TÜRK LOYDU

TL-R G

Requirements Concerning Gas Tankers

January 2020

These requirements are prepared by embedding related IACS Unified Requirements. In order to have consistency, the numbering of the requirements are kept as the same with related IACS Unified Requirements.

Unless otherwise specified, these Rules apply according to the implementation dates as defined in each requirement. See Rule Change Summary on TL website for revision details.

This latest edition incorporates all rule changes.

"General Terms and Conditions" of the respective latest edition will be applicable (see Rules for Classification and Surveys).

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TL- R G1 Cargo containment of gas tankers

G1.1 General

G1.1.1 The present text gives the general principles which are applied by TL for approval and survey of the relevant items of liquefied gas tankers for classification purposes. They do not intend to cover full details of such approval and survey procedures which are to be found in TL Rules.

G1.1.2 Where appropriate, this Requirement refers to the basic tank types which are defined under G1.2. Tanks differing from these definitions will be the subject of special consideration.

G1.1.3 This requirement does not apply to vessels which must comply with the requirements of IMO Resolution MSC.370(93) Amendments to the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)*.

G1.2 Definitions

G1.2.1 Integral tanks

Integral tanks form a structural part of the ship's hull and are influenced in the same manner and by the same loads that stress the adjacent hull structure. The design vapour pressure P_0 is not normally to exceed 0,025 N/mm^2 (0.25 bar). If, however, the hull scantlings are increased accordingly, P_0 may be increased to a higher value but less than 0,07 N/mm^2 (0.7 bar).

Integral tanks may be used for liquefied gases provided that the lowest temperature in any part of the hull structure in no circumstances will fall below –10°C. A lower temperature may be accepted by TL subject to special consideration.

G1.2.2 Membrane tanks

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. The design vapour pressure P_0 is not normally to exceed 0,025 N/mm^2 (0.25 bar). If, however, the hull scantlings are increased accordingly, P_0 may be increased to a higher value but less than 0,07 N/mm^2 (0.7 bar).

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

Note:

1. This requirement is implemented for ships contracted for construction on or after 1 July 2016.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to TL- PR 29.

G1.2.3 Semi-membrane tanks

Semi-membrane tanks are a 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. The design vapour pressure P_0 is not normally to exceed 0,025 N/mm^2 (0.25 bar). If, however, the hull scantlings are increased accordingly, P_0 may be increased to a higher value but less than 0,07 N/mm^2 (0.7 bar).

G1.2.4 Independent tanks

Independent tanks are self-supporting; they do not form part of the ship hull and are not essential to the hull strength.

Three categories of independent tanks are considered:

(i) *Independent tanks type A* which are designed primarily using TL classical structural analysis procedures. Where such tanks are primarily constructed of plane surfaces (gravity tanks), the design vapour pressure P_0 is to be less than 0,07 N/mm^2 (0.7 bar).

(ii) *Independent tanks type B* which are designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (gravity tanks), the design vapour pressure P_0 is to be less than 0,07 N/mm^2 (0.7 bar).

(iii) *Independent tanks type C* (also referred to as pressure tanks) are tanks meeting pressure vessel criteria and having a design vapour pressure P_0 not less than:

$$P_0 = 0{,}2 + 0{,}1AC\rho_0^{3/2} \quad (\text{N/mm}^2)$$

$$P_0 = 2 + AC\rho_0^{3/2} \quad (\text{bar})$$

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

σ_m = design primary membrane stress (N/mm^2)

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

= 55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steels

= 25 N/mm^2 for aluminium alloy (5083^{-0}) (for other materials the value of A will be determined in agreement with TL)

C = characteristic tank dimension to be taken the greatest of *h*: 0,75*b* 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_0 = relative density of cargo (=1 for fresh water) at the design temperature.

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

G1.2.5 Design vapour pressure

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

(i) For cargo tanks where there is no temperature control and where the pressure of the cargo is only dictated by the ambient temperature, P_0 is not to be less than the vapour pressure of the cargo at a temperature of 45°C. However, lesser values of this temperature may be accepted by TL for ships operating in restricted areas or on voyages of restricted duration and account may be taken in such cases of a possible insulation of the tanks. On the other hand, higher values of this temperature may be required for ships permanently operating in areas of high ambient temperature.

(ii) In all cases, including (i), P_0 is not to be less than the maximum allowable relief valve setting (MARVS).

(iii) Subject to special consideration and to the limitations given under G1.2.1 to G1.2.4 for the various tank types, a vapour pressure higher than P_0 may be accepted in harbour conditions where dynamic loads are reduced.

G1.2.6 Design temperature

The design temperature for selection of materials is the minimum temperature at which cargo may be loaded and/or transported in the cargo tanks.

Provisions to the satisfaction of TL are to be made so that the tank or cargo temperature cannot be lowered below the design temperature.

G1.3 Design loads

G1.3.1 General

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

Internal pressure
External pressure
Dynamic loads due to the motion of the ship
Thermal loads
Sloshing loads
Loads corresponding to ship deflection
Tank and cargo weight with the corresponding reactions in way of supports
Insulation weight
Loads in way of towers and other attachments.

The extent to which these loads are to be considered depends on the type of tank.

(b) Account is also to be taken of the loads corresponding to the pressure test mentioned in G1.10.

(c) Account is also to be taken of an increase of vapour pressure in harbour conditions (see G1.2.5 (iii)).

(d) The tanks are to be designed for the most unfavourable static heel angle within the range of 30° without exceeding allowable stresses given G1.5.

G1.3.2 Internal pressure

(a) The following formula gives the value of internal pressure head h_{eq}, in N/mm^2 or bar, resulting from the design vapour pressure P_0 and the liquid pressure defined in G1.3.2 (b) but not including effects of liquid sloshing:

$$h_{eq} = P_0 + (h_{gd})_{max.}$$

Equivalent procedures may be applied.

(b) 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 (see G1.3.4). The following formula gives the value of internal pressure head h_{gd}, in N/mm^2 or bar, resulting from combined effects of gravity and dynamical acceleration:

$$h_{gd} = a_\beta \text{ x } Z_\beta \frac{\rho}{1{,}02 \times 10^5} \text{ (N/mm}^2\text{)}$$

$$h_{gd} = a_\beta \text{ x } Z_\beta \frac{\rho}{1{,}02 \times 10^4} \text{ (bar)}$$

where:

a_β = the dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamical loads, in an arbitrary direction β (see Fig. 1)

Z_β = largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the β direction (see Fig. 2). Small tank domes not considered to be part of the accepted total volume of the cargo tank need not to be considered when determining Z_β.

ρ = the maximum density of the cargo (kg/m^3) at the design temperature.

The direction β which gives the maximum value (h_{gd}) max of h_{gd} is to be considered. Where acceleration in three directions needs to be considered an ellipsoid is to be used instead of the ellipse in Fig. 1. The above formula applies to full tanks.

