded by:

- .1 introducing inert gas to maintain a positive pressure. Storage or production capacity of the inert gas is to be sufficient to meet normal operating requirements and relief valve leakage. The oxygen content of inert gas must at no time be greater than 0,2 % by volume; or
- .2 control of cargo temperature such that a positive pressure is maintained at all times.

17.7 Moisture control

For gases which are non-flammable and may become corrosive or react dangerously with water, moisture control is to be provided to ensure that cargo tanks are dry before loading and that during discharge, dry air or cargo vapour is introduced to prevent negative pressures. For the purposes of this paragraph, dry air is air which has a dewpoint of -45°C or below at atmospheric pressure.

17.8 Inhibition

Care should be taken to ensure that the cargo is sufficiently inhibited to prevent polymerization at all times during the voyage. Ships should 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,
- .4 the action to be taken should the length of the voyage exceed the effective lifetime of the inhibitors.

17.9 Permanently installed toxic gas detectors

17.9.1 Gas sampling lines are not to be led into or through gas safe spaces. Alarms referred to in 13.6.7 are to be activated when the vapour concentration reaches the threshold limiting value.

17.9.2 The alternative of using portable equipment in accordance with 13.6.9 should not be permitted.

17.10 Flame screens on vent outlets

Cargo tank vent outlets are to be provided with readily renewable and effective flame screens or safety heads of an approved type when carrying a cargo referenced to this section. Due attention is to be paid in the design of flame screens and vent heads to the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions. Ordinary protection screens are to be fitted after removal of the flame screens.

17.11 Maximum allowable quantity of cargo per tank

When carrying a cargo referenced to this section, the quantity of the cargo should not exceed 3000 m³ in any one tank.

17.12 Submerged electric cargo pumps

The vapour space of cargo tanks equipped with submerged electric motor pumps should be inerted to a positive pressure prior to loading, during carriage and during unloading of flammable liquids.

17.13 Ammonia

17.13.1 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 17.13.2 to 17.13.8 are to be taken as appropriate.

17.13.2 Where carbon manganese steel is used, cargo tanks, process pressure vessels and cargo piping are to be made of fine grained steel with a specified minimum yield strength not exceeding 355 N/mm² and with an actual yield strength not exceeding 440 N/mm². 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/mm² shall be used; or
- .2 cargo tanks, etc., are to be post weld stress relief heat treated; or
- .3 carriage temperature is to 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.

17.13.3 If carbon manganese steel with higher yield properties are used other than those specified in 17.13.2, the completed cargo tanks, piping etc. are to be given a post weld stress relief heat treatment.

17.13.4 Process pressure vessels and piping of the condensate part of the refrigeration system are to be given a post weld stress relief heat treatment when made of materials mentioned in 17.13.1.

17.13.5 The tensile and yield properties of the welding consumables shall exceed those of the tank or piping material by the smallest practical amount.

17.13.6 Nickel steel containing more than 5 % nickel and carbon manganese steel not complying with the requirements of 17.13.2 and 17.13.3 are particularly susceptible to ammonia stress corrosion cracking and shall not be used for containment and piping systems for the carriage of this product.

17.13.7 Nickel steel containing not more than 5 % nickel may be used provided the carriage temperature complies with the requirements specified in 17.13.2.3.

17.13.8 In order to minimize the risk of ammonia stress corrosion cracking, it is advisable to keep the dissolved oxygen content below 2,5 ppm w/w. This can best be achieved by reducing the average oxygen content in the tanks prior to the introduction of liquid ammonia to less than the values given as a function of the carriage temperature T in Table 17.1.

Table 17.1 Average oxygen content

T [°C]	O ₂ [%v/v]
– 30 and below	0,90
– 20	0,50
– 10	0,28
0	0,16
10	0,10
20	0,05
30	0,03

Oxygen percentages for intermediate temperatures may be obtained by direct interpolation.

17.14 Chlorine

17.14.1 Cargo containment system

17.14.1.1 The capacity of each tank is not to exceed 600 m³ and the total capacity of all cargo tanks is not to exceed 1200 m³.

17.14.1.2 The tank design vapour pressure is not to be less than 13,5 bar (see also 7.1.3 and 17.3.2).

17.14.1.3 Parts of tanks protruding above the upper deck are to be provided with protection against thermal radiation taking into account total engulfment by fire (i.e. the insulation of such parts of tanks is to be resistant to fire).

17.14.1.4 Each tank is to be provided with two pressure relief valves. A bursting disc of appropriate material is to be installed between the tank and the safety relief valves. The rupture pressure of the bursting disc is to be 1 bar lower than the opening pressure of the safety relief valve, which is to be set at the design pressure of the tank but not less than 13,5 bar gauge. The space between the bursting disc and the relief valve is to be connected through an excess flow valve to a pressure gauge and a gas detection system. Provisions are to be made to keep this space at or near the atmospheric pressure during normal operation.

17.14.1.5 Outlets from pressure relief valves are to be arranged in such a way as to minimize the hazards on board the ship as well as to the environment. Leakage from the relief valves is to be led through the absorption plant to reduce the gas concentration as far as possible. Leakage is to be led to the absorption tower. The relief valve exhaust line is to be arranged at the forward end of the ship to discharge outboard at deck level with an arrangement to select either port or starboard side, with a mechanical interlock to ensure that one line is always open.

17.14.1.6 The Administration and the Port Administration may require that chlorine is carried in refrigerated state at a maximum pressure specified by these Administrations.

17.14.2 Cargo piping systems

17.14.2.1 Cargo discharge shall be performed by means of compressed chlorine vapour from shore, dry air or another acceptable gas or fully submerged pumps. The pressure in the vapour space of the tank during discharging should not exceed 10,5 bar gauge. Cargo discharge compressors on board ships will not be accepted by the Society.

17.14.2.2 The design pressure of the cargo piping system is to be not less than 21 bar gauge. The internal diameter of the cargo pipes is not to exceed 100 mm.

Only pipe bends will be accepted for compensation of pipe line thermal movement. The use of flanged joints is to be restricted to a minimum, and when used the flanges are to be of the welding neck type with tongue and groove.

17.14.2.3 Relief valves of the cargo piping system shall discharge to the absorption plant (see also 8.2.16).

17.14.3 Materials

17.14.3.1 The cargo tanks and cargo piping systems are to be made of steel suitable for the cargo and for a temperature of -40°C , even if a higher transport temperature is intended to be used.

17.14.3.2 The tanks are to be thermally stress relieved. Mechanical stress relief will not be accepted as an equivalent.

17.14.4 Instrumentation - safety devices

17.14.4.1 The ship shall be provided with a chlorine absorbing plant with connexions to the cargo piping system and the cargo tanks. The absorbing plant shall be capable of neutralizing at least 2 % of the maximum cargo capacity at a reasonable absorption rate.

17.14.4.2 During the gas freeing of cargo tanks, vapours should not be discharged to the atmosphere.

17.14.4.3 A gas detecting system shall be provided capable of monitoring chlorine concentrations of at least 1 ppm by volume. Suction points should 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 and machinery spaces and control stations
- .5 on deck at the forward end, in the middle and at the aft end of the cargo area. (Only required during cargo handling and gas freeing operations.)

The gas detection system shall be provided with audible and visual alarm with a set point of 5 ppm.

17.14.4.4 Each cargo tank shall be fitted with a high pressure alarm giving audible alarm at a pressure equal to 10,5 bar gauge.

17.14.5 Personnel protection

In addition to the requirements given in Section 14 the following requirements should be met:

- .1 The enclosed space required by 14.4.5 shall be easily and quickly accessible from the open deck and accommodation spaces and shall be capable of being rapidly closed gas-tight. Access to this space from the deck and from the accommodation spaces shall be by means of an airlock. The space shall be so designed as to accommodate the entire crew of the ship and be

provided with a source of uncontaminated air for a period of not less than four hours. One of the decontamination showers required by 14.4.3 shall be located near the airlock to the space.

- .2 A compressor and the necessary equipment for filling the air bottles shall be provided.
- .3 One set of oxygen therapy equipment should be carried in the space referred to in 17.14.5.1.

17.14.6 Filling limits for cargo tanks

17.14.6.1 The requirements of 15.1.4.2 do not apply when it is intended to carry chlorine.

17.14.6.2 The chlorine content of the gas in the vapour space of the cargo tank after loading should be greater than 80 % by volume.

17.14.6-0.1 When determining the filling limits of the cargo tanks for the transport of chlorine, the effect of the refrigeration plant is not to be considered.

17.15 Diethyl ether and vinyl ethyl ether

17.15.1 The cargo is to be discharged only by deep-well pumps or by hydraulically operated submerged pumps. These pumps are to be of a type designed to avoid liquid pressure against the shaft gland.

17.15.2 Inert gas displacement may be used for discharging cargo from type C independent tanks provided the cargo system is designed for the expected pressure.

17.16 Ethylene oxide

17.16.1 For the carriage of ethylene oxide the requirements of 17.20 apply analogously with the additions and modifications as given in this paragraph.

17.16.2 Deck tanks should not be used for the carriage of ethylene oxide.

17.16.3 Stainless steels types 416 and 442 as well as cast iron are not to be used in ethylene oxide cargo containment and piping systems.

17.16.4 Before loading, tanks should 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 ethyl-

ene oxide, propylene oxide or mixtures of these products. Particular care should be taken in the case of ammonia in tanks made of steel other than stainless steel.

17.16.5 Ethylene oxide is to be discharged only by deepwell pumps or inert gas displacement. The arrangement of pumps is to comply with 17.20.5.3.

17.16.6 Ethylene oxide should be carried refrigerated only and maintained at temperatures of less than 30 °C.

17.16.7 Pressure relief valves are to be set at a pressure of not less than 5,5 bar gauge. The maximum set pressure is to be specially considered by the Society.

17.16.8 The protective padding of nitrogen gas as required by 17.20.15 should be such that the nitrogen concentration in the vapour space of the cargo tank will at no time be less than 45 % by volume.

17.16.9 Before loading and at all times when cargo tank contains ethylene oxide liquid or vapour, the cargo tank should be inerted with nitrogen.

17.16.10 The water spray system required by paragraph 17.20.17 and that required by 11.3 is to operate automatically in a fire involving the cargo containment system.

17.16.11 A jettisoning arrangement is to be provided to allow the emergency discharge of ethylene oxide in the event of uncontrollable self-reaction.

17.17 Isopropylamine, monoethylamine

Separate piping systems are to be provided as defined in Section 1, C.32.

17.18 Methyl acetylene-propadiene mixtures

17.18.1 Methyl acetylene-propadiene mixtures should be suitably stabilized for transport. Additionally, upper limits of temperature and pressure during the refrigeration should be specified for the mixtures.

17.18.2 Examples of acceptable, stabilized compositions are:

.1 Composition 1:

.1.1 maximum methyl acetylene to propadiene molar ratio of 3 to 1;

.1.2 maximum combined concentration of methyl acetylene and propadiene of 65 mole %;

.1.3 minimum combined concentration of propane, butane, and isobutane of 24 mole %, of which at least one-third (on a molar basis) must be butanes and one-third propane; and

.1.4 maximum combined concentration of propylene and butadiene of 10 mole %.

.2 Composition 2:

.2.1 maximum methyl acetylene and propadiene combined concentration of 30 mole %;

.2.2 maximum methyl acetylene concentration of 20 mole %;

.2.3 maximum propadiene concentration of 20 mole %;

.2.4 maximum propylene concentration of 45 mole %;

.2.5 maximum butadiene and butylenes combined concentration of 2 mole %;

.2.6 minimum saturated C4 hydrocarbon concentration of 4 mole %; and

.2.7 minimum propane concentration of 25 mole %.

17.18.3 Other compositions may be accepted provided the stability of the mixture is demonstrated to the satisfaction of the Society.

