PART II RULES FOR THE CONSTRUCTION AND CLASSIFICATION OF SHIPS IDENTIFIED BY THEIR MISSION

TITLE 34 LIQUEFIED GAS CARRIER

INTERNATIONAL CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING LIQUEFIED GASES IN BULK, 2006, AS AMENDED

SECTION 6 PIPING

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CHAPTER A
CARGO CONTAINMENT

For ships constructed from 1986-07-01

CHAPTER CONTENTS

A1. CARGO CONTAINMENT – *STRUCTURES*

A2. CARGO CONTAINMENT – *BARRIERS AND MATERIALS*

A1. 4 CARGO CONTAINMENT - *STRUCTURES*

100. 4.1 General

101. 4.1.1 Administrations should take appropriate steps to ensure uniformity in the implementation and application of the provisions of this chapter *.

** Reference is made to the published Rules of members and associate members of the International Association of Classification Societies and in particular to IACS Unified Requirements Nos. G1 and G2.*

102. 4.1.2 In addition to the definitions in 1.3, the definitions given in this chapter apply throughout the Code.

103. 4.2 **Definitions**

a. 4.2.1 *Integral tanks*

a.1. 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.

a.2. 4.2.1.2 The design vapour pressure P_o as defined in 4.2.6 should not normally exceed 0.25 bar. If, however, the hull scantlings are increased accordingly, P_o may be increased to a higher value but less than 0.7 bar.

a.3. 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 Administration subject to special consideration.

b. 4.2.2 *Membrane tanks*

b.1. 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.

b.2. 4.2.2.2 The design vapour pressure Po should not normally 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, Po may be increased to a higher value but less than 0.7 bar.

b.3. 4.2.2.3 The definition of membrane tanks does not exclude designs such as those in which nonmetallic membranes are used or in which membranes are included or incorporated in insulation. Such designs require, however, special consideration by the Administration. In any case the thickness of the membranes should normally not exceed 1 mm.

c. 4.2.3 *Semi-membrane tanks*

c.1. 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.

c.2. 4.2.3.2 The design vapour pressure P_o should not normally 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_o may be increased to a higher value but less than 0.7 bar.

d. 4.2.4 *Independent tanks*

d.1. 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 A1.103.d.2 to d.5.

d.2. 4.2.4.2 Type A independent tanks are tanks which are designed primarily using recognized standards * of classical ship-structural analysis procedures. Where such tanks are primarily constructed of plane surfaces (gravity tanks), the design vapour pressure P_o should be less than 0.7 bar.

d.3. Recognized Standards for the purpose of chapters 4, 5 and 6 are standards laid down and maintained by a classification society recognized by the Administration.

d.4. 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_o should be less than 0.7 bar.

d.5. 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 not less than:

$P_o = 2 + A \times C(\rho_r)1.5$ (bar)

Where

$A = 0.0185 \times [\sigma_m/\Delta\sigma_A]^2$

with

σ_m = design primary membrane stress

$\Delta\sigma_A$ = *allowable dynamic membrane stress (double amplitude at probability level Q = 10-8*

55 N/mm² for ferritic-perlitic, martensitic and austenitic steels

25 N/mm² for aluminium alloy (5083-0)

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

H=0.75b, or 0,45 l

with

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

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

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

ρ_r *= the relative density of the crgo (= 1 for fresh water at the design temperature)*

e. *425. However, the Administration may allocate a tank complying with the criterion of this subparagraph to type A or type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.*

104. *IACS' unified interpretation GC7* *(1986)Carriage of products not covered by the code :*

a. 1 If the carriage of products not covered by the Code is intended, it should be verified that the double amplitude of the primary membrane stress Δσm created by the maximum dynamic pressure differential Δp does not exceed the allowable double amplitude of the dynamic membrane stress ΔσA as specified in item 103.d.5, i.e.:

$$\Delta_{\sigma m} \leq \Delta_{\sigma A}$$

b. 2 The dynamic pressure differential delta(p) should be calculated as follows:

$$\Delta\rho = \frac{P}{1{,}02 * 10^4}\left(a_{\beta 1} Z_{\beta 1} - a_{\beta 2} * Z_{\beta 2}\right)$$

where ρ, aβ, Zβ are as defined in A1.202.b, *see also figures F.A1.104.1 and F.A1.104.2. aβ1 and Zβ1 are the aβ- and Zβ- values giving the maximum liquid pressure hgdmax as defined in A1.202. In order to evaluate the maximum pressure differential Δp, pressure differentials should be evaluated over the full range of the acceleration ellipse as shown in the sketches given below.*

FIGURE F.A1.104.1 – ACCELERATION ELLIPSE

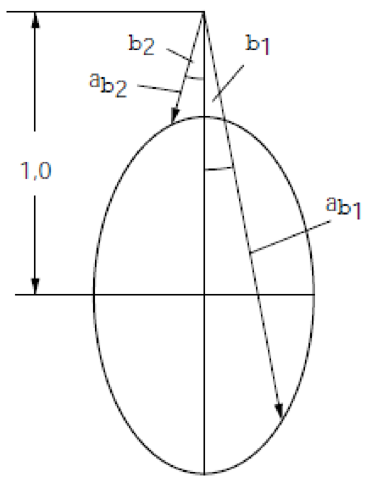
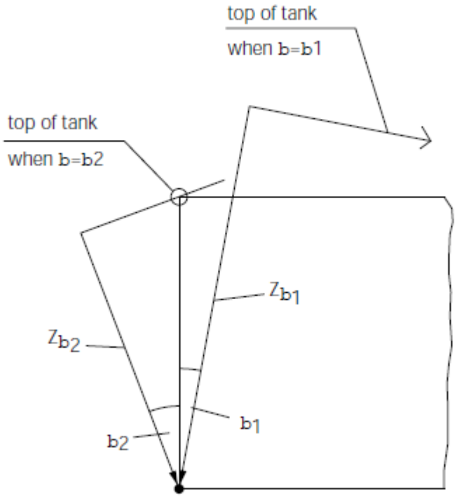


FIGURE F.A1.104.2 – SKETCHES TO OBTAIN MAXIMUM LIQUID PRESSURE



105. 1 The effective width of the associated plating should be taken as:

a. .1. *For cylindrical shells:*

an effective width (mm) not greater than

$$0,78*\sqrt{(r*t)}$$

on each side of the web. A doubler plate, if any, may be included within that distance.

where:

r = mean radius of the cylindrical shell (mm)

t = shell thickness (mm).

b. 2 *For longitudinal bulkheads (in case of lobe tanks):*

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

where

t_b = bulkhead thickness (mm).

b.1. 2.2 The stiffening ring should be loaded with circumferential forces, on each side of the ring, due to the shear stress, determined by the bi-dimensional shear flow theory from the shear force of the tank.

c. 3 The following factors should be taken into account:

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

c.2. 2 Change in contact surface between tank and support, and of the relevant reactions, due to; - thermal shrinkage of tank - elastic deformations of tank and support material. The final distribution of the reaction forces at the supports should not show any tensile forces.

d. 4 Thebuckling strength of the stiffening rings should be examined.

End of interpretation

106. 4.2.5 *Internal insulation tanks*

107. 4.2.5.11 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.

108. 4.2.5.2 The two categories of internal insulation tanks are:

a. 1 Type 1 tanks which are tanks in which the insulation or a combination of the insulation and one or more liners functions only as the primary barrier. The inner hull or an independent tank structure should function as the secondary barrier when required.

b. 2 Type 2 tanks which are tanks in which the insulation or a combination of the insulation and one or more liners functions as both the primary and the secondary barrier and where these barriers are clearly distinguishable.

109. The term "liner" means a thin, non-self-supporting, metallic, nonmetallic 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 is not intended to function alone as a liquid barrier.

110. 4.2.5.3 Internal insulation tanks should be of suitable materials enabling the cargo containment system to be designed using model tests and refined analytical methods as required in A1.421.

111. 4.2.5.4 The design vapour pressure P_o should not normally exceed 0.25 bar. If, however, the cargo containment system is designed for a higher vapour pressure, P_o 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 Administration provided the internal insulation tanks are supported by suitable independent tank structures.

112. 4.2.6 **Design vapour pressure**

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

b. 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_o should not 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 Administration 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.

c. 4.2.6.3 In all cases, including A1.112.b, P_o should not be less than MARVS.

d. 4.2.6.4 Subject to special consideration by the Administration and to the limitations given in item 103.a. to 103.e. for the various tank types, a vapour pressure higher than P_o may be accepted in harbour conditions, where dynamic loads are reduced.

113. 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. Provision to the satisfaction of the Administration should be made to ensure that the tank or cargo temperature cannot be lowered below the design temperature.

200. 4.3 Design loads

201. 4.3.1 **General**

a. 4.3.1.1 Tanks together with their supports and other fixtures should be designed taking into account proper combinations of the following loads:

a.1. internal pressure

a.2. external pressure

a.3. dynamic loads due to the motions of the ship

a.4. thermal loads

a.5. sloshing loads

a.6. loads corresponding to ship deflection

a.7. tank and cargo weight with the corresponding reactions in way of supports

a.8. insulation weight

a.9. loads in way of towers and other attachments.

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

b. 4.3.1.2 Account should be taken of the loads corresponding to the pressure test referred to in A1.100.

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

d. 4.3.1.4 The tanks should be designed for the most unfavourable static heel angle within the range 0° to 30° without exceeding allowable stresses given in A1.501.

202. 4.3.2 **Internal pressure**

a. 4.3.2.1 The internal pressure head P_{eq} in bars gauge resulting from the design vapour pressure P_o and the liquid pressure P_{gd} defined in A1.202.b, but not including effects of liquid sloshing, should be calculated as follows:

$$P_{eq} = P_o + (P_{gd})_{max} \text{(bar)}$$

Equivalent calculation procedures may be applied.

b. 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 A1.204.a. The value of internal pressure head p_{gd} resulting from combined effects of gravity and dynamic accelerations should be calculated as follows:

$$P_{gd} = a_\beta \times Z_\beta \times \rho / 10200 \text{ (bar)}$$

where:

a_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β (see figure F.A1.202.1).

FIGURE F.A1.202.1 – ACCELERATION ELLIPSE

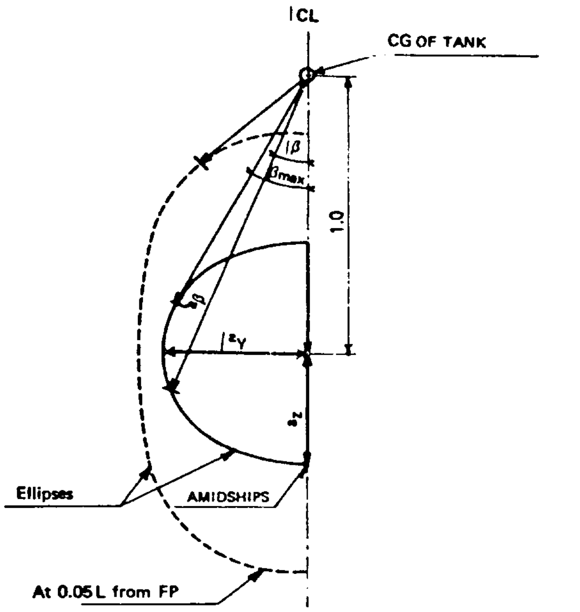
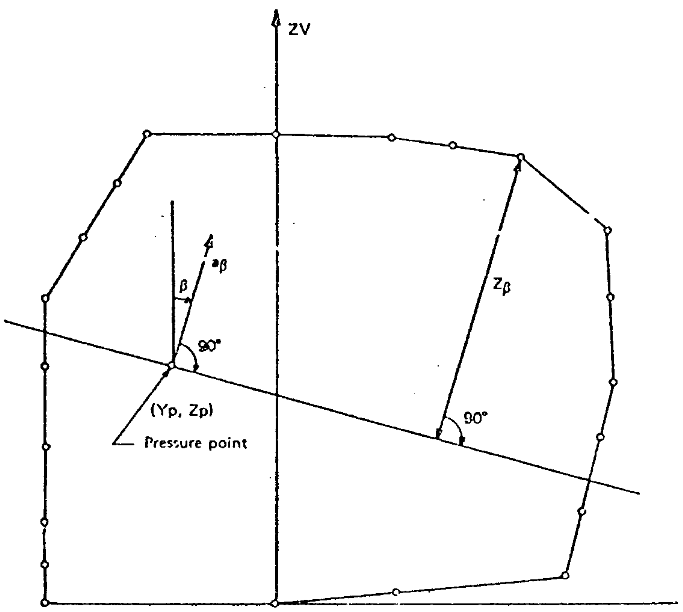


FIGURE F.A1.202.2 – DETERMINATION OF INTERNAL PRESSURE HEADS



Tank domes considered to be part of the accepted total volume of the cargo tank should be taken into account when determining Z_β unless the total volume of tank domes V_d does not exceed the following value:

$V_d=V_t\times[(100-FL)/FL]$

where:

V_t = tank volume without any domes

FL = filling limit according to chapter I (chapter 15).