G1.3.3 External pressure

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

G1.3.4 Dynamic loads due to ships motions

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

(b) For design against plastic deformation and buckling the dynamic loads are to be taken as the most probable largest loads the ship will encounter during her operating life (normally taken to correspond to a probability level of 10^{-8}). See Appendix 1 for guidance.

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

(d) In order to practically apply crack propagation estimates, simplified load distribution over a period of 15 days may be used. Such distributions may be obtained as indicated in Fig. 3.

(e) Ships for restricted service will be given special consideration.

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

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

G1.3.5 Sloshing loads

(a) When partial filling is contemplated, the risk of significant loads due to sloshing induced by any of the ship motions mentioned in G1.3.4 (f) is to be considered.

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

G1.3.6 Thermal loads

(a) Transient thermal loads during cooling down periods are to be considered for tanks intended for cargoes with a boiling point below -55°C.

(b) Stationary thermal loads are to be considered for tanks where design, supporting arrangement and operating temperature may give rise to significant thermal stress.

G1.3.7 Loads on supports

See G1.6.

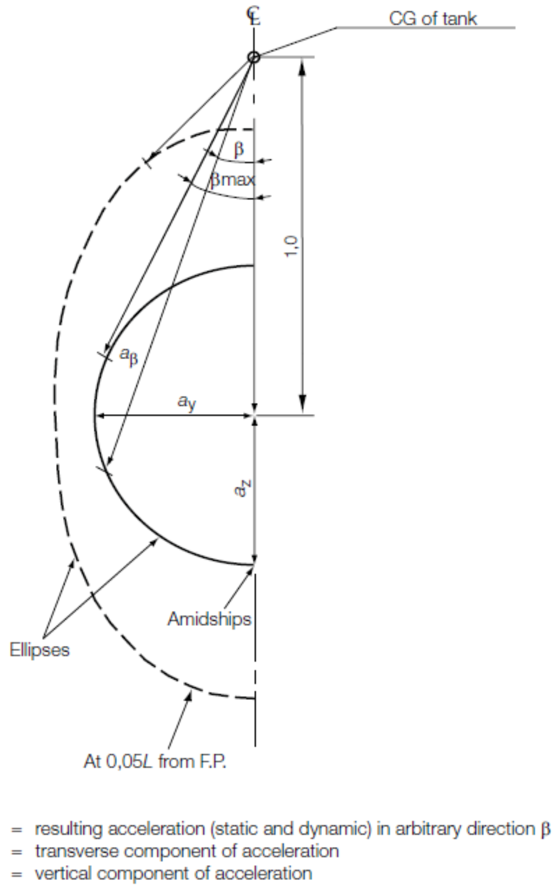


Fig.1 Acceleration ellipse

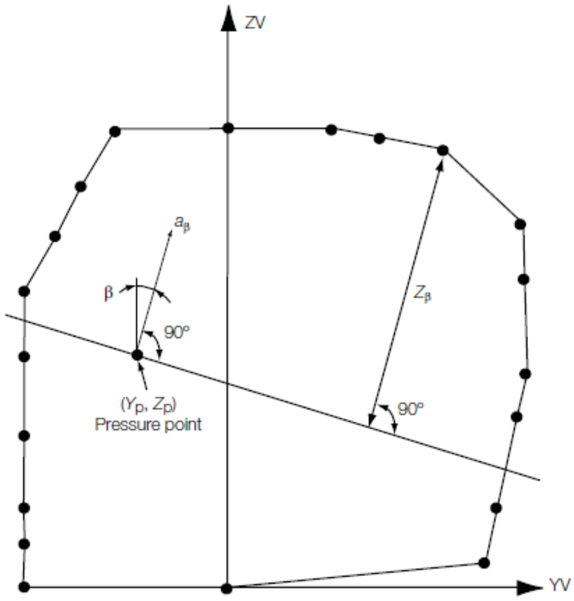
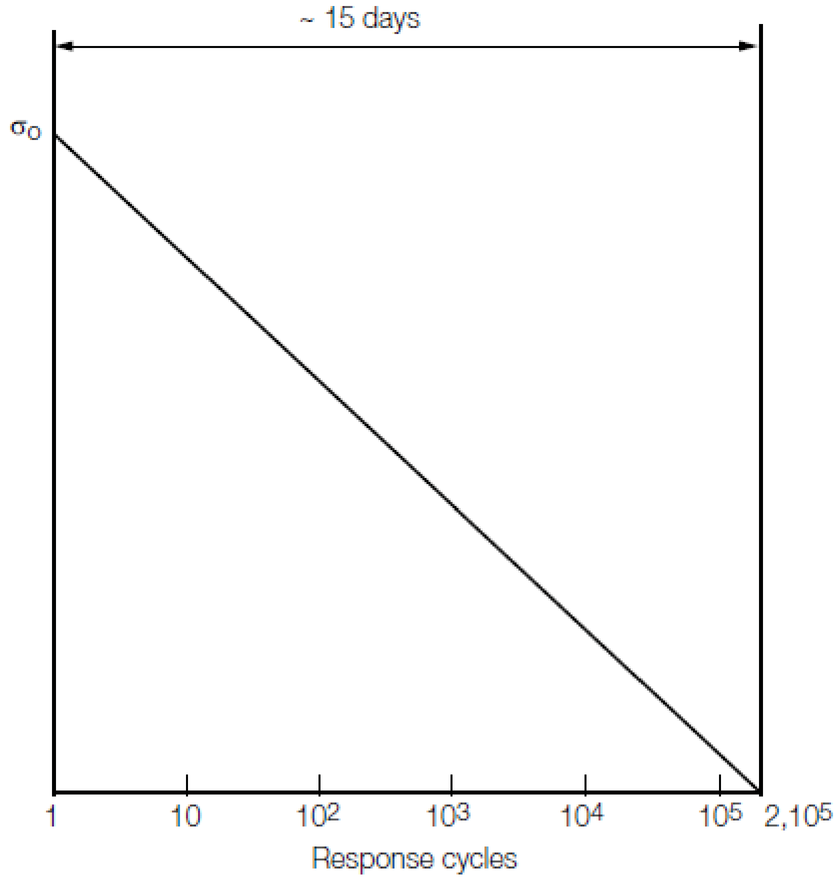


Fig.2 Determination of internal pressure heads



σ_o = most probable maximum stress over the life of the ship
Response cycle scale is logarithmic; the value of $2{,}10^5$ is given as an example of estimate

Fig.3 Simplified load distribution

G1.4 Structural analysis

G1.4.1 Integral tanks

The structural analysis of integral tanks is to be performed in accordance with the rules for hull structure of TL.

G1.4.2 Membrane tanks

(a) For membrane tanks, the effects of all static and dynamic loads are to be considered to determine the suitability of the membrane and of the associated insulation with respect to plastic deformation and fatigue.