17.18.4 A ship carrying methyl acetylene-propadiene mixtures shall preferably have an indirect refrigeration system as specified in 7.2.4.2. Alternatively, a ship not provided with indirect refrigeration may utilize direct vapour compression refrigeration subject to pressure and temperature limitations depending on the composition. For the example compositions given in 17.18.2, the following features are to be provided:

.1 A vapour compressor that does not raise the temperature and pressure of the vapour above 60 °C and 17,5 bar gauge 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:

.2.1 two temperature actuated shut-down switches set to operate at 60 °C or less;

.2.2 a pressure actuated shut-down switch set to operate at 17,5 bar gauge or less; and

- .2.3** a safety relief valve set to relieve at 18,0 bar gauge or less.
- .3** The relief valve required by 17.18.4.2.3 shall vent to a mast meeting the requirements of 8.2.9, 8.2.10, 8.2.13 and 8.2.14 and shall not relieve into the compressor suction line.
- .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.

17.18.5 The piping system including the cargo refrigeration system, for tanks to be loaded with methyl acetylene-propadiene mixture is to be either independent (as defined in [Section 1, C.20.](#)) or separate (as defined in [Section 1, C.32.](#)) from piping and refrigeration systems for other tanks. This segregation applies to all liquid and vapour piping, liquid and vapour vent lines and any other possible connexions such as common inert gas supply lines.

17.19 Nitrogen

Materials of construction and ancillary equipment such as insulation must 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 should be given to ventilation in such areas where condensation might occur to avoid the stratification of oxygen enriched atmosphere.

17.20 Propylene oxide and mixtures of ethylene oxide/propylene oxide with ethylene oxide content of not more than 30 % by weight

17.20.1 Products transported under the provisions of this section should be acetylene free.

17.20.2.1 Unless cargo tanks are properly cleaned, these products should not be carried in tanks which have contained as one of the three previous cargoes any product known to catalyse polymerization, such as:

- .1** ammonia, anhydrous and ammonia solutions;
- .2** amines and amine solutions;
- .3** oxidizing substances (e.g. chlorine).

17.20.2.2 Before loading, tanks should 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 pro-

pylene oxide or ethylene oxide/ propylene oxide mixtures. Particular care should be taken in the case of ammonia in tanks made of steel other than stainless steel.

17.20.2.3 In all cases, the effectiveness of cleaning procedures for tanks and associated pipework should 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.

17.20.2.4 Tanks should 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 should be performed at intervals of not more than two years.

17.20.2.5 Tanks for the carriage of these products are to be of steel or stainless steel construction.

17.20.2.6 Tanks which have contained these products may be used for other cargoes after thorough cleaning of tanks and associated pipework systems by washing or purging.

17.20.3.1 All valves, flanges, fittings and accessory equipment are to be of a type suitable for use with these products and are to be constructed of steel or stainless steel in accordance with recognized standards. The chemical composition of all materials used is to be submitted for approval prior to fabrication. Discs or disc faces, seats and other wearing parts of valves are to be made of stainless steel containing not less than 11 % chromium.

17.20.3.2 Gaskets are to be constructed of materials which do not react with, dissolve in, or lower the auto-ignition temperature of these products and which are fire resistant and possess adequate mechanical behaviour. The surface presented to the cargo shall be polytetrafluoroethylene (PTFE) or materials giving a similar degree of safety by their inertness. Spirally-wound stainless steel with a filler of PTFE or similar fluorinated polymer may be accepted by the Society.

17.20.3.01 Gaskets of other types and/or materials are to be type approved by the Society.

17.20.3.3 Insulation and packing if used are to be of a material which does not react with, dissolve in, or lower the auto-ignition temperature of these products.

17.20.3.4 The following materials are generally found unsatisfactory for gaskets, packing and similar uses in containment systems for these products and require testing before being approved by the Society:

- .1 Neoprene or natural rubber if it comes into contact with the products;
- .2 Asbestos or binders used with asbestos;
- .3 Materials containing oxides of magnesium, such as mineral wools.

17.20.4 Filling and discharge piping are to extend to within 100 mm of the bottom of the tank or any sump.

17.20.5.1 The products should be loaded and discharged in such a manner that venting of the tanks to atmosphere does not occur. If vapour return to shore is used during tank loading, the vapour return system connected to a containment system for the product is to be independent of all other containment systems.

17.20.5.2 During discharging operations, the pressure in the cargo tank should be maintained above 0,07 bar gauge.

17.20.5.3 The cargo should be discharged only by deepwell pumps, hydraulically operated submerged pumps, or inert gas displacement. Each cargo pump is to be arranged to ensure that the product does not heat significantly if the discharge line from the pump is shut off or otherwise blocked.

17.20.6 Tanks carrying these products are to be vented independently of tanks carrying other products. Facilities are to be provided for sampling the tank contents without opening the tank to atmosphere.

17.20.7 Cargo hoses used for transfer of these products are to be marked "FOR ALKYLENE OXIDE TRANSFER ONLY".

17.20.8 Hold spaces are to be monitored for these products. Hold spaces surrounding type A and B independent tanks are also to be inerted and monitored for oxygen. The oxygen content of these spaces is to be maintained below 2 %. Portable sampling equipment is satisfactory.

17.20.9 Prior to disconnecting shore-lines, the pressure in liquid and vapour lines should be relieved through suitable valves installed at the loading header. Liquid and vapour from these lines should not be discharged to atmosphere.

17.20.10 Tanks are to be designed for the maximum pressure expected to be encountered during loading, carriage or unloading of cargo.

17.20.11 Tanks for the carriage of propylene oxide with a design vapour pressure of less than 0,6 bar and tanks for the carriage of ethylene oxide/propylene

oxide mixtures with a design vapour pressure of less than 1,2 bar are to have a cooling system to maintain the cargo below the reference temperature. For reference temperature see 15.1.4.1.

17.20.12 Pressure relief valve settings are not to be less than 0,2 bar gauge, and for type C independent tanks not greater than 7,0 bar gauge for the carriage of propylene oxide and not greater than 5,3 bar gauge for the carriage of ethylene oxide/propylene oxide mixtures.

17.20.13.1 The piping system for tanks to be loaded with these products is to be completely separate from piping systems for all other tanks, including empty tanks, and from all cargo compressors. If the piping system for the tanks to be loaded with these products is not independent as defined in [Section 1, C.20](#), the required piping separation must 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 connexions such as common inert gas supply lines.

17.20.13.2 The products may be transported only in accordance with cargo handling plans that have been approved by the Society. Each intended loading arrangement is to be shown on a separate cargo handling plan. Cargo handling plans are to show the entire cargo piping system and the locations for installation of blank flanges needed to meet the above piping separation requirements. A copy of each approved cargo handling plan shall be kept on board the ship. The Certificate of Fitness for the Carriage of Liquefied Gases in Bulk should be endorsed to include reference to the approved cargo handling plans.

17.20.13.3 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 is to be obtained from a responsible person, acceptable to the Port Administration, and carried on board the ship. Each connexion between a blank flange and pipeline flange is to be fitted with a wire and seal by the responsible person to ensure that inadvertent removal of the blank flange is impossible.

Guidance

The "responsible person" may be e.g. the ship's master or the Society's local Surveyor.

17.20.14 The maximum allowable tank loading limits for each cargo tank are to be indicated for each loading temperature which may be applied and for the applicable maximum reference temperature, on a list to be approved by the Society. A copy of the list is to be permanently kept on board by the master.

17.20.15 The cargo should be carried under a suitable protective padding of nitrogen gas. An automatic nitrogen make-up system is to be installed to prevent the tank pressure falling below 0,07 bar in the event of product temperature fall due to ambient conditions or malfunctioning of refrigeration system. Sufficient nitrogen is to be available on board to satisfy the demand of the automatic pressure control. Nitrogen of commercially pure quality (99,9 % by volume) is to 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.

17.20.16 The cargo tank vapour space should be tested prior to and after loading to ensure that the oxygen content is 2 % by volume or less.

17.20.17 A water spray system of sufficient capacity is to 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 is to be such as to give a uniform distribution rate of [10 ℓ /m² per minute]. The water spray system is to be capable of both local and remote manual operation and the arrangement is to ensure that any spilled cargo is washed away. Remote manual operation shall be arranged such that 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. Additionally, a water hose with pressure to the nozzle, when ambient temperatures permit, shall be connected ready for immediate use during loading and unloading operations.

Guidance

For ships trading to the territorial waters of the United States of America the relevant requirements of the U.S. Coast Guard should be complied with, i.e. the water spray system required by 17.20.17 must operate automatically in case of a fire.

17.21 Vinyl chloride

In cases where polymerization of vinyl chloride is prevented by addition of an inhibitor 17.8 is applicable. In cases where no or insufficient inhibitor has been added, any inert gas used for the purposes of 17.6 should contain not more oxygen than 0,1 %. Before loading is started, inert gas samples from the tanks and piping should be analysed. When vinyl chloride is carried, a positive pressure should always be maintained in the tanks, also during ballast voyages between successive carriages.

Section 18

Operating Requirements

18.1 Cargo information

18.1.1 Information should be on board and available to all concerned, giving the necessary data for the safe carriage of the cargo. Such information should include for each product carried:

- .1 a full description of the physical and chemical properties necessary for the safe containment of the cargo;
- .2 action to be taken in the event of spills or leaks;
- .3 counter measures against accidental personal contact;
- .4 fire fighting procedures and fire fighting media;
- .5 procedures for cargo transfer, gas freeing, ballasting, tank cleaning and changing cargoes;
- .6 special equipment needed for the safe handling of the particular cargo;
- .7 minimum allowable inner hull steel temperatures, and
- .8 emergency procedures.

18.1.2 Products required to be inhibited should be refused if the certificate required by 17.8 is not supplied.

18.1.3 A copy of the IGC-Code or national regulations incorporating the provisions of the IGC-Code should be on board every ship covered by the IGC-Code.

18.2 Compatibility

18.2.1 The Master should ascertain that the quantity and characteristics of each product to be loaded are within the limits indicated in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and the Loading and Stability booklet provided for in 2.2.5 and that the products are listed in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, if so required under [Section 3](#) of the Certificate.

18.2.2 Care should be taken to avoid dangerous chemical reactions if cargoes are mixed. This is of particular significance in respect of:

- .1 tank cleaning procedures required between successive cargoes in the same tank; and
- .2 simultaneous carriage of cargoes which react when mixed. This should be permitted only if the complete cargo systems including, but not limited to, cargo pipework, tanks, vent systems and refrigeration systems are separate as defined in Section 1, C.32.

18.3 Personnel training

18.3.1 Personnel involved in cargo operations should be adequately trained in handling procedures.

18.3.2 All personnel should be adequately trained in the use of protective equipment provided on board and have basic training in the procedures, appropriate to their duties, necessary under emergency conditions.

18.3.3 Officers should be trained in emergency procedures to deal with conditions of leakage, spillage or fire involving the cargo. ¹ A sufficient number of them should be instructed and trained in essential first aid for cargoes carried.

18.4 Entry into spaces

18.4.1 Personnel should not enter cargo tanks, hold spaces, void spaces, cargo handling spaces or other enclosed spaces where gas may accumulate unless:

- .1 the gas content of the atmosphere in that space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and the absence of toxic atmosphere; or

¹ Reference is made to the Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (MFAG), which provides advice on the treatment of casualties in accordance with the symptoms exhibited as well as equipment and antidotes that may be appropriate for treating the casualty.

- .2 personnel wear breathing apparatus and other necessary protective equipment and the entire operation is under the close supervision of a responsible officer.

18.4.2 Personnel entering any space designated as gas dangerous on a ship carrying flammable products should not introduce any potential source of ignition into the space unless it has been certified gas free and is maintained in that condition.

18.4.3.1 For internal insulation tanks, special fire precautions should be taken in the event of hot work carried out in the vicinity of the tanks. The gas absorbing and de-absorbing characteristics of the insulation material should thereby be taken into account.

18.4.3.2 For internal insulation tanks, repairs should be carried out in accordance with the procedures provided for in paragraph 4.4.7.6.