ρ = maximum cargo density (kg/m³) at the design temperature.

The direction which gives the maximum value $(P_{gd})_{max}$ of P_{gd} should be considered. Where acceleration in three directions needs to be considered, an ellipsoid should be used instead of the ellipse in figure F.A1.202.1. The above formula applies only to full tanks.

203. 4.3.3 **External pressure**

External design pressure loads should 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.

204. 4.3.4 **Dynamic loads due to ship motions**

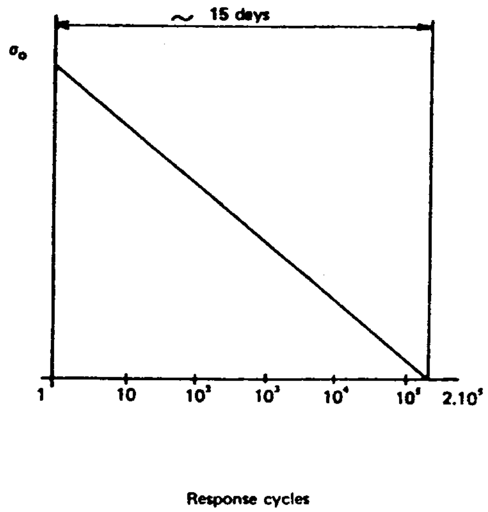
a. 4.3.4.1 The determination of dynamic loads should take account of the long-term distribution of ship motions, including the effects of surge, sway, heave, roll, pitch and yaw on irregular seas which the ship will experience during its operating life (normally taken to correspond to 10 exp 8 wave encounters). 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.

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

c. 4.3.4.3 When design against fatigue is to be considered, the dynamic spectrum should be determined by long-term distribution calculation based on the operating life of the ship (normally taken to correspond to 108 wave encounters). If simplified dynamic loading spectra are used for the estimation of the fatigue life, those should be specially considered by the Administration.

d. 4.3.4.4 For practical application of crack propagation estimates, simplified load distribution over a period of 15 days may be used. Such distributions may be obtained as indicated in figure F.A1.202.3.

FIGURE F.A1.202.3 – SIMPLIFIED LOAD DISTRIBUTION



σ_0 = most probable maximum stress over the life of the ship

Response is logarithmic: the value of **2.10^5** is given as an example of estimate.

e. 4.3.4.5 Ships for restricted service may be given special consideration.

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

TABLE T.A1.204.1 – ACCELERATIONS ACTING

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 accelerations of surge and pitch; and gravity component of pitch.

204. 4.3.5 **Sloshing loads**

a. 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 A1 204.f. should be considered.

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

205. 4.3.6 Thermal loads

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

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

206. 4.3.7 **Loads on supports**

The loads on supports are covered by A1.600.

400. 4.4 Structural analyses

401. 4.4.1 **Integral tanks**

The structural analysis of integral tanks should be in accordance with Recognized Standards. The tank boundary scantlings should meet at least the requirements for deep tanks taking into account the internal pressure as indicated A1.202, but the resulting scantlings should not be less than normally required by such standards.

402. 4.4.2 *Membrane tanks*

403. 4.4.2.1 For membrane tanks, the effects of all static and dynamic loads should be considered to determine the suitability of the membrane and of the associated insulation with respect to plastic deformation and fatigue.

404. 4.4.2.2 Before approval is given, a model of both the primary and secondary barriers, including corners and joints, should normally be tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. Test conditions should represent the most extreme service conditions the cargo containment system will see in its life. Material tests should ensure that ageing is not liable to prevent the materials from carrying out their intended function.

405. 4.4.2.3 For the purpose of the test referred to in A1.404, a complete analysis of the particular motions, accelerations and response of ships and cargo containment systems should be performed, unless these data are available from similar ships.

406. 4.4.2.4 Special attention should 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.

407. 4.4.2.5 A structural analysis of the hull should be to the satisfaction of the Administration, taking into account the internal pressure as indicated in A1.202. Special attention, however, should be paid to deflections of the hull and their compatibility with the membrane and associated insulation. Inner hull plating thickness should meet at least the requirements of Recognized Standards for deep tanks taking into account the internal pressure as indicated in A1.202. The allowable stress for the

membrane, membrane-supporting material and insulation should be determined in each particular case.

408. 4.4.3 *Semi-membrane tanks*

409. A structural analysis should be performed in accordance with the requirements for membrane tanks or independent tanks as appropriate, taking into account the internal pressure as indicated in A1.202.

410. 4.4.4 *Type A independent tanks*

411. 4.4.4.1 A structural analysis should be performed to the satisfaction of the Administration taking into account the internal pressure as indicated in A1.202. The cargo tank plating thickness should meet at least the requirements of Recognized Standards for deep tanks taking into account the internal pressure as indicated in A1.202 and any corrosion allowance required by A1.215.

412. 4.4.4.2 For parts such as structure in way of supports not otherwise covered by Recognized Standards, stresses should be determined by direct calculations, taking into account the loads referred to in A1.200 as far as applicable, and the ship deflection in way of supports.

413. 4.4.5 *Type B independent tanks*

414. For tanks of this type the following applies:

a. 1 The effects of all dynamic and static loads should be used to determine the suitability of the structure with respect to:

a.1. plastic deformation

a.2. buckling

a.3. fatigue failure

a.4. crack propagation.

Statistical wave load analysis in accordance with A1.204, finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, should be carried out.

b. 2 A three-dimensional analysis should be carried out to evaluate the stress levels contributed by the ship' s hull. The model for this analysis should include the cargo tank with its supporting and keying system as well as a reasonable part of the hull.

c. 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 should be performed unless these data are available from similar ships.

d. 4 A buckling analysis should consider the maximum construction tolerances.

e. 5 Where deemed necessary by the Administration, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

f. 6 The cumulative effect of the fatigue load should comply with:

$$\sum[(ni/Ni) + 1000/Nj] \leq Cw.$$

where:

ni = number of stress cycles at each stress level during the life of the ship

Ni = number of cycles to fracture for the respective stress level according to the Wöhler (S-N) curve

Nj = number of cycles to fracture for the fatigue loads due to loading and unloading

Cw should be less than or equal to 0.5, except that the Administration may give special consideration to the use of a value greater than 0.5 but not greater than 1.0, dependent on the test procedure and data used to establish the Wöhler (S-N) curve.

415. 4.4.6 *Type C independent tanks*

416. 4.4.6.1 Scantlings based on internal pressure should be calculated as follows:

a. 1 The thickness and form of pressure-containing parts of pressure vessels under internal pressure, including flanges should be determined according to a standard acceptable to the Administration. These calculations in all cases should be based on generally accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels should be reinforced in accordance with a standard acceptable to the Administration.

b. 2 The design liquid pressure defined in A1.202 should be taken into account in the above calculations.

c. 3 The welded joint efficiency factor to be used in the calculation according to item a. should be 0.95 when the inspection and the non-destructive testing referred to in paragraph 114 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 Administration may accept partial non-destructive examinations, 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 efficiency factor of not more than 0.85 should be adopted. For special materials, the above mentioned factors should be reduced depending on the specified mechanical properties of the welded joint.

417. 4.4.6.2 Buckling criteria should be as follows:

a. 1 The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses should be to a standard acceptable to the Administration. These calculations in all cases should be based on generally accepted pressure vessel buckling theory and should 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.

b. 2 The design external pressure Pe used for verifying the buckling of the pressure vessels should not be less than that given by:

$Pe = P1 + P2 + P3 + P$ (bar)

where:

P1 = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves P1 should be specially considered, but should not in general be taken as less than 0.25 bar.

P2 = the set pressure of the pressure relief valves for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere P2 = 0.

P3 = compressive actions in the shell due to the weight and contraction of insulation, weight of shell, including corrosion allowance, and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition the local effect of external or internal pressure or both should be taken into account.

P = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere P4 = 0.

418. 4.4.6.3 Stress analysis in respect of static and dynamic loads should be performed as follows:

a. 1 Pressure vessel scantlings should be determined in accordance with A1.416 and A1.417.

b. 2 Calculations of the loads and stresses in way of the supports and the shell attachment of the support should be made. Loads referred to in A1.200 should be used, as applicable. Stresses in way of the supports should be to a standard acceptable to the Administration. In special cases a fatigue analysis may be required by the Administration.

c. 3 If required by the Administration, secondary stresses and thermal stresses should be specially considered.

419. 4.4.6.4 For pressure vessels, the thickness calculated according to A1.416 or the thickness required by A1.417 plus the corrosion allowance, if any, should be considered as a minimum without any negative tolerance.

420. 4.4.6.5 For pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, should not be less than 5 mm for carbon-manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys.

421. 4.4.7 *Internal insulation tanks*

422. 4.4.7.1 The effects of all static and dynamic loads should be considered to determine the suitability of the tank with respect to:

a. fatigue failure

b. crack propagation from both free and supported surfaces

c. adhesive and cohesive strength

d. compressive, tensile and shear strength.

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

424. 4.4.7.2.1 Special attention should 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 should be carried out to the satisfaction of the Administration. 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 should also 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 should take account of the dynamic loads caused by water ballast under the influence of ship motions.

425. 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 should be determined in each particular case.

426. 4.4.7.2.3 Thicknesses of plating of the inner hull or of an independent tank should at least comply with the requirements of Recognized Standards, taking into account the internal pressure as indicated in 4.3.2. Tanks constructed of plane surfaces should at least comply with Recognized Standards for deep tanks.

427. 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 should be performed to the satisfaction of the Administration unless such analysis is available for a similar ship. In order to confirm the design principles, prototype testing of composite models including structural elements should be carried out under combined effects of static, dynamic and thermal loads.

428. 4.4.7.4.2 Test conditions should 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).

429. 4.4.7.4.3 Models should be representative of the actual construction including corners, joints, pump mounts, piping penetrations and other critical areas, and should take into account variations in any material properties, workmanship and quality control.

430. 4.4.7.4.4 Combined tension and fatigue tests should 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 should be subjected to the maximum hydrostatic pressure of the ballast water.

431. 4.4.7.5 The effects of fatigue loading should be determined in accordance with A1.413.f. or by an equivalent method.

432. 4.4.7.6 For internal insulation tanks, repair procedures should be developed during the prototype testing programme for both the insulation material and the inner hull or the independent tank structure.

500. 4.5 Allowable stresses and corrosion allowances

501. 4.5.1 *Allowable stresses*

502. 4.5.1.1 For integral tanks, allowable stresses should normally be those given for hull structure in Recognized Standards.

503. 4.5.1.2 For membrane tanks, reference is made to the requirements of A1.407.

504. 4.5.1.3 For type A independent tanks primarily constructed of plane surfaces, the stresses for primary and secondary members (stiffeners, web frames, stringers, girders) when calculated by classical analysis procedures should not exceed the lower of Rm/2.66 or Re/1.33 for carbon-manganese steels and aluminium alloys, where Rm and Re are defined in A1.509. However, if detailed calculations are carried out for the primary members, the equivalent stress σC as defined in paragraph 510 may be increased over that indicated above to a stress acceptable to the Administration; calculations should 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.

505. 4.5.1.4 For type B independent tanks, primarily constructed of bodies of revolution, the allowable stresses should not exceed:

TABLE T.A1.505.1 - ALLOWABLE STRESSES

σm	≤ f
σL	≤ 1.5 f
σb	≤ 1.5 F
σL + σb	≤ 1.5 F
σm + σb	≤ 1.5 F

where

σm = equivalent primary general membrane stress
σL = equivalent primary local membrane stress
σb = equivalent primary bending stress
f = the lesser of Rm/A or Re/B
F = the lesser of Rm/C or Re/D

with Rm and Re as defined in 4.5.1.7.