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

(c) For the purpose of the test referred to in G1.4.2 (b), a complete analysis of the particular motions, accelerations and response of ships and tanks is to be performed, unless these data are available from similar ships.

(d) Special attention is to be paid to the possible collapsing of the membrane due to an overpressure in the interbarrier space, to a possible vacuum in the tanks, to the sloshing effects and to hull vibration effects.

(e) The structural analysis of the hull is to be performed in accordance with the rules for hull structure of TL taking into account the internal pressure as indicated in G1.3.2. Special attention is however to be paid to deformations of the hull and their compatibility with the membrane and associated insulation. Inner hull plating thickness is to meet at least the requirements of TL for deep tanks taking into account the internal pressure as indicated in G1.3.2. The allowable stress for the membrane, membrane supporting material and insulation will be determined in each particular case.

G1.4.3 Semi-membrane tanks

Structural analysis is to be performed in accordance with the requirements for membrane tanks or independent tanks as appropriate, taking into account the internal pressure as indicated in G1.2.3.

G1.4.4 Independent tanks type A

(a) The structural analysis is normally performed in accordance with the rules for hull structure of TL taking into account the internal pressure as indicated in G1.3.2. The cargo tank plating thickness is to meet at least the requirements of TL for deep tanks taking into account the internal pressure as indicated in G1.3.2 and any corrosion allowance required by G1.5.2.

(b) For parts (structure in way of supports for instance) not covered by the Rules, stresses are to be determined by direct calculations taking into account the loads referred to in G1.3, as far as applicable, and the ship deflection in way of supports.

G1.4.5 Independent tanks type B

(a) The effects of all dynamic and static loads are to be used to determine the suitability of the structure with respect to:

plastic deformation
buckling
fatigue failure
crack propagation

Statistical wave load analysis in accordance with G1.3.4, finite element analysis or similar methods and fracture mechanics analyses or is equivalent approach, are to be carried out.

(b) A three dimensional analysis is to be carried out to elevate the stress levels contributed by the ship hull. The model for this analysis is to include the cargo tank with its supporting and keying system as well as a reasonable part of the hull.

(c) A complete analysis of the particular ship accelerations and motions in irregular waves and of the response of ships and tanks to these forces and motions is to be performed unless these data are available from similar ships.

(d) Buckling analysis is to consider the maximum construction tolerances.

(e) Where deemed necessary by TL, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

(f) The cumulative effect of the fatigue load is to comply with the following formula:

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

Where

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

N_i = number of cycles to fracture for the respective stress level according to the Wohler curve

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

$C_w \le 0,5$, except that TL 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 Wohler curve (S – N curve).

G1.4.6 Independent tanks type C

Structural analysis is to be performed in accordance with G2.

G1.5 Allowable stress – corrosion allowance

G1.5.1 Allowance stresses

(a) For integral tanks, allowable stresses are normally those given for hull structure by TL.

(b) For membrane, see G1.4.2 (e)

(c) For independent tanks type A primarily constructed of plane surfaces, the bending stresses for primary and secondary members (stiffeners, web frames, stringers, girders) when calculated by classical analysis procedures are not to exceed the lower of 0,75σ_F or 0,38σ_B for carbon-manganese steels and aluminium alloys. However, if detailed calculations are carried out for primary members, the equivalent stresses σ_c, as defined in G1.5.1 (g) may be increased over that indicated above to a value acceptable to TL; calculations have to take into account the effects of bending, shear, axial and torsional deformations as well as the hull/cargo tank interaction forces due to the deflection of the double and cargo tank bottoms. For σ_F and σ_B see G1.5.1 (h).

(d) For independent tanks B primarily constructed of bodies of revolution, the allowable stresses are not to exceed the following:

$\sigma_m \le f$

$\sigma_L \le 1{,}5f$

$\sigma_b \le 1{,}5F$

$\sigma_L + \sigma_b \le 1{,}5F$

$\sigma_m + \sigma_b \le 1{,}5F$

where

σ_m = equivalent primary general membrane stress

σ_L = equivalent primary local membrane stress

σ_b = equivalent primary bending stress

f = the lesser of σ_B/A or σ_F/B

F = the lesser of σ_B/C or σ_F/D

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

Material	A	B	C	D
C-Mn steels and Ni steels	3	2	3	1,5
Austenitic steels	3,5	1,6	3	1,5

Aluminium alloys	4	1,5	3	1,5

For σ_B and σ_F see G1.5.1 (h).

(e) For independent tanks type B, primarily constructed of plane surfaces, TL may require compliance with additional or other stress criteria.

(f) For independent tanks type C, see G2.

(g) For the purpose of G1.5.1 (a)-(f) equivalent stresses σ_c (von Mises, Huber) are determined as follows:

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

where

σ_x = total normal stress in x direction

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

σ_y = total normal stress in y direction

Unless other methods of calculation are justified, the total stresses are calculated accordingly to the following formulae for independent tanks type B:

$$\sigma_x = \sigma_{x.st} \pm \sqrt{\sum (\sigma_{x.dyn})^2}$$

$$\sigma_y = \sigma_{y.st} \pm \sqrt{\sum (\sigma_{y.dyn})^2}$$

$$\tau_{xy} = \tau_{xy.st} \pm \sqrt{\Sigma (\tau_{xy.dyn})^2}$$

where $\sigma_{x.st}$, $\sigma_{xy.st}$ and $\tau_{xy \cdot st}$ are dynamic stresses

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

(h) For the purpose of G1.5.1 (a)-(g):

σ_F = specified minimum upper yield stress at room temperature. If the stress-strain curve does not show a defined yield stress, the 0,2 % proof stress applies. For welded connections in aluminium alloys, the proof stress in the annealed conditions is to be used.

σ_B = specified minimum tensile strength at room temperature. For welded connections in aluminium alloys, the tensile strength in annealed conditions is to be used.

The above properties are to correspond to the minimum specified mechanical properties of the material, including the weld metal in the as fabricated condition. Subject to special consideration by TL, advantage may be taken of enhanced yield stress and tensile strength at low temperature.

(i) Allowable stresses for materials other than those covered by TL- R W1 will be subject to special approval in each separate case.
Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

G1.5.2 Corrosion allowance

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

(b) For pressure tanks, corrosion allowance is given in G2.

G1.6 Supports

G1.6.1 Cargo tanks are to be supported by the hull in a manner which will prevent bodily movement of the tank under static and dynamic loads while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and of the hull.

G1.6.2 The tanks with supports are also to be designed for a static inclination of 30°without exceeding allowable stresses given in G1.5.

G1.6.3 The supports are to be calculated for the most probable largest severe resulting acceleration taking into account rotational as well as translational effects. This acceleration in a given direction maybe determined as shown in Fig. 1. The half axes of the 'acceleration ellipse' are determined according to G1.3.4 (b).

G1.6.4 Suitable supports are to 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.