18.5 Carriage of cargo at low temperature

18.5.1 When carrying cargoes at low temperatures:

- .1 if provided the heating arrangements associated with cargo containment systems should be operated in such a manner as to avoid the temperature falling below that for which the material of the hull structure is designed;
- .2 loading should be carried out in such a manner as to ensure that unsatisfactory temperature gradients do not occur in any cargo tank, piping, or other ancillary equipment; and
- .3 when cooling down tanks from temperatures at or near ambient the cool down procedure laid down for that particular tank, piping and ancillary equipment should be followed closely.

18.6 Protective equipment

Personnel should be made aware of the hazards associated with the cargo being handled and should be instructed to act with care and use the appropriate protective equipment as mentioned in 14.1 during cargo handling.

18.7 Systems and controls

Cargo emergency shut-down and alarm systems involved in cargo transfer should be tested and/or checked before cargo handling operations begin. Essential cargo handling controls should also be tested and checked prior to transfer operations.

18.8 Cargo transfer operations

18.8.1 Transfer operations including emergency procedures should be discussed between ship personnel and the persons responsible at the shore facility prior to commencement and communications maintained throughout the transfer operations.

18.8.2 The closing time of the valve referred to in 13.3.1 (i.e. time from shut-down signal initiation to complete valve closure) should not be greater than:

$$\frac{3600 \cdot U}{L_R} \text{ [s]}$$

U = ullage volume at operating signal level [m³]

L_R = maximum loading rate agreed between ship and shore facility [m³/h].

The loading rate should 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.

18.9 Additional operating requirements

Additional operating requirements will be found in the following paragraphs of this Chapter:

3.8.4, 3.8.5, 7.1.1.5, 8.2.5, 8.2.7, 9.4.2,
9.5.3, 12.1.1, 12.1.10, 13.1.4, 14.2.5, 14.2.6,
14.3.1, 15.1, 15.2, 16.2.2, 17.4.2, 17.4.3,
17.6, 17.7, 17.11, 17.12, 17.13, 17.1.4,
17.15, 17.16, 17.17, 17.18, 17.20

Section 19

Summary of Minimum Requirements

19.1 Explanatory Notes to the Summary of Minimum Requirements

MFAG numbers are provided for information on the emergency procedures to be applied in the event of an incident with the products covered by the IGC Code. Where any of the products listed are carried at low temperature from which frostbite may occur MFAG No. 620 is also applicable.

UN-numbers (column b) The UN-numbers listed in column (b) of the list of products are intended for information only.

Vapour detection **F** – Flammable vapour detection

required **T** – Toxic vapour detection

(column f) **O** – Oxygen analyser

F + T – Flammable and toxic vapour detection

Gauging – types **I** – Indirect or closed, as described in 13.2.2.1 and .2

permitted **C** – Indirect or closed, as described in 13.2.2.1, .2 and .3

(column g) **R** – Indirect, closed or restricted, as described in 13.2.2.1, .2, .3 and .4

Pollution category (column o) Pollution category according to **MARPOL 73/78**, Annex II. (A "–" means that the product does not present a pollution hazard.)

Refrigerant gases Non toxic and non-flammable gases are e.g.:

Product name	UN-No.	Chemical formula	Density [kg/m ³]	Boiling point [°C]
Dichlorodifluoromethane (R 12)	1028	CCl ₂ F ₂	1487	– 30
Dichloromonofluoromethane (R 21)	1029	CHCl ₂ F	1410	9
Dichlorotetrafluoroethane (R 114)	1958	CCl F ₂ -CCl F ₂	1510	3,6
Monochlorodifluoromethane (R 22)	1018	CHCl F ₂	1414	– 41
Monochlorotetrafluoroethane (R 124)	1021	CHCl F-CF ₃		
Monochlorotrifluoromethane (R 13)	1022	CCl F ₃	1526	– 81,4

Gas mixtures 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.

Guidance

*Products to which an asterisk * is affixed, are also covered by Chapter 7 – Chemical Tankers.*

The values given in columns (j) – (n) are for guidance.

The guidance values for the product density are related to the boiling point.

Table 19.1 List of Products (columns a – h)

a	b	c	d	e	f	g	h
Product Name	UN-No.	Ship type	Type C independent tank required	Control of vapour space within cargo tanks	Vapour detection	Gauging	MFAG-No.
Acetaldehyde	1089	2 G/2 PG	—	Inert	F + T	C	300
Ammonia, anhydrous	1005	2 G/2 PG	—	—	T	C	725
Butadiene	1010	2 G/2 PG	—	—	F + T	R	310
Butane	1011	2 G/2 PG	—	—	F	R	310
Butane-propane mixtures	1011/1978	2 G/2 PG	—	—	F	R	310
Butylenes	1012	2 G/2 PG	—	—	F	R	310
Carbon dioxide	—	3G	Yes	—	—	C	—
Chlorine	1017	1 G	Yes	Dry	T	I	740
Diethyl ether*	1155	2 G/2 PG	—	Inert	F + T	C	330
Dimethylamine	1032	2 G/2 PG	—	—	F + T	C	320
Dimethyl ether	—	2G/2PG	—	—	F + T	C	—
Ethane	1961	2 G	—	—	F	R	310
Ethyl chloride	1037	2 G/2 PG	—	—	F + T	R	340
Ethylene	1038	2 G	—	—	F	R	310
Ethylene oxide	1040	1 G	Yes	Inert	F + T	C	365
Ethylene oxide/propylene oxide mixtures (max. 30 % by weight ethylene oxide)*	2983	2 G/2 PG	—	Inert	F + T	C	365
Isoprene*	1218	2 G/2 PG	—	—	F	R	310
Isopropylamine*	1221	2 G/2 PG	—	—	F + T	C	320
Methane (LNG)	1972	2 G	—	—	F	C	620
Methyl acetylene-propadiene mixtures	1060	2 G/2 PG	—	—	F	R	310
Methyl bromide	1062	1 G	Yes	—	F + T	C	345
Methyl chloride	1063	2 G/2 PG	—	—	F + T	C	340

Table 19.2 List of Products (columns i – o)

a	i	j	k	l	m	n	o
Product Name	Special requirements	Chemical formula	Density [kg/m ³]	Boiling -point [°C]	Flash- point [°C]	Auto- ignition tempe- rature [°C]	Pollution category
Acetaldehyde	14.4.3, 14.4.4, 17.4.1, 17.6.1	CH ₃ CHO	780	21	– 27	140	—
Ammonia, anhydrous	14.4.2, 14.4.3, 14.4.4, 17.2.1, 17.13	NH ₃	680	– 34	—	630	—
Butadiene	17.2.2, 17.4.2, 17.4.3, 17.6, 17.8	CH ₂ CHCHCH ₂	650	– 4,5	– 85	415	—
Butane		C ₄ H ₁₀	600	– 0,5	– 60	365	—
Butane-propane mixtures			630		– 50		—
Butylenes			630	– 6,3	– 75	440	—
Carbon dioxide		CO ₂		–79	—	—	—
Chlorine	14.4, 17.3.2, 17.4.1, 17.5, 17.7, 17.9, 17.14	Cl ₂	1560	– 34	—	—	—
Diethyl ether*	14.4.2, 14.4.3, 17.2.6, 17.3.1, 17.6.1, 17.10, 17.11, 17.15	C ₂ H ₅ OC ₂ H ₅	700	34,5	– 45	180	—
Dimethylamine	14.4.2, 14.4.3, 14.4.4, 17.2.1	(CH ₃) ₂ NH	670	7	– 18	400	—
Dimethyl ether		(CH ₃) ₂ O	735	–24,8	– 42,2	240	—
Ethane		C ₂ H ₆	550	– 88	– 183	515	—
Ethyl chloride		C ₂ H ₅ Cl	890	12	– 50	510	—
Ethylene		C ₂ H ₄	560	–104	– 136	425	—
Ethylene oxide	14.4.2, 14.4.3, 14.4.4, 14.4.6, 17.2.2, 17.3.2, 17.4.1, 17.5, 17.6.1, 17.16	(CH ₂) ₂ O	870	11	– 18	440	—
Ethylene oxide/propylene oxide mixtures (max. 30 % by weight ethylene oxide)*	14.4.3, 17.3.1, 17.4.1, 17.6.1, 17.10, 17.11, 17.20	(CH ₂) ₂ O + CH ₃ C HOCH ₂	830	27	– 20	430	C
Isoprene*	14.4.3, 17.8, 17.10, 17.12	CH ₂ C(CH ₃)CHC H ₂	680	34	– 48	220	C
Isopropylamine*	14.4.2, 14.4.3, 17.2.4, 17.10, 17.11, 17.12, 17.17	(CH ₃) ₂ CHNH ₂	670	32	– 20	400	C
Methane (LNG)		CH ₄	420	–163	– 175	595	—
Methyl acetylene-propadiene mixtures	17.18		620	– 20			—
Methyl bromide	14.4, 17.2.3, 17.32, 17.4.1, 17.5, 17.9	CH ₃ Br	1730	4	—	538	—
Methyl chloride	17.2.3	CH ₃ Cl	970	– 24	– 24	625	—

Table 19.3 List of Products (columns i – o) *(continued)*

a	b	c	d	e	f	g	h
Product Name	UN-No.	Ship type	Type C independent tank required	Control of vapour space within cargo tanks	Vapour detection	Gauging	MFAG-No.
Monoethylamine*	1036	2G/2 PG	—	—	F	R	320
Nitrogen	2040	3 G	—	—	O	C	620
Pentanes* (all isomers)	1265	2 G/2 PG	—	—	F	R	310
Pentene* (all isomers)	1108	2 G/2 PG	—	—	F	R	310
Propane	1978	2 G/2 PG	—	—	F	R	310
Propylene	1077	2 G/2 PG	—	—	F	R	310
Propylene oxide*	1280	2 G/2 PG	—	Inert	F + T	C	365
Refrigerant gases	—	3 G	—	—	—	R	350
Sulphur dioxide	1079	1 G	Yes	Dry	T	C	635
Vinyl chloride	1086	2 G/2 PG	—	—	F + T	C	340
Vinyl ethyl ether*	1302	2 G/2 PG	—	Inert	F + T	C	330
Vinylidene chloride*	1303	2 G/2 PG	—	Inert	F + T	R	340

Table 19.4 List of Products (columns i – o) (continued)

a	i	j	k	l	m	n	o
Product Name	Special requirements	Chemical formula	Density [kg/m ³]	Boiling-point [°C]	Flash-point [°C]	Auto-ignition temperature [°C]	Pollution category
Monoethylamine*	14.4.2, 14.4.3, 14.4.4, 17.2.1, 17.3.1, 17.10, 17.11, 17.12, 17.17	C ₂ H ₅ NH ₂	680	17	– 49	384	C
Nitrogen	17.19	N ₂	808	– 196	—	—	—
Pentanes* (all isomers)	14.4.4, 17.10, 17.12	CH ₃ (CH ₂) ₃ CH ₃	626	29 – 36	– 49	308	C
Pentene* (all isomers)	14.4.4, 17.10, 17.12	CH ₃ CH ₂ CH ₂ CH = CH ₂	656	30 – 37	– 18	270	C
Propane		C ₃ H ₈	590	– 42,3	– 42	470	—
Propylene		C ₃ H ₆	610	– 48	– 108	455	—
Propylene oxide*	14.4.3, 17.3.1, 17.4.1, 17.6.1, 17.10, 17.11, 17.20	CH ₃ CHOCH ₂	822	34	– 20	430	C
Refrigerant gases		See notes			—	—	—
Sulphur dioxide	14.4, 17.3.2, 17.4.1, 17.5, 17.7, 17.9	SO ₂	1460	– 10	—	—	—
Vinyl chloride	14.4.2, 14.4.3, 17.2.2, 17.2.3, 17.3.1, 17.6, 17.21	CH ₂ CHCl	970	– 14	– 77	472	—
Vinyl ethyl ether*	14.4.2, 14.4.3, 17.2.2, 17.3.1, 17.6.1, 17.8, 17.10, 17.11, 17.15	CH ₂ -CHOC ₂ H ₅	750	36	45	200	C
Vinylidene chloride*	14.4.2, 14.4.3, 17.2.5; 17.6.1, 17.8, 17.10, 17.11	CH ₂ -CCl ₂	1250	32	– 10	460	B

Annex A

Guidelines for the Evaluation of the Adequacy of Type-C Tank Vent Systems

Contents

1. General
2. Procedures
3. Equations
4. References
5. Worked Example of Procedures

These Guidelines are in accordance with the
IMO-Assembly Resolution A.829(19) adopted on 23rd November 1995.