With regard to the stresses *σm, σL*and *σb* see also the definition of stress categories in 4.13. The values of A, B, C and D should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk and should have at least the following minimum values:

TABLE T.A1.505.2 - MINIMUM VALUES OF A, B, C AND D

	Nickel steels and carbon-manganese steels	*Austenitic alloys steels*	*Aluminium*
A	3	3.5	4
B	2	1.6	1.5
C	3	3	3
D	1.5	1.5	1.5

506. 4.5.1.5 For type B independent tanks, primarily constructed of plane surfaces, the Administration may require compliance with additional or other stress criteria.

507. 4.5.1.6 For type C independent tanks the maximum allowable membrane stress to be used in calculation according to item 416.a. should be the lower of:

Rm/A or Re/B

where:

Rm and *Re* are as defined in 4.5.1.7.

508. The values of A and B should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk provided for in 1.5, and should have at least the minimum values indicated in the table of A1.505.

509. 4.5.1.7 For the purpose of A1.504, 505 and A1.507, the following apply:

a. 1 *Re* =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.

b.1. *Rm* = specified minimum tensile strength at room temperature (N/mm²). For welded connections in aluminium alloys the respective values of Re or Rm in annealed conditions should be used.

b. 2 The above properties should 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 Administration, account may be taken of enhanced yield stress and tensile strength at low temperature. The temperature on which the material properties are based should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

510. 4.5.1.8 The equivalent stress σC (von Mises, Huber) should be determined by:

$$\sigma C = \sqrt{[(\sigma x^2 + \sigma y^2 - \sigma x \sigma y + 3(txy)^2]}$$

where:
σx = total normal stress in x-direction
σy = total normal stress in y-direction
txy = total shear stress in x-y plane.

511. 4.5.1.9 When the static and dynamic stresses are calculated separately and unless other methods of calculation are justified the total stresses should be calculated according to:

$$\sigma x = \sigma x.st \pm \sqrt{[\sum(\sigma x.dyn)^2]}$$

$$\sigma y = \sigma y.st \pm \sqrt{[\sum(\sigma y.dyn)^2]}$$

$$txy = txy.st \pm \sqrt{[\sum(txy.dyn)^2]}$$

where:

$\sigma x.st$, $\sigma y.st$ and $txy.st$ = static stresses

$\sigma x.dyn$, $\sigma y.dyn$ and $txy.dyn$ = dynamic stresses

all determined separately from acceleration components and hull strain components due to deflection and torsion.

512. 4.5.1.10 For internal insulation tanks, reference is made to the requirement of A1.425.

513. 4.5.1.11 Allowable stresses for materials other than those covered by Part II, Title 34, Section 2 should be subject to approval by the Administration in each case.

514. 4.5.1.12 Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

515. 4.5.2 *Corrosion allowances*

516. 4.5.2.1 No corrosion allowance should generally be 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 Administration may require a suitable corrosion allowance.

517. 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 should not be credited as protection. Where special alloys are used with acceptable corrosion resistance, no corrosion allowance should be required. If the above conditions are not satisfied, the scantlings calculated according to A1.415 should be increased as appropriate.

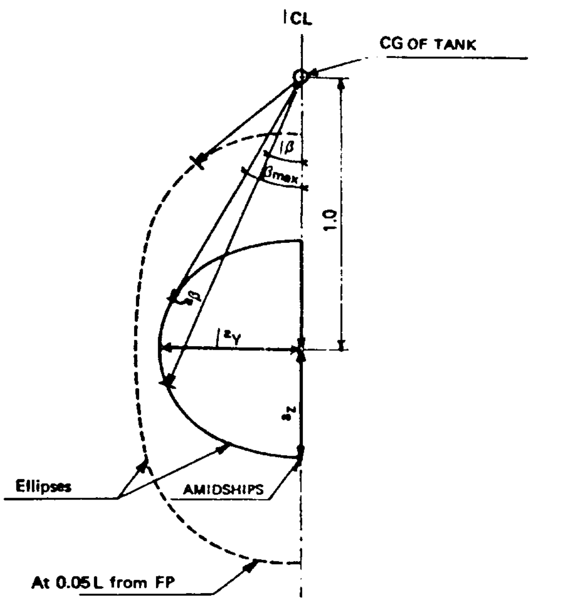
600. 4.6 Supports

601. 4.6.1 Cargo tanks should 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.

602. 4.6.2 The tanks with supports should also be designed for a static angle of heel of 30 degrees without exceeding allowable stresses given in A1.501.

603. 4.6.3 The supports should 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 F.A1.603.1 The half axes of the "acceleration ellipse" should be determined according to A1.204.b.

FIGURE F.A1.603.1 – ACCELERATION ELLIPSE



a_β = resulting acceleration (static and dynamic) in arbitrary direction β

a_y = transverse component of acceleration

a_z = vertical component of acceleration

604. 4.6.4 Suitable supports should be provided to withstand a collision force acting on the tank corresponding to one half the weight of the tank and cargo in the forward direction and one quarter the weight of the tank and cargo in the aft direction without deformation likely to endanger the tank structure.

605. 4.6.5 The loads mentioned in A1.602 and A1.604 need not be combined with each other or with wave-induced loads.

606. 4.6.6. For independent tanks and, where appropriate, for membrane and semi-membrane tanks, provision should be made to key the tanks against the rotational effects referred to A1.603.

607. 4.6.7. Anti floatation arrangements should be provided for independent tanks. The anti flotation arrangements should 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.

A2. CARGO CONTAINMENTS – *BARRIERS AND MATERIALS*

100. 4.7. Secondary barrier

101. 4.7.1. Where the cargo temperature at atmospheric pressure is below -10°C, a secondary barrier should be provided when required by A2.103 to act as a temporary containment for any envisaged leakage of liquid cargo through the primary barrier.

102. 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:

a. .1 the hull material should be suitable for the cargo temperature at atmospheric pressure as required by A2.302; and

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

103. 4.7.3. Secondary barriers in relation to tank types should normally be provided in accordance with table T.A2.103.1. For tanks which differ from the basic tank types as defined in A1.103 the secondary barrier requirements should be decided by the Administration in each case.

TABLE T.A2.103.1 - SECONDARY BARRIERS IN RELATION TO TANK TYPES

Cargo temperature at atmospheric pressure	*-10°C and above*	*Belown -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		Complete secondary barrier	
Type B		Partial secondary barrier	
Type C		No secondary barrier required	
Internal insulation			
Type 1		Complete secondary barrier	
Type 2		Complete secondary barrier is incorporated	

[1] A complete secondary barrier should normally be required if cargoes with a temperature at atmospheric pressure below -10°C are permitted in accordance with A1.103.a3.

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

104. 4.7.4. The secondary barrier should be so designed that:

a. .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 A1.204.d;

b. .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 A2.202; and

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

105. 4.7.5. The secondary barrier should fulfil its functions at a static angle of heel of 30°.

106. 4.7.6.1 Where a partial secondary barrier is required, its extent should be determined on the basis of cargo leakage corresponding to the extent of failure resulting from the load spectrum referred to in A1.204.d after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors. In all cases, however, the inner bottom adjacent to cargo tanks should be protected against liquid cargo.

107. 4.7.6.2 Clear of the partial secondary barrier, provision such as a spray shield should 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.

108. 4.7.7. The secondary barrier should 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 Administration. The method should be submitted to the Administration for approval.

109. ***IACS' unified interpretation GC12 (Secondary Barrier Testing Requirements:***

110. *For containment systems with glued secondary barriers:*

a. *A tightness test should be carried out in accordance with approved system designers'procedures before and after initial cool down.*

b. *If significant differences in the results before and after cool down for each tank or between tanks or if other anomalies are observed, an investigation is to be carried out and additional testing such as differential pressure, thermographic or acoustic emissions testing should be carried out as necessary.*

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

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

200. 4.8 Insulation

201. 4.8.1. Where a product is carried at a temperature below -10°C suitable insulation should be provided to ensure that the temperature of the hull structure does not fall below the minimum allowable design temperature given in chapter 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 seawater. These conditions may generally be used for world-wide service. However, higher values of the ambient temperatures may be accepted by the Administration for ships operated in restricted areas. Conversely, lesser values of the ambient temperatures may be fixed by the Administration 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 should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in BulK.

202. 4.8.2. Where a complete or partial secondary barrier is required, calculations should 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 in Part II, Title 34, Section 2 for the grade of steel concerned, as detailed in A2.300. The complete or partial secondary barrier should be assumed to be at the cargo temperature at atmospheric pressure.

203. 4.8.3. Calculations required by A2.201 and A2.202 should be made assuming still air and still water, and except as permitted by A2.204, no credit should be given for means of heating. In the case referred to in A2.202, the cooling effect of the rising boil-off vapour from the leaked cargo should 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.

204. 4.8.4. In all cases referred to in A2.201 and A2.202 and for ambient temperature conditions of 5°C for air and 0°C for seawater, 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 seawater without heating. Such means of heating should comply with the following requirements:

a. .1 sufficient heat should be available to maintain the hull structure above the minimum allowable temperature in the conditions referred to in A2.201 and A2.202;

b. .2 the heating system should be so arranged that, in the event of a failure in any part of the system, stand-by heating could be maintained equal to not less than 100% of the theoretical heat load;

c. .3 the heating system should be considered as an essential auxiliary; and

d. .4 the design and construction of the heating system should be to the satisfaction of the Administration.

4.8.5 In determining the insulation thickness, due regard should 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.

300 4.9 Materials

301. 4.9.1. The shell and deck plating of the ship and all stiffeners attached thereto should be in accordance with Recognized Standards, 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 should 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 should be assumed to be at the cargo temperature at atmospheric pressure and for tanks without secondary barriers, the primary barrier should be assumed to be at the cargo temperature.

302. 4.9.2. Hull material forming the secondary barrier should be in accordance with T.A1.201.1 from section 2. Metallic materials used in secondary barriers not forming part of the hull structure should be in accordance with tables T.A1.201.2 and T.A1.201.3 from section 2 as applicable. Insulation materials forming a secondary barrier should comply with the requirements of A2.307. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by T.A1.201.1 from section 2 should be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

303. 4.9.3. Materials used in the construction of cargo tanks should be in accordance with table T.A1.201.1, T.A1.201.2 or T.A1.201.3 from section 2.

304. 4.9.4. Materials other than those referred to in A2.301, 302 and 303 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 should be in accordance with table T.A1.201.1 from section 2 for temperatures as determined by A2.200. This includes inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

305. 4.9.5. The insulation materials should be suitable for loads which may be imposed on them by the adjacent structure.

306. 4.9.6. Where applicable, due to location or environmental conditions, insulation materials should have suitable properties of resistance to fire and flame spread and should be adequately protected against penetration of water vapour and mechanical damage.

307. 4.9.7.1 Materials used for thermal insulation should be tested for the following properties as applicable, to ensure that they are adequate for the intended service:

a. .1 compatibility with the cargo

b. .2 solubility in the cargo

c. .3 absorption of the cargo

d. .4 shrinkage

e. .5 ageing

f. .6 closed cell content

g. .7 density

h. .8 mechanical properties

i. .9 thermal expansion

j. .10 abrasion

k. .11 cohesion

l. .12 thermal conductivity

m. .13 resistance to vibrations

n. .14 resistance to fire and flame spread.

308. 4.9.7.2 In addition to meeting the above requirements, insulation materials which form part of the cargo containment as defined in A1.106 should be tested for the following properties after simulation of ageing and thermal cycling to ensure that they are adequate for the intended service:

a. .1 bonding (adhesive and cohesive strength)

b. .2 resistance to cargo pressure

c. .3 fatigue and crack propagation properties

d. .4 compatibility with cargo constituents and any other agent expected to be in contact with the insulation in normal service

e. .5 where applicable the influence of presence of water and water pressure on the insulation properties should be taken into account

f. .6 gas de-absorbing.

309. 4.9.7.3. The above properties, where applicable, should 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.

310. 4.9.8. The procedure for fabrication, storage, handling, erection, quality control and control against harmful exposure to sunlight of insulation materials should be to the satisfaction of the Administration.

311. 4.9.9. Where powder or granulated insulation is used, the arrangements should be such as to prevent compacting of the material due to vibrations. The design should 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.

CHAPTER B
CARGO CONTAINMENT II

CHAPTER CONTENTS

B1. CARGO CONTAINEMENT – *CONSTRUCTION AND TESTING*

B1. CARGO CONTAINMENT – *CONSTRUCTION AND TESTING*

100. 4.10 Construction and testing

101. 4.10.1.1. All welded joints of the shells of independent tanks should be of the butt weld, full penetration type. For dome-to-shell connections, the Administration 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.