G1.6.5 The loads mentioned in G1.6.2 and G1.6.4 need not be combined with each other or with wave included loads.

G1.6.6 For independent tanks and, where appropriate, for membrane and semi-membrane tanks, provisions are to be made to key the tanks against rotational effects referred to in G1.6.3.

G1.6.7 Anti-flotation chocks are to be provided for independent tanks. The anti-flotation chocks are to be suitable to withstand an upward force caused by an empty tank in a hold space flooded to the load draught of the ship, without plastic deformation likely to endanger the hull structure.

G1.7 Secondary barrier

G1.7.1 When the cargo temperature at atmospheric pressure is below -10°C a secondary barrier is to be provided, if required by G1.7.3, to act as a temporary containment for any envisaged leakage of liquid cargo through the primary barrier.

G1.7.2 When the cargo temperature at atmospheric pressure is not below -55°C, the hull structure may act as secondary barrier. In such a case:

(i) the hull material is to be suitable for the boiling point at atmospheric pressure (see TL- R W1);

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

G1.7.3 The requirements for secondary barrier in relation on tank type are as given in Table 1.

Table 1 indicates the basic requirements with respect to secondary barrier. For tanks which differ from the basic tank types as defined in G1.2, the secondary barrier requirements will be decided in each separate case.

G1.7.4 The secondary barrier is to be designed so that:

(i) it is capable of containment of any envisaged leakage of liquid cargo for a period of at least 15 days, unless different requirements apply for particular voyages. This condition is to be fulfilled taking into account the load spectrum defined in G1.3.4.(d).

(ii) it will prevent lowering of the temperature of the ship structure to an unsafe level in case of leakage of the primary barrier (see G1.8.2).

(iii) the mechanism of failure for the primary barrier does not also cause the failure of the secondary barrier and vice-versa.

Table 1

Cargo temperature t_b at atmospheric pressure	**$t_b > -55°C$**	**$-10°C < t_b \geq -55°C$**	**$t_b > -10°C$**
Basic tank type	Separate secondary barrier where required	Hull may act as secondary barrier	
Integral	Tank type not normally allowed[1]		
Membrane	Complete secondary barrier		No secondary barrier required
Semi-membrane	Complete secondary barrier[2]		
Independent Type A	Complete secondary barrier		
Independent Type B	Partial secondary barrier		
Independent Type C	No secondary barrier required		

NOTES:

1. A complete secondary barrier will be normally required if cargoes with a value of t_b below –10°C are permitted in accordance with G1.2.1.

2. In the case of semi-membrane tanks which comply in all respects with the provisions applicable to independent tanks, type B, except for the manner of support TL may consider the possibility of accepting a partial secondary barrier.

G1.7.5 The functions of the secondary barrier are to be ensured assuming a static angle of heel equal to 30°C.

G1.7.6 Where a partial secondary barrier is required, its extent is to be determined on the basis of cargo leakage corresponding to the extent of failure resulting from the load spectrum defined in G1.3.4.(d) after the initial detection of a primary barrier leak. Due account may be taken of liquid evaporation, rate of leakage, reliable pumping capacity and other relevant factors. In all cases, however, the inner bottom in way of cargo tanks is to be protected against liquid cargo. Clear of partial secondary barrier, provisions are to be made to deflect any liquid cargo down into the space between the primary and secondary barriers and to keep the temperature of the hull structure to a safe level (spray-shield).

G1.7.7 The secondary barrier is to be capable of being periodically checked for its effectiveness. Checking may be a pressure vacuum test, a visual inspection or another suitable method acceptable to TL. Procedures for the periodic checking of the secondary barrier during the life of the ship are to be submitted to TL as a condition of the approval of the cargo containment system.

G1.8 Insulation

G1.8.1 When liquified gas is carried at a temperature below –10°C, suitable insulation is to be provided to ensure that the minimum temperature of the hull structure does not fall below the minimum allowable service temperature given for the concerned grade of steel in W1 when the cargo tanks are at their design temperature and the ambient temperatures are 5°C for air and 0°C for sea water. The above conditions may generally be used for world wide service. However, higher values of the ambient temperatures maybe accepted by TL for ships operated in restricted areas. On the other hand, attention is drawn to the fact that lesser values of the ambient temperatures may be fixed by National Authorities.

G1.8.2 Where a complete or partial secondary barrier is required, calculations are to be made with the same assumptions as in G1.8.1 to check that the minimum temperature of the hull structure does not fall below the minimum allowable service temperature given for the concerned grade of steel in TL- R W1. The complete or partial secondary barrier is then to be assumed at the cargo temperature at atmospheric pressure.

G1.8.3 Calculations required by G1.8.1. and G1.8.2 are to be made assuming still air and still water. In the case referred to in G1.8.2, the cooling effect of the rising boil-off vapour from the leaked cargo is to be considered in the heat transmission studies. For members connecting inner and outer hulls, the mean temperature may be considered for determining the steel grades.

G1.8.4 In all cases referred to in G1.8.1 and G1.8.2 and for the ambient temperature conditions of 5°C for air and 0°C for sea water, approved means of heating transverse hull structural material may be used to ensure that the temperature of this material do not fall below the minimum allowable values. If lower ambient temperatures are specified, approved means of heating may also be used for longitudinal hull structural material, provided this material remains suitable for the temperature conditions of 5°C for air and 0°C for sea water without heating. Such a means of heating is to comply with the following requirements:

(i) Sufficient heat is to be available to maintain the hull structure above the minimum allowable temperature in the conditions referred to in G1.8.1 and G1.8.2.

(ii) The heating systems are to be arranged so that, in the event of a failure in any part of the system, standby heating can be maintained equal to not less than 100% of the theoretical heat load.

(iii) The heating systems are to be considered as essential auxiliaries.

(iv) The engineering of the heating systems is to be in accordance with the requirements of TL.

G1.8.5 In determining the insulation thickness, due regard is to be paid to the amount of acceptable boil-off in association with the reliquefaction plant on board, main propulsion machinery or other temperature control system.

G1.9 Materials

G1.9.1 The shell and deck plating of the ship, and all stiffeners attached thereto, are to be in accordance with TL Rules unless the calculated temperature of the material in the design condition is below –5°C due to the effect of the low temperature cargo, in which case the material is to be in accordance with Table 5 of TL- R W1, assuming ambient sea and air temperatures of 0°C and 5°C respectively. In the design condition the complete or partial secondary barrier is to be assumed to be at the cargo temperature at atmospheric pressure and for tanks without secondary barriers, the primary barrier is to be assumed to be at the cargo temperature.

G1.9.2 Hull material forming the secondary barrier is to be in accordance with Table 2 of TL- R W1.

G1.9.3 Material used in the construction of cargo tanks are to be in accordance with Tables 1, 2, or 3 of TL- R W1.