1. General

1.1 The tank outlet to the pressure relief valves (PRVs) should remain in the vapour phase at the 98 % liquid level and Code specified list and trim.

1.2 PRVs, which have been sized using the GC-Codes, have adequate capacity.

1.3 To assure adequate relieving capacity condition 1.3.1 is required and to assure adequate blow-down condition 1.3.2 is required.

1.3.1 The pressure drop in the vent pipe from the cargo tank to the PRV inlet (Δp_{inlet}) should not exceed 3 % of MARVS, at the Code PRV capacity from equation (1) at $1,2 \cdot \text{MARVS}$ on all vapour flow.

1.3.2 The blowdown (Δp_{close}) should not be less than Δp_{inlet} plus $0,02 \cdot \text{MARVS}$ at the installed rated vapour capacity where required to assure stable operation of the PRV. This calculation should be performed at MARVS on all vapour flow.

Pilot-operated valves can tolerate higher inlet-pipe pressure losses when the pilot senses at a point that is not affected by the inlet-pipe pressure drop.

1.4 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 inter-connections which join other tanks, should not exceed the following values:

.1 for unbalanced PRVs: 10 % MARVS

Special consideration may be given in cases where the back pressure exceeds 10 % of MARVS at a tank pressure of $1,2 \cdot \text{MARVS}$; and

.2 for balanced PRVs and pilot operated PRVs as advised by manufacturer; normally 30 % of MARVS for balanced PRVs and 50 % of MARVS for pilot operated PRVs,

when assuming isenthalpic expansion of saturated liquid, at $1,2 \cdot \text{MARVS}$, through the PRV with the vent piping under fire exposure. A heat flux of 108 kW/m^2 is assumed for uninsulated vent piping.

1.5 The built-up back pressure in the vent piping may be estimated by the procedures outlined in Section 2.

1.6 A more accurate procedure for evaluating tank vent systems on flashing two-phase flow should be consulted if these simplified procedures do not demonstrate compliance with the requirements stated in 1.3 and 1.4 above.

1.7 MARVS means the maximum allowable relief valve setting of a cargo tank (gauge pressure).

2. Procedures

The following procedures will demonstrate the adequacy of a tank vent system to limit the pressure rise in a cargo tank to not greater than $1,2 \cdot \text{MARVS}$ during all conditions, including fire conditions implicit in 8.5.2 of the IGC Code.

2.1 Prepare a simplified flow sheet of the cargo tank vent system, identifying the fittings and the actual diameters and lengths of pipe. (See "5. Worked Example of the Procedures").

Divide the system into sections between nodes at changes in pipe diameter and at inter-connections with flows from other relief valves.

List the fittings and their dynamic loss coefficients. Calculate the external surface area of the piping sections between the nodes.

2.2 Calculate the Code PRV capacity (Q_{GCC}) of each tank PRV, in m^3/s of air at standard conditions in accordance with 8.5.2. of the IGC Code and note the installed rated capacity (Q_{IR}) of each PRV in m^3/s air at standard conditions at $1,2 \cdot \text{MARVS}$. The calculation should be done for the highest gas factor of the products included in the cargo list. N-butane has often the highest value for gas factor "G" in the Code and usually determines the Code minimum capacity.

Determine the mass flows for cargo conditions at $1,2 \cdot \text{MARVS}$ through each PRV for the Code PRV capacity and for the installed rated capacity for both all vapour flow and for two-phase cargo flow. Also calculate the mass flow at MARVS for the installed rated capacity on all vapour flow.

Equation (1) may be used for all vapour mass flow and equations (2), (3) and (4) may be used for two-phase mass flow. Equation (2) may be applied to multi component mixtures whose boiling point range does not exceed 100 K.

2.3 Estimate the all vapour flow pressure drop in the pipe from the cargo tank connection to the PRV inlet flange, working from the known tank pressure towards the PRV. This pressure drop is calculated by using the difference in stagnation pressures. Therefore, the second term of equation (5) may be used for pipe sections of constant diameter. For contractions Equation (5.1) may be used.

2.4 Check that the pressure drop at each PRV inlet complies with 1.3.1 at the Code PRV capacity for all vapour flow to assure adequate relief capacity. For the calculation the vapour mass flow of product (W_g) from equation (1) should be used.

For control purposes, 1.3.1 should be repeated using the Code PRV two-phase flow (W' , equation (4)) at

1.2 · MARVS and 1.3.2 by using the installed rated two-phase flow at MARVS. Both calculations should give a smaller inlet pressure loss than the corresponding all vapour pressure loss.

Check that the blowdown Δp_{close} complies with 1.3.2 to assure stable operation.

2.5 Estimate the two-phase flow pressure in the discharge pipe at the location of discharge to the atmosphere. Equation (6) may be used, with the Code PRV two-phase mass flow (W' , equation (4)) to assure adequate relief capacity, to check if the exit pressure is greater than 1 bar a.

2.6 Estimate the vapour fraction and two-phase density in the vent pipe at the exit to the atmosphere, assuming transfer of the fire heat flux of 108 kW/m² through the uninsulated vent piping. Equations (7) and (8) may be used.

2.7 Estimate the built-up back pressure at the PRV outlet flange, commencing from the known vent pipe exit pressure, calculating the pressure drop between pipe nodes and working, section by section, back up the pipe to the PRV.

Equations (7), (8), (9) and (5), may be used with iteration until the upstream node absolute pressure, vapour fraction and specific volume are justified and assuming that vapour is saturated.

At pipe diameter expansion fittings where fluid velocity is reduced, a pressure recovery generally occurs. This recovery is overestimated in case of two phase flow when dynamic loss coefficients for single phase flow are used. For the purpose of these guidelines, the static exit pressure of a conical expansion fitting is assumed to be equal to the static inlet pressure.

2.8 Estimate the choking pressure (p_{ec}) at the exit of every section with the mass-flux (G_p) in that section for the pipeline between the PRV and the vent exit. Equation (6) may be used.

Compare the pressure distribution along the vent line as derived from item 2.5 – 2.7, with the different choking pressures for each section as derived from equation (6).

If choking pressure at any location exceeds the corresponding calculated pressure derived from 2.5 – 2.7, the calculation as described in 2.5 – 2.7 should be repeated commencing from choking point location and corresponding choking pressure, working back up the pipe to the PRV.

If choking pressure at more than one location exceeds the corresponding calculated pressure derived from 2.5 to 2.7, the commencing point of the recalculation should be taken as the choking location point giving the highest built-up back pressure.

2.9 Check that the built-up back pressure at each PRV outlet complies with 1.4, at the Code PRV capacity for two-phase mass flow (W' , equation (4)), to assure stable operation of the valves, thus assuring adequate relief capacity.

2.10 For conventional unbalanced valves only:

.1 If back pressure as derived from 2.5 – 2.8 is within the range of 10 % to 20 % of MARVS, an additional evaluation should be performed in order to decide whether the system is acceptable.

.2 The system has to perform with the following requirement: With one valve closed and all others discharging at the installed rated PRV capacity, the back pressure should be less than 10 % of MARVS.

3. Equations

The following equations may be used to demonstrate the adequacy of the vent system.

Equation (1) for all vapour mass flow rate from tank through PRVs:

$$W_g = \frac{71 \cdot 10^3 \cdot F \cdot A^{0.82}}{h_{fg}} \quad [\text{kg/s}] \quad (1)$$

where

F = fire exposure factor according to Section 8.5 of the IGC Code

A = external surface area of Type C tank [m²]

h_{fg} = latent heat of vaporization of cargo at 1,2 · MARVS [J/kg]

Equation (2) for isenthalpic flashing mass flux of liquid through PRV orifice:

$$G_v \approx h_{fg} \cdot \rho_g \left[\frac{1}{T_o \cdot c} \right]^{1/2} \quad \left[\text{kg}/(\text{m}^2 \cdot \text{s}) \right] \quad (2)$$

where:

h_{fg} = see equation (1)

ρ_g = vapour density at 1,2 · MARVS and corresponding boiling temperature [kg/m³]

T_o = temperature of cargo at 1,2 · MARVS [K]¹

c = liquid specific heat at 1,2 · MARVS and T_o [J/(kg K)]

¹ °C + 273,15 ≡ K

Note:

This expression is valid for multi component mixtures whose boiling point range does not exceed 100 K.

Equation (3) for two-phase mass flow rate through PRV as installed:

$$W = G_v \cdot K_w \cdot A_v \quad [\text{kg/s}] \quad (3)$$

where:

G_v = is taken from Equation (2) $[\text{kg}/(\text{m}^2 \cdot \text{s})]$

K_w = PRV discharge coefficient on water
($\approx 0,8 \cdot$ measured K_d on air)

A_v = actual orifice area of PRV $[\text{m}^2]$

Equation (4) for Code PRV capacity for two-phase mass flow:

$$W' = G_v \cdot K_w \cdot A_v \frac{Q_{GCC}}{Q_{IR}} \quad [\text{kg/s}] \quad (4)$$

where:

Q_{GCC} = Code PRV capacity of air at standard conditions in accordance with IGC Code 8.5.2 $[\text{m}^3/\text{s}]$

Q_{IR} = installed rated PRV capacity of air at $T = 273 \text{ K}$ and $p = 1,013 \text{ bar}$ $[\text{m}^3/\text{s}]$

Equation (5) for the calculation of the static pressure difference in a pipe section of constant diameter in which the mass flux (G_p) is constant:

$$\Delta p = G_p^2 (v_e - v_i) + \frac{1}{2} G_p^2 \left(\frac{v_e + v_i}{2} \right) \left(4f \frac{L}{D} + \Sigma N \right) [\text{Pa}] \quad (5)$$

$(10^5 \text{ Pa} \triangleq 1 \text{ bar} \triangleq 14,5 \text{ psi})$

where:

$$G_p = \frac{W}{\pi \cdot D^2/4} \text{ or } \frac{W'}{\pi \cdot D^2/4} \quad \left[\text{kg}/(\text{m}^2 \cdot \text{s}) \right]$$

mass flux through the pipe section

v_e = two-phase specific volume at pipe section exit $[\text{m}^3/\text{kg}]$

v_i = two-phase specific volume at pipe section inlet $[\text{m}^3/\text{kg}]$

f = Fanning friction factor $f = 0,005$ for two-phase fully turbulent flow

L = length of pipe section $[\text{m}]$

D = diameter of pipe section $[\text{m}]$

ΣN = sum of dynamic loss coefficients for fittings in the pipe section $N = 4 f L/D$ equivalent.