102. 4.10.1.2. Welding joint details for type C independent tanks should be as follows:

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

b. .2 The bevel preparation of the joints between the pressure vessel body and domes and between domes and relevant fittings should be designed according to a standard for pressure vessels acceptable to the Administration. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles should be full penetration welds extending through the entire thickness of the vessel wall or nozzle wall, unless specially approved by the Administration for small nozzle diameters.

103. 4.10.2. Workmanship should be to the satisfaction of the Administration. Inspection and non-destructive testing of welds for tanks other than type C independent tanks should be in accordance with the requirements of A1.319 from section 2.

104. 4.10.3. For membrane tanks, quality assurance measures, weld procedure qualification, design details, materials, construction, inspection and production testing of components, should be to standards developed during the prototype testing programme.

105. 4.10.4. For semi-membrane tanks the relevant requirements in this section for independent tanks or for membrane tanks should be applied as appropriate.

106. 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 should be to standards developed during the prototype test programme.

107. 4.10.5.2 A quality control specification including maximum permissible size of constructional defects, tests and inspections during the fabrication, installation and also sampling tests at each of these stages should be to the satisfaction of the Administration.

108. 4.10.6. Integral tanks should be hydrostatically or hydropneumatically tested to the satisfaction of the Administration. The test in general should be so performed that the stresses approximate, as far as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS.

109. 4.10.7. In ships fitted with membrane or semi-membrane tanks, cofferdams and all spaces which may normally contain liquid and are adjacent to the hull structure supporting the membrane should be hydrostatically or hydropneumatically tested in accordance with Recognized Standards. In addition, any other hold structure supporting the membrane should be tested for tightness. Pipe tunnels and other compartments which do not normally contain liquid need not be hydrostatically tested.

110. 4.10.8.1 In ships fitted with internal insulation tanks where the inner hull is the supporting structure, all inner hull structure should be hydrostatically or hydropneumatically tested in accordance with Recognized Standards, taking into account the MARVS.

111. 4.10.8.2 In ships fitted with internal insulation tanks where independent tanks are the supporting structure, the independent tanks should be tested in accordance with B1.116.a.

112. 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 should be carried out using techniques to the satisfaction of the Administration.

113. 4.10.8.4 These tests should be performed before the application of the materials which will form the internal insulation tank.

114. 4.10.9. For type C independent tanks, inspection and non-destructive testing should be as follows:

a. .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, should comply with standards acceptable to the Administration. The tolerances should also be related to the buckling analysis referred to in A1.417.

b. .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 should be total or partial according to standards acceptable to the Administration, but the controls to be carried out should not be less than the following:

b.1. .2.1 Total non-destructive testing referred to in A1.416.c:

i. *Radiography:*

*b*utt welds 100% and

ii. *Surface crack detection:*

all welds 10%; reinforcement rings around holes, nozzles, etc. 100%.

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

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

d.1. *Radiography:*

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

d.2. *Surface crack detection:*

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

d.3. *Ultrasonic testing:*

as may be required by the Administration in each instance.

116. 4.10.10. Each independent tank should be subjected to a hydrostatic or hydropneumatic test as follows:

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

b. .2 For type B independent tanks, the test should be performed as required in B1.116.a for type A independent tanks. In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions should not exceed 90% of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75% of the yield strength, the prototype test should be monitored by the use of strain gauges or other suitable equipment.

c. .3 Type C independent tanks should be tested as follows:

c.1. .3.1 Each pressure vessel, when completely manufactured, should be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1.5 *Po*, but in no case during the pressure test should the calculated primary membrane stress at any point exceed 90% of the yield stress of the material. The definition of *Po* 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 should be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

c.2. .3.2 The temperature of the water used for the test should be at least 30°C above the nil ductility transition temperature of the material as fabricated.

c.3 .3.3 The pressure should be held for 2 h per 25 mm of thickness but in no case less than 2 h.

c.4. .3.4 Where necessary for cargo pressure vessels, and with the specific approval of the Administration, a hydropneumatic test may be carried out under the conditions prescribed in B1.116.c.i, ii and iii..

c.5. .3.5 Special consideration may be given by the Administration to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of B1.116.c.i should be fully complied with.

c.6 .3.6 After completion and assembly, each pressure vessel and its related fittings should be subjected to an adequate tightness test.

c.7 .3.7 Pneumatic testing of pressure vessels other than cargo tanks should only be considered on an individual case basis by the Administration. Such testing should be permitted only for those vessels which are so designed 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.

117. 4.10.11. All tanks should be subjected to a tightness test which may be performed in combination with the pressure test referred to in B1.116 or separately.

118. 4.10.12. Requirements with respect to inspection of secondary barriers should be decided by the Administration in each case.

119. 4.10.13. In ships fitted with type I independent tanks, at least one tank and its support should be instrumented to confirm stress levels unless the design and arrangement for the size of ship involved are supported by full-scale experience. Similar instrumentation may be required by the Administration for type C independent tanks dependent on their configuration and on the arrangement of their supports and attachments.

120. 4.10.14. The overall performance of the cargo containment system should 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 should be maintained and be available to the Administration.

121. 4.10.15. Heating arrangements, if fitted in accordance with A2.204, should be tested for required heat output and heat distribution.

122. 4.10.16. The hull should be inspected for cold spots following the first loaded voyage.

123**. *4.10.14 and 4.10.16 IACS' unified interpretation GC13 (Examination before and after the first loaded voyage:***

a ***Application****: This UI applies to all vessels carrying liquefied natural gases (LNG) in bulk which have satisfactorily completed gas trials.*

b**.** ***Certification*** *: The following initial certificates shall be "conditionally" issued at delivery subject to satisfactory completion of the first cargo loading and unloading survey requirements below in the presence of a Surveyor:*

a.1. *1. Classification Certificate*

a.2. *2. Short Term Certificate of Fitness for the Carriage of Liquefied Gases in Bulk*

Note: The conditions may either be stated on the Classification Certificate or issued as a Condition of Class/Outstanding Recommendation in the vessel's Record.

c**.** ***Survey Requirements***

First Loading (considered to be full loading):

a.1. *1. Priority to be given to latter stages of loading (approximately last 6 hours).*

a.2. *2. Review cargo logs and alarm reports*

Note:

This Unified Interpretation is to be applied by all Members and Associates for surveys commenced on or after the 1 July 2008.

a.3. *3. Witness satisfactory operation of the following:*

i. *Gas detection system. - Cargo control and monitoring systems such as level gauging equipment, temperature sensors, pressure gauges, cargo pumps and compressors, proper control of cargo heat exchangers, if operating, etc.*

ii. *Nitrogen generating plant or inert gas generator, if operating.*

iii. *Nitrogen pressure control system for insulation, interbarrier, and annular spaces, as applicable.*

iv. *Cofferdam heating system, if in operation.*

v. *Reliquefaction plant, if fitted.*

vi. *Equipment fitted for the burning of cargo vapors such as boilers, engines, gas combustion units, etc., if operating.*

a.4. *4. Examination of on-deck cargo piping systems including expansion and supporting arrangements.*

a.5. *5. Witness topping off process for cargo tanks including high level alarms activated during normal loading.*

a.6. *6. Advise master to carry out cold spot examination of the hull and external insulation during transit voyage to unloading port.*

d. ***First Unloading:***

d.1. *1. Priority to be given to the commencement of unloading (approximately first 4 - 6 hours).*

d.2. *2. Witness emergency shutdown system testing prior to commencement of unloading.*

d.3. *3. Review cargo logs and alarm reports.*

d.4. *4. Witness satisfactory operation of the following:*

i. *Gas detection system.*

ii. *Cargo control and monitoring systems such as level gauging equipment, temperature sensors, pressure gauges, cargo pumps and compressors, proper control of cargo heat exchangers, if operating, etc.*

iii. *Nitrogen generating plant or inert gas generator, if operating.*

iv. *Nitrogen pressure control system for insulation, interbarrier, and annular spaces, as applicable.*

v. *On membrane vessels, verify that the readings of the cofferdam and inner hull temperature sensors are not below the allowable temperature for the selected grade of steel. Review previous readings.*

vi. *Cofferdam heating system, if in operation.*

vii. *Reliquefaction plant and review of records from previous voyage.*

viii. *Equipment fitted for the burning of cargo vapors such as boilers, engines, gas combustion units, etc., if operating.*

d.5. *5. Examination of on-deck cargo piping systems including expansion and supporting arrangements.*

d.6. i. *6. Obtain written statement from the Master that the cold spot examination was carried out during the transit voyage and found satisfactory. Where possible, the surveyor should examine selected spaces.*

124. 4.10.17. The insulation materials of internal insulation tanks should 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 6 months of the ship' s service after building or a major repair work is undertaken on the internal insulation tanks.

125. 4.10.18. For type C independent tanks, the required marking of the pressure vessel should be achieved by a method which does not cause unacceptable local stress raisers.

CHAPTER C
STRESS RELIEVING, GUIDANCE FORMULAE AND STRESS CATEGORIES

CHATER CONTENTS

C1. STRESS RELIEVING FOR TYPE C INDEPENDENT TANKS

STRESS RELIEVING FOR TYPE C INDEPENDENT TANKS

100. 4.11 Stress relieving for type c independent tanks

101. 4.11.1. For type C independent tanks of carbon and carbon-manganese steel, post-weld heat treatment should 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 should be to the satisfaction of the Administration. The soaking temperature and holding time should be to the satisfaction of the Administration.

102. 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 and subject to the following conditions:

a. .1 Complicated welded pressure vessel parts such as sumps or domes with nozzles, with adjacent shell plates should be heat treated before they are welded to larger parts of the pressure vessel.

b. .2 The mechanical stress relieving process should preferably be carried out during the hydrostatic pressure test required by paragraph B1.116.c, by applying a higher pressure than the test pressure required by B1.116.c.i. The pressurizing medium should be water.

c. .3 For the water temperature, paragraph B1.116.c.ii applies.

d. .4 Stress relieving should be performed while the tank is supported by its regular saddles or supporting structure or, when stress relieving cannot be carried out on board, in a manner which will give the same stresses and stress distribution as when supported by its regular saddles or supporting structure.

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

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

equivalent general primary membrane stress: 0.9 ·*Re*

equivalent stress composed of primary bending stress plus membrane stress:

1.35 ·*Re*

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

g. .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 should be included in the mechanical stress relieving procedure to be submitted in accordance with B1.102.n.

h. .8 The test procedure should demonstrate that a linear relationship between pressure and strain is achieved at the end of the stress relieving process when the pressure is raised again up to the design pressure.

i. .9 High stress areas in way of geometrical discontinuities such as nozzles and other openings should be checked for cracks by dye penetrant or magnetic particle inspection after mechanical stress relieving. Particular attention in this respect should be given to plates exceeding 30 mm in thickness.

j. 10 Steels which have a ratio of yield stress to ultimate tensile strength greater than 0.8 should generally not be mechanically stress relieved. If, however, the yield stress is raised by a method giving high ductility of the steel, slightly higher rates may be accepted upon consideration in each case.

k. 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.

l. .12 The thickness of the shell and heads of the tank should not exceed 40 mm. Higher thicknesses may be accepted for parts which are thermally stress relieved.

m. .13 Local buckling should be guarded against particularly when tori-spherical heads are used for tanks and domes.

n. .14 The procedure for mechanical stress relieving should be submitted beforehand to the Administration for approval.

200. 4.12. Guidance formulae for acceleration components

201. The following formulae are given as guidance for the components of acceleration due to ship' s motions corresponding to a probability level of 10-8 in the North Atlantic and apply to ships with a length exceeding 50 m.

202. Vertical acceleration as defined in 4.3.4.6

$$a_z = \pm a_o \times \sqrt{1+\left(5.3-\frac{45}{L_o}\right)^2 \times \left(\frac{x}{L_o}+0.05\right)^2 \times \left(\frac{0.6}{C_B}\right)^{1.5}}$$

203. Transverse acceleration as defined in 4.3.4.6

$$a_y = \pm a_o \times \sqrt{0.6+2.5\times\left(\frac{x}{L_o}+0.05\right)+K\times\left(1+0.6K\frac{Z}{B}\right)^2}$$

204. Longitudinal acceleration as defined in 4.3.4.6

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

With:

$$A = \left(0.7-\frac{L_o}{1200}+5\frac{Z}{L_o}\right)\times\left(\frac{0.6}{C_B}\right)$$

where:

Lo = length of the ship for determination of scantlings as defined in Recognized Standards (m)

CB = block coefficient

B = greatest moulded breadth of the ship (m)

x = longitudinal distance (m) from amidships to the centre of gravity of the tank with contents; 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 contents; z is positive above and negative below the waterline.

$$a_o = 0.2\frac{V}{\sqrt{L_o}} + \frac{34 - \frac{600}{L_o}}{L_o}$$

where:

V = service speed in knots

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

a_{x1}, a_y and 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 purposes, 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.