G1.9.4 All other materials used in the construction of the ship which are subject to reduced temperature due to the cargo and which do not form part of the secondary barrier are to be in accordance with Table 5 of TL- R W1 for temperature determined by G1.8. This includes inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

G1.9.5 The insulation materials are to be suitable for loads which may be imposed on them by the adjacent structure.

G1.9.6 Where applicable, insulation materials are to have suitable properties of fire resistance and are to be adequately protected against penetration of water vapour and mechanical damage.

G1.9.7 Insulation materials are to be tested and found acceptable with regard to the following properties as applicable:

compatibility with the cargo
solubility in the cargo
absorption of the cargo
shrinkage
ageing
closed cell content
density
mechanical properties
thermal expansion
abrasion
cohesion
thermal conductivity
resistance to vibrations
resistance to fire and flame spread

G1.9.8 The procedures for quality control of insulation materials during fabrication and/or *in situ* erection are to be to the satisfaction of TL.

G1.9.9 Where power or granulated insulation is used, the arrangements are to be such as to prevent compacting of the material due to vibrations.

The design is to incorporate means to ensure that the material remains sufficiently buoyant to maintain the required thermal conductibility and also prevent any undue increase of pressure on the containment system.

G1.10 Construction and testing

G1.10.1 All welded joints of the shell of independent tanks are to be of the butt-weld full-penetration type. For dome to shell connections, TL may approve filler welds of the full penetration type. Except for small penetrations on domes, nozzle welds are also generally to be designed with full penetration. For tank type C, see G2.

G1.10.2 Workmanship is to be to the satisfaction of TL. Inspection of welds including non destructive testing are to be in accordance with TL- R W1.

G1.10.3 For membrane tanks, quality assurance measures, weld procedure qualification, design details, materials, construction, inspection and production testing of components are to be to standards developed during the prototype testing programme.

G1.10.4 For semi-membrane tanks the relevant requirements for independent tanks or for membrane tanks are to be applied as appropriate.

G1.10.5 Integral tanks are to be hydrostatically or hydropneumatically tested in accordance with TL Rules. The test is in general to be performed so that the stresses approximate, as far as practicable, the design stresses and so that the pressure at the top of the tank corresponds at least to the MARVS.

G1.10.6 For ships fitted with membrane or semi-membrane tanks, cofferdams and all spaces which may normally contain liquid and are adjacent to the hull structure supporting the membrane are to be hydrostatically or hydropneumatically tested in accordance with the requirements of TL. Pipe tunnels and other compartments which do not normally contain liquid are not required to be hydrostatically tested.
In addition, the ship hold structure supporting the membrane is to be given a tightness testing.

G1.10.7 Each independent tank is to be subjected to a hydrostatic or hydropneumatic test. For tanks type A, this test is to be performed so that the stresses approximate, as far as practicable, the design stresses and so that the pressure at the top of the tank corresponds at least to the MARVS. When the hydropneumatic test is performed, the conditions are to simulate, as far as possible, the actual loading of the tank and of its supports. For tanks type B, the test is to be performed as for tanks type A. Moreover, the maximum primary membrane stress or maximum bending stress in a primary membrane under test conditions is not to exceed 90% of the yield strength of the material (as fabricated) as the test temperature. To ensure that this condition is satisfied, when calculations indicate that stress exceeds 75% of the yield strength, the prototype test is to be monitored by the use of strain gauges or other suitable equipment. For tanks type C, see G2.

G1.10.8 All tanks are to be subjected to a tightness testing which may be performed in combination with the pressure test mentioned above or separately.

G1.10.9 Requirements with respect to inspection of the secondary barrier will be decided in each separate case.
G1.10.10 On ships using independent tanks type B, at least one tank and its support is to be instrumented to confirm stress levels unless the design and arrangement for the size of the ship involved are supported by full scale experience. Similar instrumentation may be required

by TL for independent tanks type C dependent on their configuration and on the arrangement of their supports and attachments.

G1.10.11 The ship is to be surveyed during the initial cool-down, loading and discharging of the cargo to verify the overall performance of the containment system for compliance with the design parameters. Records on performance of the components and equipment essential to verify the design parameters are to be maintained and these records are to be available to TL.

G1.10.12 Heating arrangements, if fitted in accordance with G1.8.4, are to be tested for compliance with the design requirements.

G1.10.13 Inspection of the hull for cold spots is to be performed following the first loaded voyage.

APPENDIX 1

Guidance formulae for acceleration components

In pursuance of G1.3.4, the following formulae are given as guidance for the components of acceleration due to ship's motions in the case of ships with L< 50 m. These formulae correspond to a probability level of 10^{-8} in the North Atlantic.

vertical acceleration

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

transverse acceleration

$$a_y = \pm a_0 \sqrt{0{,}6 + 2{,}5\left(\frac{x}{L} - 0{,}05\right)^2 + K\left(1 + 0{,}6K\frac{z}{B}\right)^2}$$

longitudinal acceleration

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

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

where

L	=	length of ship between perpendiculars (m)
C_B	=	block coefficient
B	=	greatest moulded breadth (m)
x	=	longitudinal distance (m) from amidship to centre of gravity of the tank with content, *x* is positive forward of amidship, negative aft of amidship
z	=	vertical distance (m) from the ship's actual waterline to the centre of gravity of tank with content, *z* is positive above and negative below the waterline

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

V	=	service speed (knots).

Generally, *K*= 1,0. For particular loading conditions and hull forms, determination of *K* according to the formulae below may be necessary.

$$K = \frac{13G_M}{B}$$

$$K \geq 1,0$$

where G_M= metacentric height (m).

a_x, a_y and a_z are the maximum dimensionless (i.e. relative to the acceleration of gravity) accelerations in the respective directions and they are considered as acting separately for calculation purposes.
a_z does not include the component of the static weight.
a_y includes the component of the static weight in the transverse direction due to rolling.
a_x includes the component of the static weight in the longitudinal direction due to pitching.

TL- R G2 Liquefied gas cargo tanks and process pressure vessels

G2.1 General

G2.1.1 The present texts give the general principles which are applied by TL for approval and survey of the relevant items of liquefied gas tankers for classification purpose. They do not intend to cover full details of such approval and survey procedures which are to be found in TL Rules.

G2.1.2 Where appropriate, these Rules refer to the basic tank types which are defined under 4.1 of IMO Resolution MSC.370(93) Amendments to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). Tanks differing from these definitions will be the subject of special consideration.

G2.1.3 Consideration of future technical advances may warrant modifications to the principles and details set forth in the text. TL will accordingly review continuously these requirements.

G2.2 Scope

The requirements here below apply to independent cargo tanks type C (pressure cargo tanks) such as defined in 4.23 of the IGC Code. They may also apply to process pressure vessels if required by TL. The words 'pressure vessels' are used in this text to cover the two above-mentioned categories. These requirements apply to tanks and vessels made of materials defined in TL- R W1.