(Typical values of N are given in Table A.2)

Equation (5.1) for contractions, the difference in stagnation pressure is defined by:

$$\Delta p = \frac{1}{2} \cdot G_{p,e}^2 \cdot v_i \cdot N \quad [\text{Pa}] \quad (5.1)$$

where:

N = dynamic loss coefficients of the contraction

$G_{p,e}$ = mass flux at the exit of the contraction $[\text{kg}/(\text{m}^2 \cdot \text{s})]$

v_i = specific volume at the inlet of the contraction $[\text{m}^3/\text{kg}]$

Equation (6) for two-phase critical choking pressure at vent mast exit or at exit from any vent pipe section:

$$P_{ec} = G_p \left[\frac{p_o \cdot \omega}{\rho_o} \right]^{1/2} \quad [\text{Pa}] \quad (6)$$

where

G_p = as defined in equation (5)

p_o = cargo vapour pressure in tank at inlet to PRV $[\text{Pa}]$

ρ_o = cargo liquid density in tank at inlet to PRV at p_o and T_o $[\text{kg}/\text{m}^3]$

ω = compressible flow parameter in tank at inlet to PRV

$$= \alpha_o + (1 - \alpha_o) \frac{\rho_o \cdot c \cdot T_o \cdot p_o \cdot (v_{go} - v_{fo})^2}{(h_{go} - h_{fo})^2}$$

where:

α_o = inlet void fraction or vapour volume fraction at inlet to PRV

= 0, when assuming isenthalpic expansion of saturated liquid, at $1,2 \cdot \text{MARVS}$, through the PRV

c = see equation (2)

T_o = see equation (2)

$(v_{go} - v_{fo})$ = difference in gaseous and liquid specific volume at temperature T_o at inlet to PRV (m^3/kg)

$(h_{go} - h_{fo})$ = difference in gaseous and liquid enthalpy at temperature T_o at inlet to PRV (J/kg)

Equation (7) for exit quality, or vapour mass fraction at pipe section exit:

$$x_e = \frac{h_{fo} - h_{fe} + 1000 \cdot q \cdot \sum a/W}{h_{fg}} \quad (7)$$

(e.g. $x_e = 0,3 \equiv 30\%$ quality $\equiv 30\%$ vapour + 70 % liquid by mass)

where:

- h_{fo} = liquid enthalpy in tank at inlet to PRV [J/kg]
- h_{fe} = liquid enthalpy at back pressure at pipe section exit [J/kg]
- h_{fg} = latent heat of vaporization at back pressure at pipe section exit [J/kg]
- q = heat flux from fire exposure into vent pipe equal to 108 [kW/m²]
- a = heated external surface area of vent pipe sections [m²]
- W = mass flow rate in vent pipe section [kg/s]

Equation (8), (9) for two-phase density (ρ) and specific volume (v):

$$\rho = \frac{\rho_g}{x} \left[\text{kg/m}^3 \right] \quad (8)$$

where:

- ρ_g = saturated vapour density at pipe section inlet or exit
- x = vapour fraction at pipe section inlet or exit

$$v = \frac{1}{\rho} \left[\text{m}^3/\text{kg} \right] \quad (9)$$

4. References

1. General
 - 1.1 IGC-, GC-Codes 8.2.17 draft text of amendments BCH 22/14 Annex 8
Code for Existing Ships 8.2.15 draft text of amendments BCH 22/14 Annex 8
 - 1.2 BCH 20/7 Annex 4, validated by BCH 21/INF.3 Annex 2
 - 1.3 IGC Code 8.2.16 draft amendment BCH 22/14 Annex 9; API RP 520 Part II, Third Edition, November 1988, 2.2.2 on page 2
 - 1.4 IGC Code 8.2.16 draft amendment BCH 22/14 Annex 9; API RP 521, Third Edition, November 1990, 5.4.1.3.1 on page 45 and API RP 520, Part I, Fifth Edition, July 1990, 2.2.4.1 on page 7 and 4.3.2.1 Fig. 27 on page 30.

- 1.5 BCH 20/7 Annex 5 and as referenced in 3. Equations.

2.4 Frank J. Heller:

Safety relief valve sizing: API versus CGA requirements plus a new concept for tank cars: API-Proceedings 1983, Refining Department, Vol. 62, API, W.D.C, pp. 123-135

3 Equations

- (1) "Some Notes on the Practical Application of the IMCO Gas Carrier Code to Pressure Vessel Type Cargo Tanks", M. Böckenhauer, GASTECH 1981, Hamburg 1981.
- (2) "Flashing Flows or: Some Practical Guidelines for Emergency Releases" Fauske and Associates, Plant/Operations Progress, July 1985, Private communication SIGTTO/Fauske and Associates, June 1st 1994
- (5) Private communication SIGTTO/Fauske and Associates, January 21, 1993. "The Discharge of Two-Phase Flashing Flow in a Horizontal Duct", Fauske and Associates, AIChE Journal, March 1987 on pages 524(equation) and 526(Fanning friction factor in two-phase flows).
- (6) "Size Safety Relief Valves for Flashing Liquids"; J.C. Leung (Fauske and Associates), Chemical Engineering Progress, Feb.(1992), pp. 70-75
- (7) BCH 20/7 Annex 5
- (8) BCH 20/7 Annex 5
- (9) BCH 20/7 Annex 5

5. Worked example of the procedures

Procedures Reference No.

By 2.1 Figure A.1 is a simplified flow sheet of a cargo tank vent system with one vent stack connected to two tanks. The system has been divided into sections between nodes, marked by capital letters A to N, at changes in pipe diameter and at interconnections with flows from other relief valves at F and J.

By 2.2 The IGC Code minimum tank relief capacity, Q_{GCC} , is calculated for the Case Study ship tank analysed in BCH 20/7, annexes 2 to 5 which has an external surface area of 747 m² and a MARVS of 11,0 bar g.

By IGC Code 8.5.2 for propane:

for

$$\begin{aligned} 1,2 \cdot \text{MARVS} &= 11,0 \cdot 1,2 + 1,0 = 14,2 \text{ bar a} \\ L^2 &= 308,6 \text{ kJ/kg} \end{aligned}$$

² L ist the latent heat "r" according to Section 8, 5.2.

$$T = 273 + 41 = 314 \text{ K}$$

$$D = 0,635, \text{ for } k = 1,13$$

$$Z = 1,0$$

$$M = 44$$

$$A^{0,82} = 227,05$$

$$F = 0,2$$

$$Q_{GCC} = 0,2 \cdot \frac{12,4}{308,6 \cdot 0,635} \cdot \sqrt{\left(\frac{1,0 \cdot 314}{44}\right)} \cdot$$

$$\cdot 227,05 = 7,68 \text{ m}^3/\text{s} \text{ of air at STP}$$

The Q_{GCC} for the actual case study ship tank is 7,71 m³/s of air at standard conditions (STP) of 273 K and 1,013 bar a.

The installed rated capacity for two 75 mm × 100 mm AGCo Type 95 POPRVs

$$Q_{IR} = 20,52 \text{ m}^3/\text{s} \text{ of air at STP}$$

$$\text{or } 20,52/7,71 = 2,66 \text{ times the } Q_{GCC}.$$

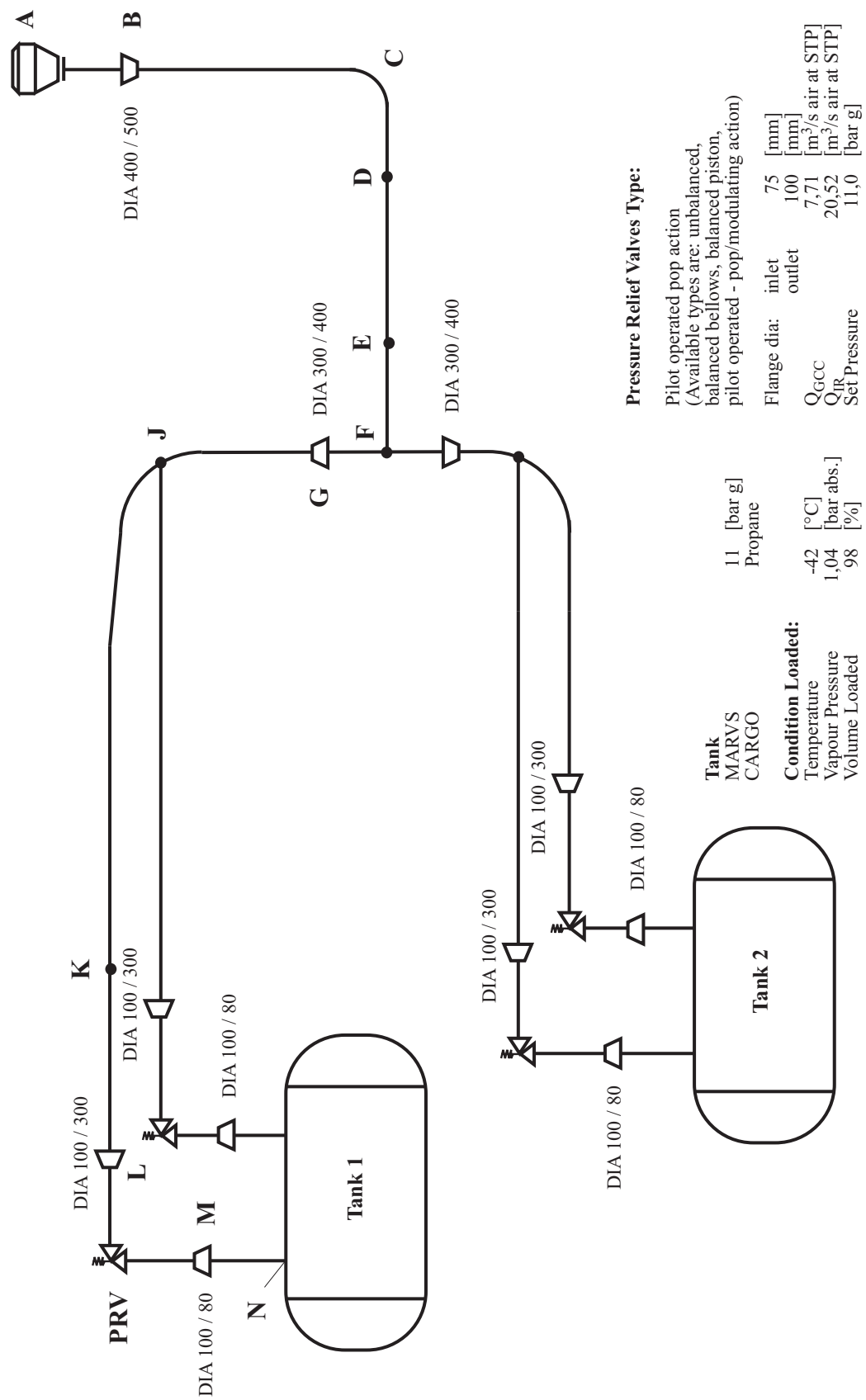


Fig. A.1 Simplified Flow Sheet of a Cargo Tank Vent System with one Vent Stack connected to two Tanks

Table A.1: List of Vent Pipe Lengths and Surface Areas, Fittings and Dynamic Loss Coefficients

Pipe section	Length [mm]	Pipe diameter [mm]	Surface area [m ²]	Fitting	Specification	Dynamic Loss Coefficients N	Pipe $4 f \frac{L}{D}$	$4 f \frac{L}{D} + \Sigma N$
A	1 080	500/700	2,04	A = Cowl / Vent Exit	---	2,25	---	2,25
A-B	1 565	500	2,46				0,063	0,063
Section total			4,50					2,313
B-C	2 650	400	3,331	B = Conical Expansion	d/D = 0,8	*)	0,132	0,132
C-D	2 546	400	3,20	C = Long Radius Bend	90°	0,3	0,127	0,427
D-E	14 880	400	18,701	D = Bend	45°	0,2	0,744	0,944
E-F	2 093	400	2,63	E = Bend	45°	0,2	0,105	0,305
Section total			27,86					2,008
F-G	642	400	0,81	F = Hard Tee	---	1,1	0,032	1,132
G-J	1 066	300	1,00	G = Conical Expansion	d/D = 0,75	*)	0,071	0,071
Section total			1,81					
J-K	1 340	300	1,263	J = Soft Tee	---	0,3	0,089	0,389
K-L	481	300	0,453	K = Bend	45°	0,2	0,032	0,232
Section total			1,72					0,621
L-PRV	216	300/100	---	L = Conical Expansion	d/D = 0,33	*)	0,043	0,043
PRV-M	108	80	---				0,027	0,027
M	108	80	---	M = Conical Reduction	d/D = 0,8	0,1	---	0,1
M-N	142	100	---	N = Square Edged Inlet	---	0,5	0,028	0,528

*) Ignored under Procedure 2.7

Table A.2: Typical values for Dynamic Loss Coefficient (N) for vent system fittings.
"N" may vary with pipe diameter.