300. 4.13. Stress categories

301. For the purpose of stress evaluation referred to in A1.501.d, stress categories are defined in this section. A1.300.a Normal stress is the component of stress normal to the plane of reference.

302. 4.13.2. Membrane stress is 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.

303. 4.13.3. Bending stress is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

304. 4.13.4. Shear stress is the component of the stress acting in the plane of reference.

305. 4.13.5. Primary stress is 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.

306. 4.13.6. Primary general membrane stress is a primary membrane stress which is so distributed in the structure that no redistribution of load occurs as a result of yielding.

307. 4.13.7. Primary local membrane stress arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress although it has some characteristics of a secondary stress. A stress region may be considered as local if :

$S1 \leq 0.5 \times \sqrt{(R \times t)}$

And

$S2 \geq 2.5 \times \sqrt{(R \times t)}$

where:

S1 = distance in the meridional direction over which the equivalent stress exceeds 1.1 f

S2 = 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.

308. 4.13.8. Secondary stress is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions which cause the stress to occur.

CHAPTER D
PROCESS PRESSURE VESSELS AND LIQUID, VAPOUR, AND PRESSURE PIPING SYSTEMS

CHAPTER CONTENTS

D1. PROCESS PRESSURE VESSELS AND LIQUID, VAPOUR AND PRESSURE PIPING SYSTEMS

D1. 5 PROCESS PRESSURE VESSELS AND LIQUID, VAPOUR, AND PRESSURE PIPING SYSTEMS

100. 5.1 General

101. 5.1.1 Administrations should take appropriate steps to ensure uniformity in the implementation and application of the provisions of this chapter.*

* Reference is made to the published Rules of members and associate members of the International Association of Classification Societies and in particular to IACS Unified Requirement No. G3.

102. 5.1.2 The requirements for type C independent tanks in chapter 4 may also apply to process pressure vessels if required by the Administration. If so required the term "pressure vessels" as used in chapter 4 covers both type C independent tanks and process pressure vessels.

200. 5.2 Cargo and process piping

201. 5.2.1 *General*

202. 5.2.1.1 The requirements of D1.200 to D1.500 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.

203. 5.2.1.2 Provision should 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 hull structure. Where mechanical expansion joints are used in piping they should be held to a minimum and, where located outside cargo tanks, should be of the bellows type.

204. 5.2.1.3 Low-temperature piping should 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 should be provided.

205. 5.2.1.4 Where tanks or piping are separated from the ship' s structure by thermal isolation, provision should be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections should be electrically bonded.

206. 5.2.1.5 Suitable means should 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.

207. 5.2.1.6 All pipelines or components which may be isolated in a liquid full condition should be provided with relief valves.

208. 5.2.1.7 Relief valves discharging liquid cargo from the cargo piping system should 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 should discharge to the pump suction.

209. 5.2.2 *Scantlings based on internal pressure*

210. 5.2.2.1 Subject to the conditions stated in 5.2.4, the wall thickness of pipes should not be less than:

TABLE T.D1.201.1 - WALL THICKNESS OF PIPES

	t =	$(t_o + b + c)/(1 - a/100)$ (mm)
where:		
	t_o =	theoretical thickness
	t_o =	$PD/(20 \times K \times e + P)$ (mm)
	with:	
	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 equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, which are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with Recognized Standards. In other cases an efficiency factor of less than 1.0, in accordance with recognized standards, may be required depending on the manufacturing process.
	b =	allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b should be: $b = D \times t_o/(2.5 \times r)$ with r = mean radius of the bend (mm)
	c =	corrosion allowance (mm). If corrosion or erosion is expected, the wall thickness of the piping should be increased over that required by other design requirements. This allowance should be consistent with the expected life of the piping.
	a =	negative manufacturing tolerance for thickness (%)

211. 5.2.3 *Scantlings based on internal pressure*

212. 5.2.3.1 The design pressure P in the formula for to in 5.2.2.1 is the maximum gauge pressure to which the system may be subjected in service.

213. 5.2.3.2 The greater of the following design conditions should be used for piping, piping systems and components as appropriate:

a. 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 Administration (see A1.112.b);

b. 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 Administration (see A1.112.b), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

c. 3 the MARVS of the cargo tanks and cargo processing systems; or

d. 4 the pressure setting of the associated pump or compressor discharge relief valve; or

e. 5 the maximum total discharge or loading head of the cargo piping system; or

f. 6 the relief valve setting on a pipeline system.

214. 5.2.3.3 The design pressure should not be less than 10 bar gauge except for open-ended lines where it should be not less than 5 bar gauge.

215. 5.2.4 *Permissible stresses*

216. 5.2.4.1 For pipes, the permissible stress to be considered in the formula for t in D1.210 is the lower of the following values:

R_m/A or R_e/B

where:

R_m = specified minimum tensile strength at room temperature (N/mm²)

R_e = 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.

217. The values of A and B should be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk as provided for in 1.5 and have values of at least A = 2.7 and B = 1.8.

218. 5.2.4.2 The minimum wall thickness should be in accordance with Recognized Standards.

219. 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 should be increased over that required by D1.509, or, if this is impracticable or would cause excessive local stresses, these loads should be reduced, protected against or eliminated by other design methods.

220. 5.2.4.4 Flanges, valves and other fittings should be to a standard acceptable to the Administration, taking into account the design pressure defined in D1.209. For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted by the Administration.

221. 5.2.4.5 For flanges not complying with a standard, the dimensions of flanges and related bolts should be to the satisfaction of the Administration.

222. 5.2.5 *Stress analysis*

223. 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 should be submitted to the Administration. For temperatures of above -110°C, a stress analysis may be required by the Administration in relation to such matters as the design or stiffness of the piping system and the choice of materials. In any case, consideration should 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 Administration.

224. 5.2.6 *Materials*

225. 5.2.6.1 The choice and testing of materials used in piping systems should comply with the requirements of chapter 6 taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of material of open-ended vent piping, provided the temperature of the cargo at the pressure relief valve setting is -55°C or greater and provided no liquid discharge to the vent piping can occur. Similar relaxations may be permitted under the same temperature conditions to open-ended piping inside cargo tanks, excluding discharge piping and all piping inside membrane and semi-membrane tanks.

226. 5.2.6.2 Materials having a melting point below 925°C should not be used for piping outside the cargo tanks except for short lengths of pipes attached to the cargo tanks, in which case fire-resisting insulation should be provided.

300. 5.3 Type tests on piping components

301. 5.3.1 Each type of piping component should be subject to type tests.

302. 5.3.2.1 Each size and type of valve intended to be used at a working temperature below -55°C should 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 valve. During the test the satisfactory operation of the valve should be ascertained.

303. 5.3.2.2 The following type tests should 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:

a. 1 type element of the bellows, not precompressed, should be pressure tested at not less than 5 times the design pressure without bursting. The duration of the test should not be less than 5 min.

b. 2 pressure test should be performed 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 Administration may require the test to be at the minimum design temperature.

c. 3 cyclic test (thermal movements) should 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 ambient temperature is permitted, when this testing is at least as severe as testing at the service temperature.

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

e. 5 he Administration 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 justify the design method used, with particular reference to correlation between calculation and test results.

400. 5.4 Piping fabrication and joining details

401. 5.4.1 The requirements of this section apply to piping inside and outside the cargo tanks. However, the Administration may accept relaxations from these requirements for piping inside cargo tanks and open-ended piping.

402. 5.4.2 The following direct connection of pipe lengths, without flanges, may be considered:

a. 1 Butt welded joints with complete penetration at the root may be used in all applications. For design temperatures below -10°C, butt welds should 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°C or lower, backing rings should be removed.

b. 2 Slip-on welded joints with sleeves and related welding, having dimensions satisfactory to the Administration, should only be used for open-ended lines with external diameter of 50 mm or less and design temperatures not lower than -55°C.

c. 3 Screwed couplings acceptable to the Administration should only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

403. 5.4.3.1 Flanges in flange connections should be of the welded neck, slip-on or socket welded type.

404. 5.4.3.2 Flanges should comply with standards acceptable to the Administration as to their type, manufacture and test. In particular, for all piping except open ended, the following restrictions apply:

a. 1 For design temperatures lower than -55°C, only welded neck flanges should be used.

b. 2 For design temperatures lower than -10°C, slip-on flanges should not be used in nominal sizes above 100 mm and socket welded flanges should not be used in nominal sizes above 50 mm.

405. 5.4.4 Piping connections, other than those mentioned in D1.402, D1.403 and D1.404, may be accepted by the Administration in each case.

406. 5.4.5 Bellows and expansion joints should be provided to allow for expansion of piping.

a. 1 If necessary, bellows should be protected against icing.

b. 2 Slip joints should not be used except within the cargo tanks.

407. 5.4.6 Welding, post-weld heat treatment and non-destructive testing.

a. 1 Welding should be carried out in accordance with 6.3.

b. 2 Post-weld heat treatment should be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Administration 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.

c. 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 should be required:

c.1. 3.1 100% radiographic inspection of butt welded joints for piping systems with design temperatures lower than -10°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 by the Administration, 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 should be increased to 100% and should 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 Administration to assess the ability of the manufacturer to produce satisfactory welds consistently.

c.2. 3.2 For other butt welded joints of pipes not covered by D1.407.c1, spot radiographic tests or other non-destructive tests should be carried out at the discretion of the Administration depending upon service, position and materials. In general, at least 10% of butt welded joints of pipes should be radio-graphed.

500. 5.5 Testing of piping

501. 5.5.1 The requirements of this section apply to piping inside and outside the cargo tanks. However, the Administration may accept relaxations from these requirements for piping inside cargo tanks and open-ended piping.

502. 5.5.2 After assembly, all cargo and process piping should 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 should 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 should be submitted to the Administration for approval.

503. 5.5.3 After assembly on board, each cargo and process piping system should be subjected to a leak test

using air, halides, or other suitable medium to a pressure depending on the leak detection method applied.

504. 5.5.4 All piping systems including valves, fittings and associated equipment for handling cargo or vapours should be tested under normal operating conditions not later than at the first loading operation.

600. 5.6 Cargo system valving requirements

601. 5.6.1 Every cargo piping system and cargo-tank should be provided with the following valves, as applicable:

a. 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, should have shut-off valves located as close to the tank as practicable. These valves may be remotely controlled but should be capable of local manual operation and provide full closure. One or more remotely controlled emergency shutdown valves should 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 D1.606 and should comply with the requirements of D1.607.

b. 2 For cargo tanks with a MARVS exceeding 0.7 bar gauge, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, should be equipped with a manually operated stop valve and a remotely controlled emergency shutdown valve. These valves should 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 shutdown valve. A single valve may be substituted for the two separate valves provided the valve complies with the requirements of D1.607, is capable of local manual operation and provides full closure of the line.

c. 3 Cargo pumps and compressors should be arranged to shutdown automatically if the emergency shutdown valves required by D1.601.a and .b are closed by the emergency shutdown system required by D1.607.

602. 5.6.2 Cargo tank connections for gauging or measuring devices need not be equipped with excess flow or emergency shutdown valves provided that the devices are so constructed that the outward flow of tank contents cannot exceed that passed by a 1.5 mm diameter circular hole.

603. IMO's interpretation (MSC/Circ.406/Rev.1):

604. Cargo tank connections for gauging or measuring devices.

605. The requirements of paragraph 5.6.2, providing relaxations for cargo tanks referred to in paragraph 5.6.1.2, should not apply to cargo tank connections for gauging or measuring devices of cargo tanks referred to in paragraph 5.6.1.1.

606. 5.6.3 One remotely operated emergency shutdown valve should 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.

607. 5.6.4 The control system for all required emergency shutdown valves should 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 should be the control position required by H1.103 or cargo control room. The control system should 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 should include the tank domes and loading stations. Emergency shutdown valves should 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 should fully close under all service conditions within 30 s of actuation. Information about the closing time of the valves and their operating characteristics should be available on board and the closing time should be verifiable and reproducible. Such valves should close smoothly.

608. 5.6.5 The closure time of 30 s for the emergency shutdown valve referred to in D1.607 should be 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 pressure in pipelines. Such valves should close in such a manner as to cut off the flows smoothly.