Note:

1. This requirement is implemented by for independent cargo tanks type C (pressure cargo tanks) such as defined in 4.23 of the IGC Code:

    i) when an application for certification is dated on or after 1 January 2020; and

    ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2020.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to TL- PR 29.

G2.3 Calculation of thickness under internal pressure

G2.3.1 General

For pressure vessels, the thickness calculated according to 4.23.2.4 of the IGC Code shall be considered as a minimum thickness after forming, without any negative tolerance.

Scantlings based on internal pressure shall be calculated as follows: the thickness and form of pressure containing parts of pressure vessels under internal pressure, including flanges, are to be determined according to TL Rules. These calculations are to be based in all cases on generally accepted pressure vessel design theory. Openings in pressure containing parts of pressure vessels are to be reinforced in accordance with TL Rules.

G2.3.2 Design pressure

For calculation according to G2.3.1, the design liquid pressure defined under 4.13.2 of the IGC Code is to be taken into account in the internal pressure calculations.

G2.3.3 Efficiency factor for welded joints

The welded joint efficiency factor to be used in calculation according to G2.3.1 is to be 0.95 when the inspection and nondestructive examination stated under G2.9.2 (i) are carried out.

This figure may be increased up to 1.0 taking into account other considerations, such as materials used, type of joints, welding procedure, type of loading, etc. For process pressure vessels, TL may accept partial nondestructive examinations, but not less than those under G2.9.2 (ii) may be allowed depending on the material used, the design temperature, the nil ductility temperature of the material as fabricated, the type of joint, welding procedure, etc., but in this case the efficiency factor 0.85 is to be adopted.

For special materials, the above mentioned factors are to be reduced depending on the specified mechanical properties of the welded joint.

G2.3.4 Maximum allowable stress

The maximum allowable stresses to be used in calculation according to G2.3.1 shall not exceed the value defined in 4.23.3.1 of the IGC Code.

G2.3.5 Corrosion allowance

Corrosion allowance need not be required in addition to the thickness resulting from the structural analysis. However, where there is no environmental control, such as inerting around the cargo tank, or where the cargo is of a corrosive nature, TL require a suitable corrosion allowance.

G2.3.6 Minimum thickness of shell and heads

The thickness, including corrosion allowance, after forming of any shell and head is not to be less than 5mm for C-Mn steels and Ni steels, 3 mm for austenitic steel or 7 mm for aluminium alloy.

G2.4 Buckling criteria

G2.4.1 General

Buckling criteria shall be as follows: the thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses are to be calculated according to TL Rules. These calculations in all cases are to be based on generally accepted pressure vessel buckling theory and are to adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

G2.4.2 Design external pressure

The design external pressure Pe to be used for verifying the buckling of the pressure vessels is given by the following formula:

$$Pe = P_1 + P_2 + P_3 + P_4 \text{ (MPa)}$$

Where

P_1 = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves, $P1$ is to be specially considered, but is, in general, not to be taken less than 0.025 MPa.

P_2 = for pressure vessels or parts of pressure vessels in completely closed spaces: the set pressure of the pressure relief valves for these spaces.
Elsewhere P_2 = 0.

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

P_4 = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks.
Elsewhere P_4 = 0.

G2.5 Stress analysis in respect of static and dynamic loads

G2.5.1 Pressure vessel scantlings are to be determined in accordance with G2.3 and G2.4.

G2.5.2 Calculations of the loads and stresses in way of the supports and the shell attachment of the support are to be made. Loads as applicable, from 4.12 to 4.15 of the IGC Code, are to be used. Stresses in way of the supports are to be according to a recognized standard acceptable to TL.

G2.5.3 Furthermore, when required by TL, secondary stresses and thermal stresses are to be specially considered.

G2.5.4 In special cases, a fatigue analysis may be required by TL.

G2.6 Accident design condition

G2.6.1 The tanks and the tank supporting structures shall be designed for the accidental loads and design conditions specified in 4.3.4.3 and 4.15 of the IGC Code, as applicable.

G2.6.2 When subjected to the accidental loads specified in 4.15 of the IGC Code, the stress shall comply with the acceptance criteria specified in 4.23.3.1 of the IGC Code, modified as appropriate taking into account their lower probability of occurrence.

G2.7 Welding joints details

G2.7.1 All longitudinal and circumferential joints of pressure vessels are to be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds are to be obtained by double welding or by the use of backing rings. If used, backing rings are to be removed except from very small process pressure vessels. Other edge preparations may be permitted depending on the results of the tests carried out at the approval of the welding procedure.

G2.7.2 The bevel preparation of the joints between the pressure vessel body and domes and between domes and relevant fittings are to be designed according to a standard acceptable to TL. All welds connecting nozzles, domes or other penetrations to the vessel and all welds connecting flanges to the vessel or nozzles, are to be full penetration welds.

G2.8 Stress relieving

G2.8.1 For pressure vessels made of carbon and carbon-manganese steel, post-weld heat treatment is to be performed after welding if the design temperature is below -10°C. Post-weld treatment in all other cases and for materials other than those mentioned above shall be to recognized standards acceptable to TL. The soaking temperature and holding time are to be according to the recognized standards acceptable to TL.

G2.8.2 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 if agreed by TL and subject to the conditions of 6.6.2.3 of the IGC Code.

G2.9 Inspection and nondestructive examination

G2.9.1 Manufacture and workmanship

The tolerances relating to manufacture and workmanship (i.e. out-of-roundness, local deviations from the true form, welded joints alignment, tapering of plates having different thicknesses, etc.) are to comply with recognized standards acceptable to TL. The tolerances are also to be related to the buckling analysis (see G2.4).

G2.9.2 Nondestructive examination

The extent of nondestructive testing shall be total or partial according to recognized standards acceptable to TL, but the controls to be carried out shall not be less than the following:

(i) Total nondestructive examination (see G2.3.3)

Radiography
butt welds: 100%
Surface crack detection
all welds: 10%
reinforcement rings around holes, nozzles, etc: 100%

Ultrasonic testing
Ultrasonic testing may be accepted for replacing partially the radiographic examination, if so specially allowed by TL. In addition TL may require a total ultrasonic examination on welding of reinforcement rings and holes, nozzles, etc.

(ii) Partial nondestructive examination (see G2.3.3)

Radiography
butt welds: all welded joints crossing and at least 10% of the full length at selected positions uniformly distributed
Surface crack detection
reinforcement rings around holes, nozzles, etc 100%

Ultrasonic testing
as may be required by TL each instance.

G2.10 Pressure testing

G2.10.1 Each pressure vessel is to be subjected to a hydrostatic test according to TL Rules , at a pressure, measured at the top of the tanks, of not less than 1.5 P_0, In no case during the pressure test is the calculated primary membrane stress at any point to exceed 90% of the yield stress of material (for definition of P_0, see 4.1.2 of the IGC Code). To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the prototype test is to be monitored by the use of strain gauges or other suitable equipment in pressure vessels except simple cylindrical and spherical pressure vessels.