Fitting		Equivalent $4f L/D = N$
Inlet pipe from tank to PRV:		
Square-edged inlet		0,5
Protruding conical inlet		0,15
Conical reduction		0,1
Discharge piping from PRV to mast vent exit:		
45° bend		0,2
45° single-mitre elbow		0,45
90° long radius bend		0,3
90° short radius bend		0,5
90° double-mitre elbow		0,6
Soft-Tee		0,3
Hard-Tee		1,1
Cowl mast vent exit		2,25
Top-Hat mast vent exit		[4,5]
Flame screen for IGC Code 17.10		1,4
References:		
"Sizing Safety Valve Inlet Lines" Chemical Engineering Progress, November 1980		
"Engineering Data Book, Figure 17-4" Gas Processors Association, 10th Edition, 1987		
"Guide for Pressure-Relieving and Depressuring Systems" Table 5, API RP 521 Third Edition, November 1990		

By equation (1) for all vapour mass flow rate from tank for propane:

where h_{fg} at $1,2 \cdot \text{MARVS} = 308600 \text{ J/kg}$

$$W_g = \frac{71000 \cdot 0,2 \cdot 227,05}{308600} = 10,44 \text{ kg/s}$$

or Code PRV all vapour mass flow rate per PRV = 5,22 kg/s

and Installed Rated all vapour mass flow rate PRV = $5,22 \cdot 2,66 = 13,89 \text{ kg/s}$

where h_{fg} at MARVS = 322800 J/kg

$$W_g = \frac{71000 \cdot 0,2 \cdot 227,05}{322800} = 9,99 \text{ kg/s}$$

or Installed Rated all vapour mass flow rate per PRV = $4,99 \cdot 2,66 = 13,27 \text{ kg/s}$

By equation (2) for two-phase mass flux through PRV orifice for propane.

At 1,2 · MARVS where $C = 2931 \text{ J/kg}$

$$G_v = 308600 \cdot 30,3 \cdot \left[\frac{1}{314 \cdot 2931} \right]^{\frac{1}{2}} = 9727 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

At MARVS where $C = 2750 \text{ J/kg}$

$$G_v = 322800 \cdot 25,5 \cdot \left[\frac{1}{307 \cdot 2750} \right]^{\frac{1}{2}} = 8959 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

By equation (3) for two-phase mass flow rate through installed rated PRV orifice area:

$$A_v = 0,004032 \text{ m}^2; K_w = 0,72$$

At 1,2 · MARVS:

$$W = 9727 \cdot 0,72 \cdot 0,004032 = 28,35 \text{ kg/s}$$

At MARVS:

$$W = 8959 \cdot 0,72 \cdot 0,004032 = 26,01 \text{ kg/s}$$

By equation (4) for two-phase mass flow rate through Code PRV:

At 1,2 · MARVS:

$$W' = 28,25 \cdot \frac{7,71}{20,52} = 10,6 \text{ kg/s}$$

By 2.3 The all vapour capacity and two-phase pressure drops in the pipe from the cargo tank to the PRV inlet are calculated as the difference in stagnation pressures by using the second term of equation (5) for pipe sections of constant diameter and by using equation (5.1) for conical reduction fittings (contractions).

For Code PRV all vapour capacity at 1,2 · MARVS

Section N to M and from Table A.1:

where

$$G_p = \frac{5,22}{\pi} \cdot \frac{0,1^2}{4} = 665 \text{ kg}/(\text{m}^2 \cdot \text{s});$$

$$v = 0,0330 \text{ m}^3/\text{kg}$$

with incompressible flow assumed.

$$\Delta P = 0,5 \cdot 665^2 \cdot 0,0330 \cdot 0,528 = 3900 \text{ Pa} (0,039 \text{ bar})$$

Conical reduction fitting M:

where

$$G_p = \frac{5,22}{\pi} \cdot \frac{0,08^2}{4} = 1038 \text{ kg}/(\text{m}^2 \cdot \text{s});$$

$$N = 0,1$$

$$\Delta P = 0,5 \cdot 1038^2 \cdot 0,0330 \cdot 0,1 = 1800 \text{ Pa} (0,018 \text{ bar})$$

Section M to PRV and from Table A.1:

where

$$G_p = 1038 \text{ kg}/(\text{m}^2 \cdot \text{s});$$

$$4f \frac{L}{D} + \sum N = 0,027$$

$$\Delta P = 0,5 \cdot 1038^2 \cdot 0,0330 \cdot 0,027 = 500 \text{ Pa} (0,005 \text{ bar})$$

Section N to PRV total $\Delta P = 0,039 + 0,018 + 0,005 = 0,06 \text{ bar}$

For installed rated all vapour capacity at MARVS

Section N to M:

where

$$G_p = \frac{13,27}{\pi} \cdot \frac{0,1^2}{4} = 1689 \text{ kg}/(\text{m}^2 \cdot \text{s});$$

$$v = 0,0392 \text{ m}^3/\text{kg}$$

with incompressible flow assumed

$$\Delta P = 0,5 \cdot 1689^2 \cdot 0,0392 \cdot 0,528 = 29500 \text{ Pa} (0,295 \text{ bar})$$

Conical reduction fitting M:

where

$$G_p = \frac{13,27}{\pi} \cdot \frac{0,08^2}{4} = 2640 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

$$\Delta P = 0,5 \cdot 2640^2 \cdot 0,0392 \cdot 0,1 = 13700 \text{ Pa} (0,137 \text{ bar})$$

Section M to PRV:

where

$$G_p = 2640 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

$$\Delta P = 0,5 \cdot 2640^2 \cdot 0,0392 \cdot 0,027 = 3700 \text{ Pa} (0,037 \text{ bar})$$

Section N to PRV total $\Delta P = 0,295 + 0,137 + 0,037 = 0,47 \text{ bar}$

For Code PRV two-phase capacity at 1,2 · MARVS

Section N to M:

where

$$G_p = \frac{10,6}{\pi} \cdot \frac{0,1^2}{4} = 1349 \text{ kg}/(\text{m}^2 \cdot \text{s});$$

$$v = 0,002145 \text{ m}^3/\text{kg}$$

with saturated liquid flow assumed

$$\Delta P = 0,5 \cdot 1349^2 \cdot 0,002145 \cdot 0,528 = 1000 \text{ Pa (0,01 bar)}$$

Conical reduction fitting M:

where

$$G_p = \frac{10,6}{\pi} \cdot \frac{0,08^2}{4} = 2109 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

$$\Delta P = 0,5 \cdot 2109^2 \cdot 0,002145 \cdot 0,1 = 500 \text{ Pa (0,005 bar)}$$

Section M to PRV:

where

$$G_p = 2109 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

$$\Delta P = 0,5 \cdot 2109^2 \cdot 0,002145 \cdot 0,027 = 100 \text{ Pa (0,001 bar)}$$

Section N to PRV total $\Delta P = 0,01 + 0,005 + 0,001 = 0,016$ bar

For Installed Rated two-phase capacity at MARVS

Section N to M:

where

$$G_p = \frac{26,01}{\pi} \cdot \frac{0,1^2}{4} = 3311 \text{ kg}/(\text{m}^2 \cdot \text{s});$$

$$v = 0,002088 \text{ m}^3/\text{kg}$$

with saturated liquid flow assumed

$$\Delta P = 0,5 \cdot 3311^2 \cdot 0,002088 \cdot 0,528 = 6000 \text{ Pa (0,06 bar)}$$

Conical reduction fitting M:

where

$$G_p = \frac{26,01}{\pi} \cdot \frac{0,08^2}{4} = 5174 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

$$\Delta P = 0,5 \cdot 5174^2 \cdot 0,002088 \cdot 0,1 = 2800 \text{ Pa (0,028 bar)}$$

Section M to PRV:

where

$$G_p = 5174 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

$$\Delta P = 0,5 \cdot 5174^2 \cdot 0,002088 \cdot 0,027 = 800 \text{ Pa (0,008 bar)}$$

Section N to PRV total $\Delta P = 0,06 + 0,028 + 0,008 = 0,10$ bar

By 2.4 Check system compliance with requirements of General Section ref. 1.3

1.3.1 At Code PRV all vapour capacity at 1,2 · MARVS

$$\Delta P \cdot \frac{100}{P_{\text{MARVS}}} = 0,06 \cdot \frac{100}{11,0} = 0,55 \%$$

Guideline 1,3 = 3 % maximum

At Code PRV two-phase capacity at 1,2 · MARVS

$$= 0,016 \cdot \frac{100}{11,0} = 0,15 \%$$

1.3.2 At installed rated all vapour capacity at MARVS

$$= 0,47 \cdot \frac{100}{11,0} = 4,27 \% \quad ^3$$

At installed rated two-phase capacity at MARVS

$$= 0,10 \cdot \frac{100}{11,0} = 0,91 \%$$

$$\Delta P_{\text{close}} > 0,02 \cdot P_{\text{MARVS}} + \Delta P_{\text{inlet}}$$

$$> 0,02 \cdot 11,0 + 0,47 > 0,69 \text{ bar}$$

For stable operation of the PRV, closing pressure should be less than:

$$11,0 - 0,69 \leq 10,31 \text{ bar g for a pop-action POPRV}$$

By 2.5 The two-phase critical exit choking pressure is estimated, using saturated propane properties at 1,2 · MARVS (14,2 bar a)

By equation (6)

where

$$w = 0 + (1 - 0) \frac{466,2 \cdot 2931 \cdot 314 \cdot 1420000 (0,0330 - 0,0021)^2}{(832800 \cdot 524200)^2}$$

$$= 6,09$$

and where W' for Code discharge from four PRVs

³ Acceptable because pilot senses at a point that is not affected by the inlet pipe pressure drop. If a protruding conical inlet (N = 0,15) had been added to the square-edged inlet (N = 0,5), the pressure drop would have been reduced, by $0,15/0,5 \cdot 29500 = 8900$ Pa, to 38000 Pa which is 3,5 % of set pressure.

$$\begin{aligned}
 &= 10,6 \cdot 4 = 42,4 \text{ kg/s;} \\
 D_{\text{exit}} &= 0,5 \text{ m,} \\
 G_p &= \frac{42,4}{\pi \cdot 0,5^2/4} = 215,9 \text{ kg/(m}^2 \cdot \text{s)}; \\
 P_{\text{ec}} &= 215,9 \cdot \left[\frac{1420000 \cdot 6,09}{466,2} \right]^{1/2} = \\
 &= 215,9 \cdot 136,2 = 29400 \text{ Pa (0,29 bar a)}
 \end{aligned}$$

Thus the exit flow is not choked and the vent pipe exit pressure is 100000 Pa (1 bar a)

By 2.6 The exit vapour fraction, x_e , assuming a fire exposure heat flux of 108 kW/m² into uninsulated vent discharge piping at the Code rated two-phase flow rate, is estimated.

By equation (7) and from Table A.1:

where

$$\sum \frac{a}{W} = \frac{27,86 + 4,50}{42,4} + \frac{1,81}{21,2} + \frac{1,72}{10,6} = 1,011 \text{ m}^2 \cdot \text{s/kg}$$

and

$$x_e = \frac{524200 - 320300 + 108000 \cdot 1,011}{425200} = 0,74$$

By equation (8) and (9)

$$\rho_e = \frac{2,32}{0,74} = 3,14 \text{ kg/m}^3 \text{ and } v_e = 0,319 \text{ m}^3/\text{kg}$$

By 2.7 The pressure drops between the vent discharge piping nodes are estimated by equation (5), with iteration until the upstream node absolute pressure, vapour fraction and specific volume are justified, and working section by section back up the pipe to the PRV.