609. 5.6.6 Excess flow valves should 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, should have a greater capacity than the rated closing flow of the excess flow valve. Excess flow valves may be designed with a bypass not exceeding an area of 1.0 mm diameter circular opening to allow equalization of pressure, after an operating shutdown.

700. 5.7 Ship's cargo hoses

701. 5.7.1 Liquid and vapour hoses used for cargo transfer should be compatible with the cargo and suitable for the cargo temperature.

702. 5.7.2 Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, should be designed for a bursting pressure not less than 5 times the maximum pressure the hose will be subjected to during cargo transfer.

703. 5.7.3 For cargo hoses installed on board ships on or after 1 July 2002, each new type of cargo hose, complete with end-fittings, should be prototype-tested at a normal ambient temperature with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test should demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the extreme service temperature. Hoses used for prototype testing should not be used for cargo service. Thereafter, before being placed in service, each new length of cargo hose produced should be hydrostatically tested at ambient temperature to a pressure not less than 1.5 times its specified maximum working pressure but not more than two-fifths of its bursting pressure. The hose should be stencilled or otherwise marked with the date of testing, its specified maximum working pressure and, if used in services other than the ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure should not be less than 10 bar gauge.

800. 5.8 Cargo transfer methods

801. 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 should be provided to transfer cargo from each cargo tank and the design should 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.

802. 5.8.2 The procedure for transfer of cargo by gas pressurization should preclude lifting of the relief valves during such transfer. Gas pressurization 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.

900. 5.9 Vapour return connections

901. Connections for vapour return lines to the shore installations should be provided.

902. **5.2.1.4 / 5.6.4** See MSC.1/Circ.1213 Interpr./appl. of IGC Code for ships carrying liquefied carbon dioxide in bulk.

903**. 5.6.2 IMO's interpretation (MSC/Circ.406/Rev.1):**

*904. **Cargo tank connections for gauging or measuring devices.***

905. The requirements of paragraph D1.602, providing relaxations for cargo tanks referred to in paragraph D1.601.b, should not apply to cargo tank connections for gauging or measuring devices of cargo tanks referred to in D1.601.a.

CHAPTER E
CARGO PRESSURE / TEMPERATURE CONTROL

CHAPTER CONTENTS

E1. CARGO PRESSURE / TEMPERATURE CONTROL

E1. 7 CARGO PRESSURE / TEMPERATURE CONTROL

100. 7.1 General

101. 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 should be provided by one or more of the following means, except as otherwise provided in this section:

a. 1 a system which regulates the pressure in the cargo tanks by the use of mechanical refrigeration;

b. 2 a system whereby the boil-off vapours are utilized as fuel for shipboard use or waste heat system subject to the provisions of section 5. 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 Administration;

c. 3 a system allowing the product to warm up and increase in pressure. The insulation or cargo tank design pressure or both should be adequate to provide for a suitable margin for the operating time and temperatures involved. The system should be acceptable to the Administration in each case;

d. 4 other systems acceptable to the Administration;

e. 5 in addition to the above means, the Administration may permit certain cargoes to be controlled by venting cargo vapours to the atmosphere at sea. This may also be permitted in port with the permission of the port Administration.

102. 7.1.2 The systems required by E1.101 should be constructed, fitted and tested to the satisfaction of the Administration. Materials used in their construction should be suitable for use with the cargoes to be carried. For normal service, the upper ambient design temperature should be:

a. sea: 32°C

b. air: 45°C.

103. For service in especially hot or cold zones these design temperatures should be increased or reduced, as appropriate, by the Administration.

104. 7.1.3 For certain highly dangerous cargoes specified in ANNEX I, the cargo containment system should 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.

200. 7.2 Refrigeration systems

201. 7.2.1 A refrigeration system should 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 Administration, a stand-by unit (or units) affording spare capacity at least equal to the largest required single unit should be provided. A stand-by unit should 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 should be provided unless the normal heat exchanger for the unit has an excess capacity of at least 25% of the largest required capacity. Separate piping systems are not required.

202. 7.2.2.1 Where two or more refrigerated cargoes which may react chemically in a dangerous manner are carried simultaneously, special consideration should 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 E1.201, should 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.

203. 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 should be given to the refrigeration systems to avoid the possibility of mixing cargoes.

204. 7.2.3 Where cooling water is required in refrigeration systems, an adequate supply should be provided by a pump or pumps used exclusively for this purpose. This pump or these pumps should have at least two sea suction lines, where practicable leading from sea-chests, one port and one starboard. A spare pump of adequate capacity should be provided, which may be a pump used for other services so long as its use for cooling would not interfere with any other essential service.

205. 7.2.4 The refrigeration system may be arranged in one of the following ways:

a. 1 a direct system where evaporated cargo is compressed, condensed and returned to cargo tanks. For certain cargoes specified in ANNEX I this system should not be used;

b. 2 an indirect system where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed;

c. 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 ANNEX I this system should not be used.

206. 7.2.5 All primary and secondary refrigerants must be compatible with each other and with the cargo with which they come into contact. The heat exchange may take place either remotely from the cargo tank or by cooling coils fitted inside or outside the cargo tank.

207. 7.2 IACS Unified Interpretation GC10 (1988)

208. Reliquefaction plant of motor-driven LNG-carriers:

209. 1 *Mechanical refrigeration fitted as the primary system for cargo pressure control*

a. E1.207 is based on the assumption that E1.101 is being compiled with by using means defined in E1.101.a. That is to say, a mechanical refrigeration system is fitted as the primary means of maintaining the cargo tank pressure below MARVS.

b. Section 7.2 should apply to refrigeration systems when fitted on LNG carriers, ie standby capacity will be required as detailed in E1.201. A stand-by LNG/refrigerant heat exchanger need not be provided and the fitted LNG/refrigerant heat exchanger will not be required to have 25% excess capacity over that for normal requirements.* Other heat exchangers utilizing water cooling should have a stand-by or have at least 25 per cent excess capacity.

*The reason for this relaxation is that corrosion and fouling problems are not expected in LNG/refrigerant heat exchangers.

c. 1.3 E1.201 states that unless an alternative means of controlling the cargo pressure/temperature is provided to the satisfaction of the Administration, a stand-by unit (or units) affording spare capacity at least equal to the largest required single unit should be fitted. For the purpose of complying with the above, a suitable alternative means of pressure/temperature control would be:

c.1. 1.3.1 Auxiliary boiler(s) capable of burning the boil-off vapours and disposing of the generated steam or an alternative waste heat system acceptable to the Society. Consideration will be given to systems burning only part of the boil-off vapour if it can be shown that MARVS will not be reached within a period of 21 days.

c.2. Controlled venting of cargo vapours as specified in paragraph E1.101.e if permitted by the Administrations concerned.

210 *Mechanical refrigeration fitted as secondary system for cargo pressure control*

211. Where a refrigeration plant is fitted as a means of disposing of excess energy as detailed in the 2nd sentence of paragraph E1.101.b, no stand-by unit will be required for the refrigeration plant.

CHAPTER F
CARGO TANK VENT SYSTEMS

CHAPTER CONTENTS

F1. CARGO TANK VENT SYSTEMS

F1. 8 CARGO TANK VENT SYSTEMS

100. 8.1 General

101. All cargo tanks should 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 should also be provided with a suitable pressure relief system. The pressure relief system should be connected to a vent piping system so designed as to minimize the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, control stations and machinery spaces, or other spaces where it may create a dangerous condition. Pressure control systems specified by chapter 7 should be independent of the pressure relief valves.

200. 8.2 Pressure relief systems

201. 8.2.1 Each cargo tank with a volume exceeding 20 m3 should 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 m^3 , a single relief valve may be fitted.

202. 8.2.2 Interbarrier spaces should be provided with pressure relief devices complying with recognized standards.

203. ***8.2 - IACS Unified Interpretation GC9 (1988)***

204. ***Guidance for sizing pressure relief systems for interbarrier spaces:***

205. ***1 General***

206. *1.1 The formula for determining the relieving capacity given in section 2 is developed for interbarrier spaces surrounding independent type A cargo tanks, where the thermal insulation is fitted to the cargo tanks.*

207. *1.2 The relieving capacity of pressure relief devices of interbarrier spaces surrounding independent type B cargo tanks may be determined on the basis of the method given in section 2, however, the leakage rate is to be determined in accordance with A2.106 of the IGC-Code. 1.3 The relieving capacity of pressure relief devices for interbarrier spaces of membrane and semi-membrane tanks is to be evaluated on the basis of specific membrane/semi-membrane tank design.*

208. *1.4 The relieving capacity of pressure relief devices for interbarrier spaces adjacent to integral type cargo tanks may, if applicable, be determined as for type A independent cargo tanks. 1.5 Interbarrier space pressure relief devices in the scope of this interpretation are emergency devices for protecting the hull structure from being unduly overstressed in case of a pressure rise in the interbarrier space due to primary barrier failure. Therefore such devices need not comply with the requirements of F1.217 and F1.218 of the IGC-Code.*

209. ***2 Size of pressure relief devices***

210. *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:*

$Q_{sa} = 3,4 \cdot A_c \times (\rho / \rho_v) \times \sqrt{h}$ (m^3/s
where:

Q_{sa} = minimum required discharge rate of air at standard conditions of 273 K and 1.013 bar

A_c = design crack opening area (m^2)

$A_c = (\pi/4) \times \delta . 1$ (m^2)

δ = max, crack opening width (m)

$\delta = 0,2.t$ (m)

t = thickness of tank bottom plating (m)

l = design crack length (m) equal to the diagonal of the largest plate panel of the tank bottom, see sketch below.

h = max liquid height above tank bottom plus 10.MARVS (m)

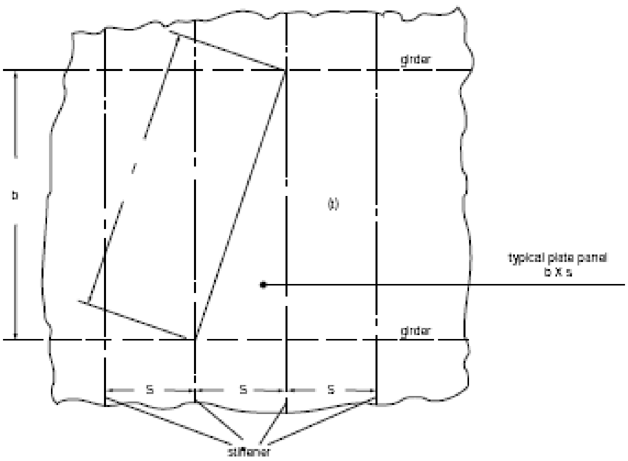
ρ = density of product liquid phase (kg/m^3) at the set pressure of the interbarrier space relief device

ρ_v = density of product vapour phase (kg/m^3) at the set pressure of the interbarrier space relief device and a temperature of 273 K

MARVS = max allowable relief valve setting of the cargo tank (bar).

Sketch

FIGURE F1.209.1 - SIZE OF PRESSURE RELIEF DEVICES
SKETCH



See MSC/Circ.845 dated 12 June 1998 for Proposed amendments to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code).

211. 8.2.3 In general, the setting of the pressure relief valves should not be higher than the vapour pressure which has been used in the design of the tank. However, where two or more pressure relief valves are fitted, valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS.

212. 8.2.4 Pressure relief valves should 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 should be arranged to prevent their becoming inoperative due to ice formation when they are closed. Due consideration should be given to the construction and arrangement of pressure relief valves on cargo tanks subject to low ambient temperatures. Valves should be constructed of materials with a melting point above 925°C. Consideration of lower melting point materials for internal parts and seals should be given if their use provides significant improvement to the general operation of the valve.

213. 8.2.5 Pressure relief valves should be prototype tested to ensure that the valves have the capacity required. Each valve should 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 should be set and sealed by a competent authority acceptable to the Administration and a record of this action, including the values of set pressure, should be retained aboard the ship.

214. 8.2.6 In the case of cargo tanks permitted to have more than one relief valve setting this may be accomplished by:

a. 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; or

b. 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 should be sealed.

215. 8.2.7 The changing of the set pressure under the provisions of F1.214, and the corresponding resetting of the alarms referred to in H1.401 should be carried out under the supervision of the master in accordance with procedures approved by the Administration and specified in the ship's operating manual. Changes in set pressures should be recorded in the ship's log and a sign posted in the cargo control room, if provided, and at each relief valve, stating the set pressure.