G2.10.2 The temperature of the water used for test is to be at least 30°C above the nil ductility transition temperature of the material as fabricated.

G2.10.3 The pressure is to be held for two hours per 25 mm of thickness but in no case less than two hours.

G2.10.4 Where necessary for cargo pressure vessels, there may be carried out with specific approval of TL, a hydropneumatic test in the conditions prescribed under G2.10.1, G2.10.2 and G2.10.3.

G2.10.5 Special consideration will be given to testing of tanks in which higher allowable stresses are used depending on service temperature. However, the requirements of G2.10.1 are to be fully complied with.

G2.10.6 After completion and assembly, each pressure vessel and relative fittings are to be subjected to an adequate tightness test which may be performed in combination with the pressure testing referred to in G2.10.1.

G2.10.7 Pneumatic testing of pressure vessels other than cargo tanks will be considered on an individual case basis by TL. Such testing will be permitted only for those vessels which are so designed and/or supported that they cannot be safely filled with water, or for those vessels which cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

TL- R G3 Liquefied gas cargo and process piping

G3.1 General

G3.1.1 The present texts give general principles for approval and survey of the relevant items of liquefied gas tankers for classification purposes. They do not intend to cover full details of such approval and survey procedures which are to be found in the rules of TL.

G3.1.2 Consideration of future technical advances may warrant modifications to the principles and details set forth in the text. TL will accordingly review continuously these requirements.

G3.2 Scope

The requirements here below apply to liquefied gas cargo and process piping including cargo gas piping and exhaust lines of safety valves or similar piping.

Note:

1. The requirements of TL- R G3.6 are implemented for piping components and pumps:
   i) when an application for testing is dated on or after 1 January 2017; and
   ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2017.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to TL- PR 29.

G3.3 Scantlings for internal pressure

G3.3.1 General

Subject to the conditions stated in G3.3.4, the wall thickness of pipes is not to be less than that determined from the following formula:

$$t = (t_0 + b + c) \Big/ \left(1 - \frac{a}{100}\right) \quad (1)$$

where t = minimum thickness (mm)

t_0 = theoretical thickness (mm)

$$\left.\begin{array}{l} t_0 = PD/(2Ke + P) \\ \quad \text{when } P \text{ (N/mm}^2\text{)} \\ t_0 = PD/(20Ke + \mathrm{P}) \\ \quad \text{when } P \text{ bar} \end{array}\right\} (2)$$

P = design pressure (N/mm^2 (bar))

D = outside diameter (mm)

K = allowable stress (N/mm^2) (see G3.3.2)

e = efficiency factor

(i) $e = 1$ for seamless pipes and for longitudinally or spirally welded pipes, delivered by manufactures approved for making welded pipes which are considered equivalent to seamless pipes when nondestructive testing on welds is carried out in accordance with the Rules of TL.

(ii) in other cases an efficiency factor of less than 1.0 may be required by TL depending on the manufacturing process.

b = allowance for bending (mm). The value of b is to be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b is to be determined from the following formula:

$$b = \frac{1}{2{,}5} \frac{D}{r} t_0 \qquad (3)$$

with r = mean radius of the bend (mm)

c = corrosion allowance (mm). When corrosion or erosion is expected, an increase in wall thickness of the piping is to be provided over that required by other design requirements.
This allowance is to be consistent with the expected life of the piping.

a = negative manufacturing tolerance for thickness (%).

G3.3.2 Design pressure

(a) The design pressure P in the formula (2) of G3.3.1 is the maximum pressure to which the system may be subjected in service.

(b) The greatest of the following design conditions is to be used for piping, piping systems and components as appropriate:

(i) for vapour piping systems or components which may be separated from their relief valves and which may which contain some liquid, the saturated vapour pressure at 45°C, or higher or lower if agreed upon by TL (see G1.2.5).

(ii) for systems or components which may be separated from their relief valves and which contain only vapour at times, the superheated vapour pressure at 45°C or higher or lower if agreed upon by TL (see G1.2.5), assuming an initial condition of saturated vapour in the system operating pressure and temperature; or

(iii) the MARVS of the cargo tanks and cargo processing systems; or
(iv) the pressure setting or the associated pump or compressor discharge relief valve; or
(v) the maximum total discharge or loading head of the cargo piping system; or
(vi) the relief valve setting on a pipe line system.

(c) The design pressure is not to be less than 1 N/mm^2 (10 bar), except for open-ended lines where it is to be not less than 0,5 N/mm^2 (5 bar).

G3.3.3 Allowable stress

For pipes made of steel including stainless steel, the permissible stress to be considered in the formula (2) of G3.3.1 is the lower of the following values:

σ_B /2,7 or σ_F /1,8 *

where σ_B = specified minimum tensile strength at room temperature (N/mm^2)
σ_F = specified lower minimum yield stress or 0,2% proof at room temperature (N/mm^2).

For pipes made of materials other than steel, the allowable stress is to be specially considered by TL.

G3.3.4 Minimum wall thickness

(a) The minimum thickness is to be in accordance with the Rules of TL.

(b) Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of piping due to superimposed loads from supports, ship deflection or other causes, the wall thickness is to be increased over that required by G3.3.1, or, if this is impracticable or would cause excessive local stresses, these loads are to be reduced, protected against or eliminated by other design methods.

G3.3.5 Flanges, valves, fittings etc.

(a) For selection of flanges, valves, fittings etc., a recognised Standard is to used taking into account the design pressure defined under G3.3.1.

(b) For flanges not complying with a recognised Standard the dimension of flanges and relative bolts are to be to the satisfaction of TL.

* At discretion of TL a safety factor less than 1,8 may be allowed provided a detailed stress analysis according to the method indicated under G3.4 is carried out.

G3.4 Stress analysis

G3.4.1 When design temperature is -110°C or lower, a complete stress analysis, taking into account all the stresses due to weight of pipes (including acceleration if significant), internal pressure, thermal contraction and loads induced by hog and sag of the ship for each branch of the piping system is to be submitted to TL. For temperatures above - 110°C, stress analysis may be required in relation to design or stiffness of the piping system, choice of materials, etc; in any case, consideration is to be given by the designer to thermal stresses, even though calculations are not submitted.

G3.4.2 This analysis is to take into account the various loads such as pressure, weight of piping with insulation and internal medium, loads due to the contraction, for the various operating conditions. The analysis may be carried out according to the Rules of TL or to a recognised code of practice.

G3.5 Materials

G3.5.1 Choice and testing of materials used in piping systems are to comply with TL- R W1 taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of the material of the 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 relaxation may be permitted under the same temperature conditions for open ended piping inside cargo tanks, excluding discharge piping and all piping inside of membrane and semi-membrane tanks.