Section B to A and from Table A.1:

where

$$G_p = 4 \cdot \frac{10,6}{\pi} \cdot \frac{0,5^2}{4} = 215,9 \text{ kg/(m}^2 \cdot \text{s)}$$

By first approximation

$$\begin{aligned}
 \Delta P &= 0,5 \cdot 215,9^2 \cdot 0,319 \cdot 2,313 \\
 &= 17200 \text{ Pa (0,17 bar)}
 \end{aligned}$$

Try $P_B = 1,18 \text{ bar a}$

By equation (7) and from Table A.1:

where

$$\sum \frac{a}{W} = \frac{27,86}{42,4} + \frac{1,81}{21,2} + \frac{1,72}{10,6} = 0,9048 \text{ m}^2 \cdot \text{s/kg}$$

and

$$x_B = \frac{524200 - 328700 + 108000 \cdot 0,9048}{421600} = 0,70$$

By equations (8) and (9):

$$\rho_B = \frac{2,73}{0,70} = 3,90 \text{ kg/m}^3;$$

$$v_B = 0,256 \text{ m}^3/\text{kg}$$

By equations (5):

$$\begin{aligned}
 \Delta P &= 215,9^2 \cdot (0,319 - 0,256) + 0,5 \cdot 215,9^2 \cdot \\
 &\quad \cdot \frac{(0,319 + 0,256)}{2} \cdot 2,313 \\
 &= 2900 + 15500 = 18400 \text{ Pa (0,18 bar)} \text{ and}
 \end{aligned}$$

$$P_B = 1,18 \text{ bar a}$$

By 2,8 and P_{ec} at

$$B = 337,3 \cdot 136,2 = 46000 \text{ Pa (0,46 bar a)}$$

using mass flux at exit from section F to B

Section F to B and from Table A.1:

where

$$G_p = 4 \cdot \frac{10,6}{\pi} \cdot \frac{0,4^2}{4} = 337,3 \text{ kg/(m}^2 \cdot \text{s)}$$

By first approximation:

$$\begin{aligned}
 \Delta P &= 0,5 \cdot 337,3^2 \cdot 0,256 \cdot 1,808 \\
 &= 26300 \text{ Pa (0,26 bar)}
 \end{aligned}$$

$$P_F = 1,18 + 0,26 = 1,44, \text{ Try } 1,51 \text{ bar a}$$

By equation (7) and from Table A.1:

where

$$\sum \frac{a}{W} = \frac{1,81}{21,2} + \frac{1,72}{10,6} = 0,2477 \text{ m}^2 \cdot \text{s/kg}$$

and

$$x_F = \frac{524200 - 343300 + 108000 \cdot 0,2477}{412600} = 0,50$$

By equations (8) and (9):

$$\rho_F = \frac{3,45}{0,50} = 6,90 \text{ kg/m}^3;$$

$$v_F = 0,145 \text{ m}^3/\text{kg}$$

By equation (5):

$$\begin{aligned} \Delta P &= 337,3^2 (0,256 - 0,145) + 0,5 \cdot 337,3^2 \\ &\quad \frac{(0,256 + 0,145)}{2} \cdot 1,808 \\ &= 12600 + 20600 = 33200 \text{ Pa (0,33 bar)} \end{aligned}$$

and

$$P_F = 1,18 + 0,33 = 1,51 \text{ bar a}$$

By 2,8 and P_{ec} at

$$F = 168,7 \cdot 136,2 = 23000 \text{ Pa (0,23 bar a)}$$

Section G to F and from Table A.1:

where

$$G_P = 2 \cdot \frac{10,6}{\pi} \frac{0,4^2}{4} = 168,7 \text{ kg/(m}^2 \cdot \text{s)}$$

By first approximation

$$\begin{aligned} \Delta P &= 0,5 \cdot 168,7^2 \cdot 0,145 \cdot 1,132 \\ &= 2300 \text{ Pa (0,02 bar)} \end{aligned}$$

This pressure drop is too small to justify a more accurate estimation. For the purposes of this calculation, we can assume the specific volume remains constant from G to L.

Section J to G and from Table A.1:

where

$$G_P = 2 \cdot \frac{10,6}{\pi} \frac{0,3^2}{4} = 299,9 \text{ kg/(m}^2 \cdot \text{s)}$$

By first approximation:

$$\begin{aligned} \Delta P &= 0,5 \cdot 299,9^2 \cdot 0,145 \cdot 0,071 \\ &= 500 \text{ Pa (0,01 bar)} \end{aligned}$$

Section L to J and from Table A.1:

where

$$G_P = \frac{10,6}{\pi} \frac{0,3^2}{4} = 149,9 \text{ kg/(m}^2 \cdot \text{s)}$$

By first approximation

$$\begin{aligned} \Delta P &= 0,5 \cdot 149,9^2 \cdot 0,145 \cdot 0,621 \\ &= 1000 \text{ Pa (0,01 bar)} \end{aligned}$$

$P_L = 1,51 + 0,02 + 0,01 + 0,01 = 1,55 \text{ bar a}$ at exit from conical expansion fitting.

By equation (7):

$$x_L = \frac{524200 - 344600 + 0}{415800} = 0,432$$

By equations (8) and (9):

$$\begin{aligned} \rho_L &= \frac{3,54}{0,432} = 8,19 \text{ kg/m}^3; \\ v &= 0,122 \text{ m}^3/\text{kg} \end{aligned}$$

Conical expansion fitting at L:

In accordance with Procedure 2.7 last paragraph, the static inlet pressure to this fitting is assumed to be 1,55 bar a.

Section PRV and from Table A.1:

where

$$G_P = \frac{10,6}{\pi} \frac{0,1^2}{4} = 1349,9 \text{ kg/(m}^2 \cdot \text{s)}$$

By 2.8 and P_{ec} at exit of pipe section from PRV to L $= 1349 \cdot 136,2 = 184000 \text{ Pa (1,84 bar a)}$

Therefore, the exit of the 100 mm diameter pipe section PRV to L is choked and the exit pressure at L is 1,84 bar a.

By equation (7) at 1,84 bar a:

$$x_L = \frac{524200 - 355100 + 0}{411600} = 0,411$$

By equations (8) and (9):

$$\begin{aligned} \rho_L &= \frac{4,18}{0,411} = 10,17 \text{ kg/m}^3; \\ v_L &= 0,098 \text{ m}^3/\text{kg} \end{aligned}$$

By first approximation:

$$\begin{aligned} \Delta P &= 0,5 \cdot 1349^2 \cdot 0,098 \cdot 0,043 \\ &= 3800 \text{ Pa (0,04 bar)} \end{aligned}$$

$\rho_{PRV} = 1,84 + 0,04 = 1,88 \text{ bar a}$, Try 2,42 bar a

By equation (7):

$$x_{PRV} = \frac{524200 - 371800}{403600} = 0,378$$

By equations (8) and (9):

$$\rho_{PRV} = \frac{5,49}{0,378} = 14,52 \text{ kg/m}^3;$$

$$v_{PRV} = 0,069 \text{ m}^3/\text{kg}$$

By equation (5):

$$\begin{aligned} \Delta P &= 1349^2 (0,098 - 0,069) + 0,5 \cdot 1349^2 \\ &\quad \left(\frac{0,098 + 0,069}{2} \right) \cdot 0,043 \\ &= 52800 + 3300 = 56100 \text{ Pa (0,56 bar)} \end{aligned}$$

and

$$P_{PRV} = 1,84 + 0,56 = 2,40 \text{ bar a (1,40 bar a)}$$

By 2.9 Back pressure at Code PRV two-phase flow at 14,2 bar a is $1,40 \cdot 100/11,0 = 12,7\%$ of set pressure (gauge) which assures adequate relief capacity for POPRVs.

By 2.10 Procedure for unbalanced PRVs only. The Procedures 2.5 to 2.8 are repeated in this worked example using the installed rated mass flow for information only.

By 2.5 At the installed rated two-phase mass flow $W = 28,25 \cdot 4 = 113,0 \text{ kg/s}$

By equation (6):

$$\begin{aligned} P_{ec} &= \frac{113,0}{\pi \cdot 0,5^2/4} \left[\frac{1420000 \cdot 6,09}{466,2} \right]^{1/2} \\ &= 78400 \text{ Pa (0,78 bar a)}. \end{aligned}$$

Thus exit flow is not choked and vent pipe exit pressure is 100000 Pa (1 bar a).

By 2.6 The exit vapour fraction is estimated by equation (7) $x_e = 0,58$ and the two-phase exit density and specific volume by equations (8) and (9).

$$\rho_e = 4,00 \text{ kg/m}^3;$$

$$v_e = 0,250 \text{ m}^3/\text{kg}$$

By 2.7 Section B to A:

where

$$G_p = 575 \text{ kg/(m}^2 \cdot \text{s)}; \quad \Sigma \frac{a}{W} = 0,339 \text{ m}^2 \cdot \text{s/kg}$$

$$x_B = 0,48; \quad \rho_B = 10,31 \text{ kg/m}^3; \quad v_B = 0,097 \text{ m}^3/\text{kg}$$

$$\Delta P = 116900 \text{ Pa (1,17 bar)}$$

$$P_B = 2,17 \text{ bar a}$$

$$P_{ec} = 899 \cdot 136,2 = 122000 \text{ Pa (1,22 bar a)}$$

Section F to B:

where

$$G_p = 899 \text{ kg/m}^2 \cdot \text{s}; \quad \Sigma \frac{a}{W} = 0,0929 \text{ m}^2 \cdot \text{s/kg}$$

$$x_F = 0,37; \quad \rho_F = 18,17 \text{ kg/m}^3; \quad v_F = 0,055 \text{ m}^3/\text{kg}$$

$$\Delta P = 89500 \text{ Pa (0,89 bar)}$$

$$P_F = 2,17 + 0,89 = 3,06 \text{ bar a}$$

$$P_{ec} = 449 \cdot 136,2 = 61000 \text{ Pa (0,61 bar a)}$$

Section G to F:

where

$$G_p = 499 \text{ kg/(m}^2 \cdot \text{s)}$$

$$\Delta P = 6300 \text{ Pa (0,06 bar)}$$

Section J to G:

where

$$G_p = 799 \text{ kg/(m}^2 \cdot \text{s)}$$

$$\Delta P = 1200 \text{ Pa (0,01 bar)}$$

Section L to J:

where

$$G_p = 400 \text{ kg/(m}^2 \cdot \text{s)}$$

$$\Delta P = 2600 \text{ Pa (0,03 bar)}$$

$$P_L = 3,06 + 0,06 + 0,01 + 0,03 = 3,16 \text{ bar a}$$

$$x_L = 0,34; \quad \rho_L = 20,44 \text{ kg/m}^3; \quad v_L = 0,049 \text{ m}^3/\text{kg}$$

$$P_{ec} = 400 \cdot 136,2 = 54000 \text{ Pa (0,54 bar a)}$$

Conical Expansion Fitting at L:

By procedure 2.7, static inlet pressure is 3,16 bar a.

Section PRV to L:

where

$$G_p = 3596 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

$$P_{ec} = 3596 \cdot 136,2 = 490000 \text{ Pa (4,9 bar a)}$$

Thus,

$$P_L = 4,90 \text{ bar a}$$

$$x_L = 0,270$$

$$x_{PRV} = 0,241$$

$$\Delta P = 83700 \text{ Pa (0,84 bar)}$$

$$P_{PRV} = 4,90 + 0,84 = 5,74 \text{ bar a or } 4,74 \text{ bar g}$$

By 2.9 Back pressure at installed rated two-phase flow at 14,2 bar a is $4,74 \cdot 100/11,0 = 43,1$ % of set pressure (gauge) which as-

ures normal full capacity operation of the POPRVs.

Summary of predictions

The predicted two-phase propane properties are shown at five node points in the PRV discharge vent piping, in Figure A.2 at the Code PRV flow-rate, and in Figure A.3 at the installed rated flow-rate. The flowing pressure drop in the piping to the PRV inlet is less than Guideline 1.3 requires. The built-up back pressure at the PRV outlet is also less than Guideline 1.4 requires for the pilot-operated PRVs installed.

The flowing pressure drop in the PRV inlet piping is well within Guideline 1.3 for the Code PRV all vapour flow-rate but exceeds the requirement for the installed rated all vapour flow-rate. However, the pressure drop is acceptable for reason expressed in the footnote to para. 1.3.2. The blowdown and closing pressure should be set to assure stable operation when both PRVs are open.