216. 8.2.8 Stop valves or other means of blanking off pipes between tanks and pressure relief valves to facilitate maintenance should not be fitted unless all the following arrangements are provided:

a. 1 suitable arrangements to prevent more than one pressure relief valve being out of service at the same time;

b. 2 a device which automatically and in a clearly visible way indicates which one of the pressure relief valves is out of service; and

c. 3 pressure relief valve capacities such that if one valve is out of service the remaining valves 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.

217. 8.2.9 Each pressure relief valve installed on a cargo tank should be connected to a venting system which should 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 should not be less than B/3 or 6 m, whichever is the greater, above the weather deck and 6 m above the working area, the fore and aft gangway, deck storage tanks and cargo liquid lines.

218. 8.2.10 Cargo tank pressure relief valve vent exits should 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 spaces, service spaces and control stations, or other gas-safe spaces. For ships less than 90 m in length, smaller distances may he permitted by the Administration. All other vent exits connected to the cargo containment system should 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.

219. ***MSC/Circ. 1116*** ***of 2 June 2004 made the following interpretations to paragraph 8.2.10 of the IGC Code (also included in IACS Unified Interpretation SC70 (Rev2 Nov. 2005)):***

220. ***Paragraph 8.2.10 - Area classification and selection of electrical equipment***

221. *1 Areas on an open deck, or semi-enclosed spaces on an open deck, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet which permit the flow of large volumes of vapour, air or inert gas mixtures during loading/discharging/ballasting are defined as Zone 1.*

a. *Permitted electrical equipment:*

a.1. *Certified safe type equipment for Zone 1.*

222. *2 Areas within 4 m beyond the zone specified in paragraph 1 above are defined as Zone 2.*

a. *Permitted electrical equipment:*

a.1. *.1 certified safe type equipment for Zone 1;*

a.2. .2 equipment of a type which ensures the absence of sparks, arcs and of hot spots during its normal operation;

a.3. .3 equipment having an enclosure filled with a liquid dielectric, when required by the application, or encapsulated;

a.4. .4 pressured equipment; and

a.5. 5 equipment specifically designed for Zone 2 (for example type "n" protection in accordance with IEC 60079-15)."

223. 8.2.11 All other cargo vent exits not dealt with in other chapters should be arranged in accordance with H1.217 and H1.218.

224. 8.2.12 If cargoes which react in a hazardous manner with each other are carried simultaneously, a separate pressure relief system should be fitted for each cargo carried.

225. 8.2.13 In the vent piping system, means for draining liquid from places where it may accumulate should be provided. The pressure relief valves and piping should be so arranged that liquid can under no circumstances accumulate in or near the pressure relief valves.

226. 8.2.14 Suitable protection screens should be fitted on vent outlets to prevent the ingress of foreign objects.

227. 8.2.15 All vent piping should 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.

228. 8.2.16 The back pressure in the vent lines from the pressure relief valves should 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 should not exceed 3% of the valve set pressure. For unbalanced pressure relief valves the back pressure in the discharge line should not exceed 10% of the gauge pressure at the relief valve inlet with the vent lines under fire exposure as referred to in 8.5.2.

229. 8.2.17 Pressure relief valves should be positioned on the cargo tank so that they will remain in the vapour phase under conditions of 15 ° list and 0.015 L trim, where L is as defined in Section 1, A1.323 at the maximum allowable filling limit (FL).

230. 8.2.18 The adequacy of the vent system fitted on tanks loaded in accordance with I1.105 is to be

demonstrated using the guidelines developed by the Organization *. A relevant certificate should be permanently kept on board the ship. For the purposes of this paragraph, vent system means:

* Refer to res. A.829(19) adopted by the Organization.

a. 1 the tank outlet and the piping to the pressure relief valve;

b. 2 the pressure relief valve;

c. 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.

231. This paragraph may apply to all ships regardless of the date of construction.

300. 8.3 Additional pressure relieving system for liquid level control

301. 8.3.1 Where required by I1.104.b, an additional pressure relieving system to prevent the tank from becoming liquid full at any time during relief under the fire exposure conditions referred to in F1.500 should be fitted to each tank. This pressure relieving system should consist of:

a. 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 I1.104.b; and

b. 2 an override arrangement, whenever necessary, to prevent its normal operation. This arrangement should include fusible elements designed to melt at temperatures between 98°C and 104°C and to cause relief valves specified in F1.301.a to become operable. The fusible elements should be located, in particular, in the vicinity of relief valves. The system should become operable upon loss of system power if provided. The override arrangement should not be dependent on any source of ship's power.

302. ***8.3.1 IMO's interpretation (MSC/Circ.406/Rev.1):***

303. *Meaning of the term "liquid full". The words "to prevent the tank from becoming liquid full" contained in paragraphs F1.301 and I1.104.b have the following meaning:*

304. *At no time during the loading, transport or unloading of the cargo including fire conditions will the tank be more than 98 per cent liquid full, except as permitted by paragraph I1.103. These requirements, along with those of paragraph F1.229, are intended to ensure that the pressure relief valves remain in the vapour phase, since their design and capacity are based on such a condition.*

305. 8.3.2 The total relieving capacity of the additional pressure relieving system at the pressure mentioned in F1.301.a should not be less than:

Q' = F × G' × A0.82 (m3/s)

where:

Q' = minimum required rate of discharge of air at standard condition of 273 K and 1.013 bar.

$$G' = \frac{12.4}{(L + \rho_r \times m) \times D} \times \sqrt{\frac{Z \times T'}{M}}$$

with:

ρ_r = relative density of liquid phase of product at relieving conditions (ρ_r = 1.0 for fresh water),

$m = -d_i / d\rho_r$ = gradient of decrease of liquid phase enthalpy against increase of liquid phase density (kJ/kg) at relieving 306. conditions. For set pressures not higher than 2.0 bar the values in table F1.309.a may be used. For products not listed in the table and for higher set pressures, the value of *m* should be calculated on the basis of the thermo-dynamic data of the product itself;

i =enthalpy of liquid (kJ/kg);

T' =temperature in kelvins (K) at relieving conditions, i.e. at the pressure at which the additional pressure relieving system is set;

F, *A*, *L*, *D*, *Z* and *M* are defined in F1.501.b.

307. 8.3.3 Compliance with F1.301.a requires changing of the setting of the relief valves provided for in this section. This should be accomplished in accordance with the provisions of F1.214 and F1.215.

308. 8.3.4 Relief valves mentioned under F1.301.a above may be the same as the pressure relief valves mentioned in F1.200, provided the setting pressure and the relieving capacity are in compliance with the requirements of this section.

309. 8.3.5 The exhaust of such pressure relief valves may be led to the venting system referred to in F1.217. If separate venting arrangements are fitted these should be in accordance with the requirements of F1.217 to F1.227.

TABLE T.F1.309.1 - FACTOR *(m)*

Product	*m = -di/dρ*(kJ/kg)
Ammonia, anhydrous	3400
Butadiene	1800
Butane	2000
Butylenes	1900
Ethane	2100
Ethylene	1500
Methane	2300
Methyl chloride	816
Nitrogene	400
Propane	2000
Propylene	1600
Propylene oxide	1550
Vinyl chloride	900

310. The values in this table may be used for set pressures not higher than 2.0 bar.

400. 8.4 Vacuum protection systems

401. 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 operation of a cargo refrigeration system, need no vacuum relief protection.

402. 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, should be fitted with:

a. 1 two independent pressure switches to sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank, and refrigeration equipment if fitted, by suitable means at a pressure sufficiently below the maximum external designed pressure differential of the cargo tank; or

b. 2 vacuum relief valves with a gasflow 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

c. 3 other vacuum relief systems acceptable to the Administration.

403. 8.4.3 Subject to the requirements of ANNEX I, the vacuum relief valves should admit an inert gas, cargo vapour or air to the cargo tank and should be arranged to minimize the possibility of the entrance of water or snow. If cargo vapour is admitted, it should be from a source other than the cargo vapour lines.

404. 8.4.4 The vacuum protection system should be capable of being tested to ensure that it operates at the prescribed pressure.

500. 8.5 Size of valves

501. Pressure relief valves should 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:

a. 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

b. 2 vapours generated under fire exposure computed using the following formula:

$$Q = F \times G \times A^{0.82} \text{ (m}^3\text{/s)}$$

where

Q = minimum required rate of discharge of air at standard conditions of 273 K and 1.013 bar.

F = fire exposure factor for different cargo tank types

F = 1.0 for tanks without insulation located on deck;

F = 0.5 for tanks above the deck when insulation is approved by the Administration. (Approval will be based on the use of an approved fireproofing material, the thermal conductance of insulation, and its stability under fire exposure);

F = 0.5 for tanks above the deck when insulation is approved by the Administration. (Approval will be based on the use of an approved fireproofing material, the thermal conductance of insulation, and its stability under fire exposure;

F = 0.5 for uninsulated independent tanks installed in holds;

F = 0.2 for insulated independent tanks in holds (or uninsulated independ tanks in insulated holds);

F = 0.1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds);

F = 0.1 for membrane and semi membrane tanks. For independent tanks partly protruding through the open deck, the fire exposure factor should be determined on the basis of the surface areas above and below deck

G = gas factor

$$G = \frac{12.4}{L \times D} \times \sqrt{\frac{Z \times T}{M}}$$

T= temperature in Kelvins (K) at relieving conditions, i.e. 120% of the pressure at which the pressure relief valve is set;

L= latent heat of the material being vaporized at relieving conditions, in kJ/kg;

D= constant based on relation of specific heats k, shown in table 8.2; if k is not known, D = 0.606 should be used. The constant D may also be calculated by the following formula:

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

Z= compressibility factor of the gas at relieving conditions; if not known, Z = 1.0 should be used.

M= molecular mass of the product.

A= external surface area of the tank (m²) for different tank types:

A= external surface area;

A external surface area less the projected bottom surface area;

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

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

FIGURE F.F1.501.1 - EXTERNAL SURFACE AREA OF THE ARRAY OF PRESSURE VESSELS

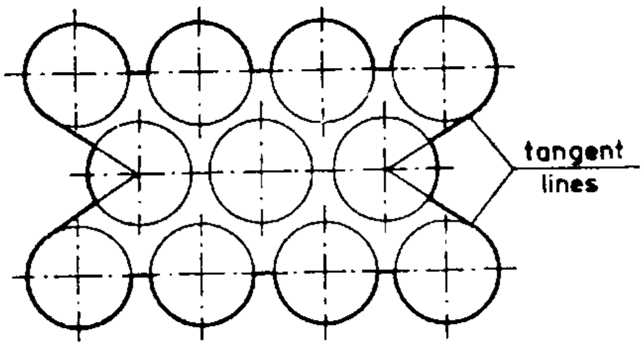


TABLE T.F1.501.1 - CONSTANT D.

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

CHAPTER G
ENVIRONMENTAL CONTROL

CHAPTER CONTENTS

G1. ENVIRONMENTAL CONTROL

G1. 9 ENVIRONMENTAL CONTROL

100. 9.1 Environmental control within cargo tanks and cargo piping systems

101. 9.1.1 A piping system should 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 should be arranged to minimize the possibility of pockets of gas or air remaining after gas-freeing or purging.

102. 9.1.2 A sufficient number of gas sampling points should be provided for each cargo tank in order to adequately monitor the progress of purging and gas-freeing. Gas sampling connections should be valved and capped above the main deck.

103. 9.1.3 For flammable gases, the system should 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 should 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.

104. 9.1.4 Piping systems which may contain cargo should be capable of being gas-freed and purged as provided in G1.101 and G1.103.

105. 9.1.5 Inert gas utilized in these procedures may be provided from the shore or from the ship.

200. 9.2 Environmental control within the hold spaces (cargo containment systems other than type C independent tanks)

201. 9.2.1 Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring full secondary barriers should be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage which should be sufficient for normal consumption for at least 30 days.

202. 9.2.2.1 Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring partial secondary barriers should be inerted with suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system or by shipboard storage which should be sufficient for normal consumption for at least 30 days.

203. 9.2.2.2 Alternatively, subject to the restrictions specified in chapter 17, the Administration may allow the spaces referred to in G1.202 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 should be provided.

204. 9.2.3 For non-flammable gases, the spaces referred to in G1.201 and G1.202 may be maintained with a suitable dry air or inert atmosphere.

205. 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 materials complying with 4.9.7.2.

300. 9.3 Environmental control of spaces surrounding type C independent tanks

301. Spaces surrounding refrigerated cargo tanks not having secondary barriers should 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.