G3.5.2 Materials having a melting point below 925°C are not to be used for piping systems outside the cargo tanks, except for short lengths attached to the cargo tanks, in which case fire resisting insulation should be provided.

G3.6 Tests of piping components and pumps prior to installation on board

G3.6.1 Valves

G3.6.1.1 Prototype Testing

Each size and type of valve intended to be used at a working temperature below -55°C is to be approved through design assessment and prototype testing. Prototype testing for all valves to the minimum design temperature or lower and to a pressure not lower than the maximum design pressure foreseen for the valves is to be witnessed in the presence of the Society’s representative. Prototype testing is to include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure, and cryogenic testing consisting of valve operation or safety valve set pressure, and leakage verification. In addition, for valves other than safety valves, a seat and stem leakage test at a pressure equal to 1.1 times the design pressure.

For valves intended to be used at a working temperature above -55°C, prototype testing is not required.

G3.6.1.2 Unit Production Testing

All valves are to be tested at the plant of manufacturer in the presence of the Society’s representative. Testing is to include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves, seat and stem leakage test at a pressure equal to

1.1 times the design pressure for valves other than safety valves. In addition, cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55°C. The set pressure of safety valves is to be tested at ambient temperature.

For valves used for isolation of instrumentation in piping not greater than 25mm, unit production testing need not be witnessed by the surveyor. Records of testing are to be available for review.

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

- The valve has been approved as required by 3.6.1.1 for valves intended to be used at a working temperature below -55°C, and

- The manufacturer has a recognized quality system that has been assessed and certified by TL subject to periodic audits, and

- The quality control plan contains a provision to subject each valve to a hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves and seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves. The set pressure of safety valves is to be tested at ambient temperature. The manufacturer is to maintain records of such tests, and

- Cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55°C in the presence of TL's representative.

G3.6.2 Bellows

The following prototype tests are to be performed on each type of expansion bellows intended for use on cargo piping, primarily on those used outside the cargo tank:

- An overpressure test. A type element of the bellows, not precompressed, is to be pressure tested to a pressure not less than five times the design pressure without bursting. The duration of the test is not to be less than 5 minutes.

- A pressure test on a type expansion joint complete with all the accessories (flanges, stays, articulations, etc) at twice the design pressure at the extreme displacement conditions recommended by the Manufacturer. No permanent deformations are allowed.

  Depending on materials it may be required that the test be performed at the minimum design temperature.

- A cycle test (thermal movements). The test is to be performed on a complete expansion joint, which is to successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. Testing at room temperature, when conservative, is permitted.

- A cycle fatigue test (ship deformation): the test is to be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length for at least 2000000 cycles at a frequency not higher than 5 cycles/second. The test is only required when, owing to the piping arrangement, ship deformation loads are actually experienced. The Classification Society may waive performance of the above mentioned tests 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 0,1 N/mm^2 (1 bar) this documentation is to include sufficient test data to substantiate the design method used, with particular reference to correlation between calculation and test results.

G3.6.3 Cargo Pumps

G3.6.3.1 Prototype Testing

Each size and type of pump is to be approved through design assessment and prototype testing. Prototype testing is to be witnessed in the presence of TL's representative. In lieu of prototype testing, satisfactory in-service experience, of an existing pump design approved by TL submitted by the manufacturer may be considered.

Prototype testing is to include hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. In addition, for shaft driven deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the minimum design temperature. The full length of shafting is not required for the spin test, but must be of sufficient length to include at least one bearing and sealing arrangements. After completion of tests, the pump is to be opened out for examination.

G3.6.3.2 Unit Production Testing

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

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

- The pump has been approved as required by 3.6.3.1, and

- The manufacturer has a recognised quality system that has been assessed and certified by TL subject to periodic audits, and

- The quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.

G3.7 Piping fabrication and joining details

G3.7.1 General

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

G3.7.2 Direct connection of pipe lengths (without flanges)

The following types of connections may be considered:

(i) Butt welded joints with complete penetration at the root. For design temperature below -10°C, butt welds are to be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass.
For design pressures in excess of 1 N/mm^2 (10 bar) and design temperatures ≤ -10°C backing rings are to be removed.

(ii) Slip-on welded joints with sleeves and related welding having suitable dimensions in accordance with the rules of TL.

(iii) Screwed couplings in accordance with the rules of TL.
The above mentioned types of connections are allowed dependent upon the diameter of pipes and service, as follows;
joints (i) : all applications
joints (ii) : for open end lines for design temperature down to -55°C for external diameters ≤ 50 mm
joints (iii) : for accessory lines and instrumentation lines with external diameters ≤ 25 mm.

G3.7.3 Flange connections

(a) Flanges are to be of the welding neck, slip-on or socket welding type.

(b) Flanges are to be selected as to type, made and tested in accordance with the Rules of TL. In particular, for all piping (except open end lines) the following restrictions apply:
  (i) For design temperatures < -55°C: only welding neck flanges are to be used.
  (ii) For design temperatures < -10°C: slip-on flanges are not to be used in nominal sizes above 100 mm and socket welding flanges are not to be used in nominal sizes above 50 mm.

G3.7.4 Other types of pipes connections

Acceptance of types of piping connections other than those mentioned in G3.7.2 and G3.7.3 may be considered by TL in each particular case.

G3.7.5 Bellows and expansion joints

(a) If necessary, bellows are to be protected against icing.

(b) Slip joints are not to be used except within the cargo tanks.

G3.7.6 Welding, post-weld heat treatments and nondestructive tests

(a) Welding is to be carried out in accordance with TL- R W1.

(b) Post-weld heat treatments are required for all butt welds of pipes made with carbon-manganese and low alloy steels.
TL may waive the requirement for thermal stress relieving for pipes having a wall thickness less than 10 mm in relation to the design temperature and pressure of the concerned piping system.

(c) In addition to normal procedures before and during the welding and also visual inspection of the finished welds, as necessary for proving that the manufacture has been carried out in a correct way according to the requirements, the following inspections are required:
  (i) 100% radiographic testing of butt welded joints for piping systems with service temperatures lower than -10°C and with inside diameters of more than 75 mm or wall thickness greater than 10 mm.
  (ii) For butt welded joints of pipes not included in (i), spot radiographic controls or other non-destructive controls are to be carried out at the discretion of the Classification Society depending upon service, position and materials. In general at least 10% of butt welded joints of pipe are to be radiographed.

G3.8 Tests onboard

G3.8.1 General

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

G3.8.2 Pressure tests (strength and leak test)

(a) After assembly, all cargo and process piping should be subjected to a hydrostatic test to at least 1,5 times the design pressure. However, when piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard ship. Joints welded on board 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 TL for approval.

(b) After assembly on board each cargo and process piping system is to be subjected to a leak test (by air, halides, etc.) to a pressure depending on the leak detection method applied.

G3.8.3 Functional tests

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