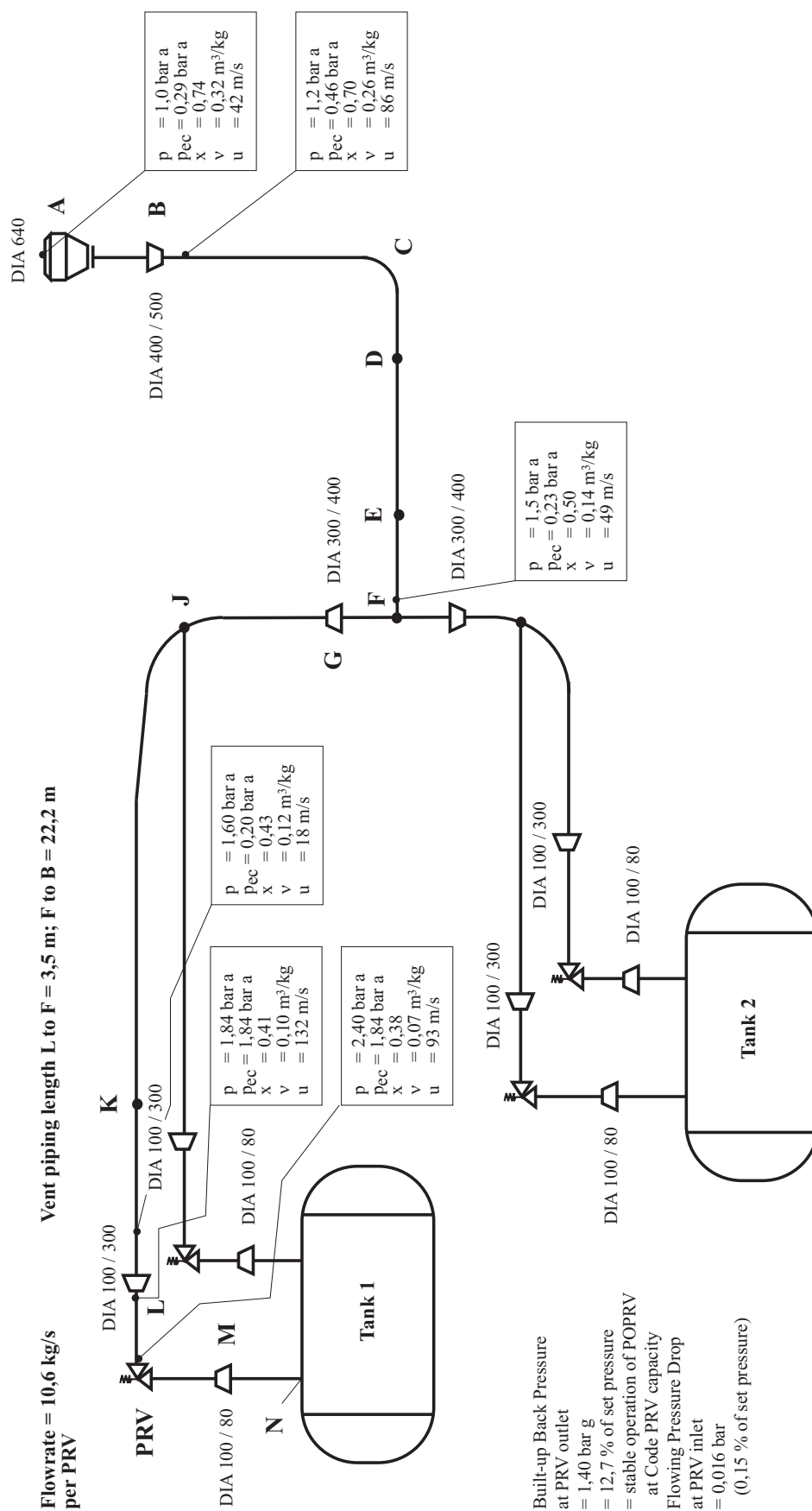
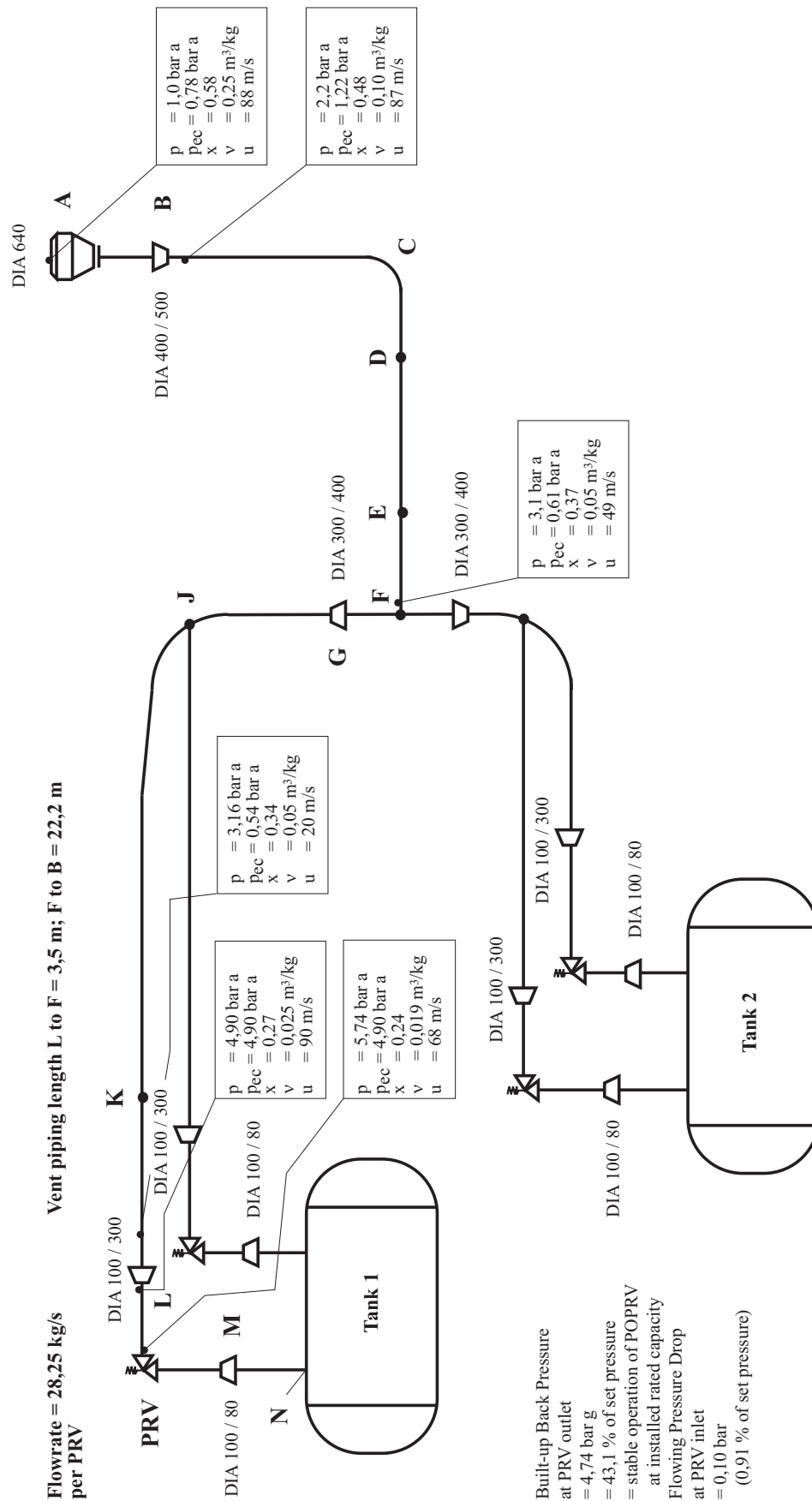


Fig. A.2 Two-Phase Propane Properties at Code PRV Relief Flowrate
(Simplified Flow Sheet of a Cargo Tank Vent System with one Vent Stack connected to two Tanks)



**Fig. A.3 Two-Phase Propane Properties at Installed Rated Flowrate
(Simplified Flow Sheet of a Cargo Tank Vent System with one Vent Stack connected to two Tanks)**

These procedures are now applied to example case 3B in Dow Chemical Company's Report to CTAC using their RELief DESign program, February 25, 1992 (BCH 22/INF.6). Per RELDES RESULTS on page 9, the last two-phase flow of 106 lbs/sec (48,1 kg/s) occurs at a tank pressure of 169 psig (12,66 bar a), Quality (percent vapour by mass) is stated to be 0,10 % and Vessel Inventory is 76,2 % liquid propane. The PRV discharge vent pipe is assumed to be 10 ft long by 8 inches diameter (3,04 m length $\times$ 0,203 m dia) and PRV Orifice Area is 12,3 sq. in. ($7,935 \cdot 10^{-3} \text{ m}^2$), $K_d = 0,953$.

By equation (2):

$$G_v = 318600 \cdot 26,9 \cdot \left[\frac{1}{309,3 \cdot 2722} \right]^{1/2}$$

$$= 9341 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

By equation (3), assuming $K_w = 0,8 \cdot 0,953 = 0,76$

$$W = 0,76 \cdot 0,007935 \cdot 9341 = 56,3 \text{ kg/s}$$

RELDES
prediction = 48,1 kg/s

Thus equations (2) and (3) predict a flow rate 17 % higher than RELDES.

By equation (6):

where

$$\alpha_o = \text{vapour fraction by volume in tank}$$

$$= 0,238 \text{ from Vessel Inventory}$$

$$w = 0,238 + 0,762 \cdot 475,0 \cdot 2722 \cdot 309,3 \cdot$$

$$\cdot \frac{1266000 (0,0372 - 0,002106)^2}{318600^2} = 4,92$$

and

$$P_{ec} = \frac{48,1}{0,03237} \left[\frac{1266000 \cdot 4,92}{475,0} \right]^{1/2} =$$

$$= 170200 \text{ Pa (1,70 bar a)}$$

At 12,66 bar a, Vapour Fraction by mass at PRV inlet.

$$\text{Vapour mass per cubic metre} = 0,238 \cdot 26,9 = 6,402 \text{ kg}$$

$$\text{Liquid Mass per cubic metre} = 0,762 \cdot 475,0 = 361,95 \text{ kg}$$

$$\text{Total Mass per cubic metre} = \underline{368,35 \text{ kg}}$$

$$\text{and Vapour Fraction} = 6,4/368 = 0,017$$

$$\text{or Quality} = 1,7 \% \text{ compared to RELDES } 0,10 \%$$

$$\text{At vent piping exit back pressure} = 1,70 \text{ bar a}$$

$$x_e = 0,0017 \cdot 0,983 \cdot \left[\frac{510400 \cdot 350500}{413700} \right] = 0,40$$

and

$$\rho_e = \frac{3,88}{0,40} = 9,70 \text{ kg}/\text{m}^3;$$

$$v_e = 0,103 \text{ m}^3/\text{kg}$$

$$G_p = \frac{48,1}{0,03237} = 1486 \text{ kg}/(\text{m}^2 \cdot \text{s})$$

say at inlet to vent discharge pipe back pressure = 3,31 bar a:

$$x_i = 0,017 + 0,983 \left[\frac{510400 - 392300}{393600} \right] = 0,31$$

and

$$\rho_i = \frac{7,33}{0,31} = 23,6 \text{ kg}/\text{m}^3;$$

$$v_i = 0,042 \text{ m}^3/\text{kg}$$

By equation (5), where $4f L/D = 4 \cdot 0,005 \cdot 3,04/0,203 = 0,30$

$$\Delta P = 1486^2 \cdot (0,103 - 0,042) + 0,5 \cdot 1486^2 \cdot$$

$$\cdot \frac{(0,103 + 0,042)}{2} \cdot 0,3$$

$$= 134700 + 24000 = 158700 \text{ Pa (1,59 bar)}$$

Thus Back Pressure at PRV discharge flange:

$$= 1,70 + 1,59 = 3,29 \text{ bar a or } = 2,29 \text{ bar g}$$

(33,2 psig) for comparison with RELDES prediction 32,8 psig

= Thus **equations (6), (7), (8), (9) and (5)** predict a Back Pressure 1 % higher than RELDES