400. 9.4 Inerting

401. 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 produced on board the ship or supplied from the shore. The inert gases should 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 should be taken into consideration.

402. 9.4.2 Where inert gas is also stored for fire-fighting purposes, it should be carried in separate containers and should not be used for cargo services.

403. 9.4.3 Where inert gas is stored at temperatures below 0°C, either as a liquid or as a vapour, the storage and supply system should be so designed that the temperature of the ship's structure is not reduced below the limiting values imposed on it.

404. 9.4.4 Arrangements suitable for the cargo carried should be provided to prevent the backflow of cargo vapour into the inert gas system.

405. 9.4.5 The arrangements should be such that each space being inerted can be isolated and the necessary controls and relief valves etc. should be provided for controlling pressure in these spaces.

500. 9.5 Inert gas production on board

501. 9.5.1 The equipment should be capable of producing inert gas with an oxygen content at no time greater than 5% by volume subject to the special requirements of ANNEX I. A continuous-reading oxygen content meter should be fitted to the inert gas supply from the equipment and should be fitted with an alarm set at a maximum of 5% oxygen content by volume subject to the requirements of ANNEX I. Additionally, where inert gas is made by an on-board 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 should be monitored for traces of oxygen to avoid possible initial high oxygen enrichment of the gas when released for inerting purposes.

502. 9.5.2 An inert gas system should have pressure controls and monitoring arrangements appropriate to the cargo containment system. A means acceptable to the Administration, located in the cargo area, of preventing the backflow of cargo gas should be provided.

503. 9.5.3 Spaces containing inert gas generating plants should have no direct access to accommodation spaces, service spaces or control stations, 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 should be fitted in the inert gas main in the cargo area as required in H1.502. Inert gas piping should not pass through accommodation spaces, service spaces or control stations.

504. When not in use, the inert gas system should be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.

505. 9.5.4 Flame burning equipment for generating inert gas should not be located within the cargo area. Special consideration may be given to the location of inert gas generating equipment using the catalytic combustion process.

CHAPTER H
ENVIRONMENTAL CONTROL

CHAPTER CONTENTS

H1. ENVIRONMENTAL CONTROL

H1. 13 ENVIRONMENTAL CONTROL

100. 13.1 General

101. 13.1.1 Each cargo tank should be provided with means for indicating level, pressure and temperature of the cargo. Pressure gauges and temperature indicating devices should be installed in the liquid and vapour piping systems, in cargo refrigerating installations and in the inert gas systems as detailed in this chapter.

102. 13.1.2 Where a secondary barrier is required, permanently installed instrumentation should 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 should consist of appropriate gas detecting devices according to H1.600. 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.

103. 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 should be concentrated in one control position.

104. 13.1.4 Instruments should be tested to ensure reliability in the working conditions and re-calibrated at regular intervals. Test procedures for instruments and the intervals between recalibration should be approved by the Administration.

200. 13.2 Level indicators for cargo tanks

201. 13.2.1 Each cargo tank should 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 should be so arranged that any necessary maintenance can be carried out while the cargo tank is in service.

202. *13.2.1 IACS' unified interpretation GC2*

203. *Interpretation of the second sentence of paragraph 13.2.1 (1977).*

(Note: This interpretation actually refers to the 1976 edition of the Code. However, paragraph 13.2.1 is identical in the 1976 and the present editions):

204. *In order to assess whether or not only one level gauge is acceptable in relation to the aforesaid sentence, 'any maintenance' means that 'any part' of the level gauge can be overhauled while the cargo tank is in service.*

205. 13.2.2 Cargo tank liquid level gauges may be of the following types subject to any special requirement for particular cargoes shown in column "g" in the table of ANNEX III:

a. 1 indirect devices, which determine the amount of cargo by means such as weighing or pipe flow meters;

b. 2 closed devices, which do not penetrate the cargo tank, such as devices using radioisotopes or ultrasonic devices;

c. 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 should be provided with a shut-off valve located as close as possible to the tank; and

d. 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 should be kept completely closed. The design and installation should ensure that no dangerous escape of cargo can take place when opening the device. Such gauging devices should 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.

206. 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 Administration as a secondary means of gauging for cargo tanks having a design vapour pressure not higher than 0.7 bar.

207. 13.2.4 Tubular gauge glasses should 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 Administration for deck tanks, subject to any provisions of ANNEX I.

300. 13.3 Overflow control

301. 13.3.1 Except as provided in H1.305, each cargo tank should 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 should automatically actuate a shut-off valve 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 D1.601 and D1.606 may be used for this purpose. If another valve is used for this purpose, the same information as referred to in D1.607 should be available on board. During loading, whenever the use of these valves may possibly create a potential excess pressure surge in the loading system, the port State authority may agree to alternative arrangements such as limiting the loading rate, etc.

302. ***13.3.1 IMO's interpretation (MSC/Circ.406/Rev.1):***

303. ***Independency of systems***

304. *The sensor for automatic closing of the loading valve for overflow control as required in H1.301 may be combined with the liquid level indicators required by paragraph H1.201.*

305. 13.3.2 A high liquid level alarm and automatic shut-off of cargo tank filling need not be required when the cargo tank:

a. 1 is a pressure tank with a volume not more than 200 m³; or

b. 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.

306. 13.3.3 Electrical circuits, if any, of level alarms should be capable of being tested prior to loading.

400. 13.4 Pressure gauges

401. 13.4.1 The vapour space of each cargo tank should be provided with a pressure gauge which should incorporate an indicator in the control position required by 13.1.3. In addition, a high-pressure alarm and, if vacuum protection is required, a low-pressure alarm, should be provided on the navigating bridge. Maximum and minimum allowable pressures should be marked on the indicators. The alarms should be activated before the set pressures are reached. For cargo tanks fitted with pressure relief valves, which can be set at more than one set pressure in accordance with F1.214, high-pressure alarms should be provided for each set pressure.

402. 13.4.2 Each cargo pump discharge line and each liquid and vapour cargo manifold should be provided with at least one pressure gauge.

403. 13.4.3 Local-reading manifold pressure gauges should be provided to indicate the pressure between stop valves and hose connections to the shore.

404. 13.4.4 Hold spaces and interbarrier spaces without open connection to the atmosphere should be provided with pressure gauges.

500. 13.5 Temperature indicating devices

501. 13.5.1 Each cargo tank should 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 should be marked to show the lowest temperature for which the cargo tank has been approved by the Administration.

502. 3.5.2 When a cargo is carried in a cargo containment system with a secondary barrier at a temperature lower than -55°C, temperature indicating devices should be provided within the insulation or on the hull structure adjacent to cargo containment systems. The devices should give readings at regular intervals and, where applicable, audible warning of temperatures approaching the lowest for which the hull steel is suitable.

503. 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, should be fitted with temperature indicating devices as follows:

a. 1 A sufficient number of devices to establish that an unsatisfactory temperature gradient does not occur.

b. 2 On one tank a number of devices in excess of those required in item a 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 is built, the second and successive ships need not comply with the requirements of this subparagraph.

504. 13.5.4 The number and position of temperature indicating devices should be to the satisfaction of the Administration.

600. 13.6 Gas detection requirements

601. 13.6.1 Gas detection equipment acceptable to the Administration and suitable for the gases to be carried should be provided in accordance with column "f" in the table of ANNEX III.

602. 13.6.2 In every installation, the positions of fixed sampling heads should 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.

603. 13.6.3 Pipe runs from sampling heads should not be led through gas-safe spaces except as permitted by H1.605.

604. 13.6.4 Audible and visual alarms from the gas detection equipment, if required by this section, should be located on the navigating bridge, in the control position required by H1.103, and at the gas detector readout location.

605. 13.6.5 Gas detection equipment may be located in the control position required by H1.103, on the navigating bridge or at other suitable locations. When such equipment is located in a gas-safe space the following conditions should be met:

a. 1 gas-sampling lines should have shut-off valves or an equivalent arrangement to prevent cross-communication with gas-dangerous spaces; and

b. 2 exhaust gas from the detector should be discharged to the atmosphere in a safe location.

606. 13.6.6 Gas detection equipment should be so designed that it may readily be tested. Testing and calibration should be carried out at regular intervals. Suitable equipment and span gas for this purpose should be carried on board. Where practicable, permanent connections for such equipment should be fitted.

607. 13.6.7 A permanently installed system of gas detection and audible and visual alarms should be provided for:

a. 1 cargo pump rooms;

b. 2 cargo compressor rooms;

c. 3 motor rooms or cargo handling machinery;

d. 4 cargo control rooms unless designated as gas-safe;

e. 5 other enclosed spaces in the cargo area where vapour may accumulated including hold spaces and interbarrier spaces for independent tanks other than type C;

f. 6 ventilation hoods and gas ducts where required by chapter 16; and

g. 7 air-locks.

608. 13.6.8 The gas detection equipment should be capable of sampling and analysing from each sampling head location sequentially at intervals not exceeding 30 min, except that in the case of gas detection for the ventilation hoods and gas ducts referred to in.

609. 13.6.7.6 sampling should be continuous. Common sampling lines to the detection equipment should not be fitted.

610. 13.6.9 In the case of products which are toxic or both toxic and flammable, the Administration, except when column "i" in the table of ANNEX III refers to ANNEX I, A1.900, may authorize the use of portable

equipment for detection of toxic products as an alternative to a permanently installed system, if such equipment is used before personnel enter the spaces listed in H1.607 and at 30 min intervals while they remain therein.

611. 13.6.10 For the spaces listed in H1.607, alarms should be activated for flammable products when the vapour concentration reaches 30% of the lower flammable limit.

612. 13.6.11 In the case of flammable products, where cargo containment systems other than independent tanks are used, hold spaces and interbarrier spaces should be provided with a permanently installed gas detection system capable of measuring gas concentrations of 0 to 100% by volume. The detection equipment, equipped with audible and visual alarms, should be capable of monitoring from each sampling head location sequentially at intervals not exceeding 30 min. 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 Administration in the light of particular cargo containment arrangements. Common sampling lines to the detection equipment should not be fitted.

613. 13.6.12 In the case of toxic gases, hold spaces and interbarrier spaces should be provided with a permanently installed piping system for obtaining gas samples from the spaces. Gas from these spaces should be sampled and analyzed from each sampling head location by means of fixed or portable equipment at intervals not exceeding 4 h and in any event before personnel enter the space and at 30 min intervals while they remain therein.

614. 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.

615. 13.6.14 A suitable instrument for the measurement of oxygen levels in inert atmospheres should be provided.

CHAPTER I
FILLING LIMITS FOR CARGO TANKS

For ships constructed from 1986-07-01

CHAPTER CONTENTS

I1. FILLING LIMITS FOR CARO TANKS

I1. 15 FILLING LIMITS FOR CARGO TANKS

100. 15.1 General

101. 15.1.1 No cargo tanks should have a higher filling limit (FL) than 98% at the reference temperature, except as permitted by I1.103.

102. 15.1.2 The maximum loading limit (LL) to which a cargo tank may be loaded should be determined by the following formula:

$$LL = FL\ (\rho_R/\rho_L)$$

where:

LL = loading limit expressed in percent which means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded;

FL = filling limit as specified in I1.101 or I1.103;

ρ_R = relative density of cargo at the reference temperature; and

ρ_L = relative density of cargo at the loading temperature and pressure.

103. 15.1.3 The Administration may allow a higher filling limit (FL) than the limit of 98% specified in I1.101 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 specified in F1.229 are maintained.

104. 15.1.4 For the purposes of this chapter only, "reference temperature" means:

a. 1 the temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valves when no cargo vapour pressure/temperature control as referred to in chapter E is provided;

b. 2 the temperature of the cargo upon termination of loading, during transport, or at unloading, whichever is the greatest, when a cargo vapour pressure/temperature control as referred to in chapter E 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 F1.200, an additional pressure relieving system complying with F1.300 should be fitted.

105. 15.1.5 The Administration 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 F1.230:

$LL = FL\ (\rho_R/\rho_L)$

where:

LL = loading limit as specified in I1.102;
FL = filling limit as specified in I1.101 or I1.103;
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 E.102; and
ρ_L = as specified in 15.1.2.

106. This paragraph does not apply to products requiring a type 1G ship.

200. 15.2 Information to be provided to the master

201. The maximum allowable loading limits for each cargo tank should 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 Administration. Pressures at which the pressure relief valves, including those valves required by F1.300, have been set should also be stated on the list. A copy of the list should be permanently kept on board by the master.

300. 15.3 Application

301. Chapter I applies to all ships regardless of the date of construction.