G1 Cargo containment of gas tankers

(1974)
(Rev.1
1979)
(Rev.2
1997)
(Corr.1
Sept 2003)
(Rev.3
June 2016)
(Corr.1
May 2018)

G1.1 General

G1.1.1   The present text gives the general principles which are applied by Classification Societies 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 individual Rules of Classification Societies.

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 UR 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 ~~not~~ 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 the Classification Society 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 the Classification Society.

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Note:

1.   Rev.3 of this UR is to be uniformly implemented by IACS Societies 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 IACS Procedural Requirement (PR) No. 29.

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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 Classification Society 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:

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

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

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 the Classification Society)

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)

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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 the Classification Society 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 the Classification Society 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 the Classification Society are to be made so that the tank or cargo temperature cannot be lowered below the design temperature.

G1.3 Design loads
(1974)
(Rev.1 1979)

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.

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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:

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

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:

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

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

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.

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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 the Classification Society.

(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.

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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.
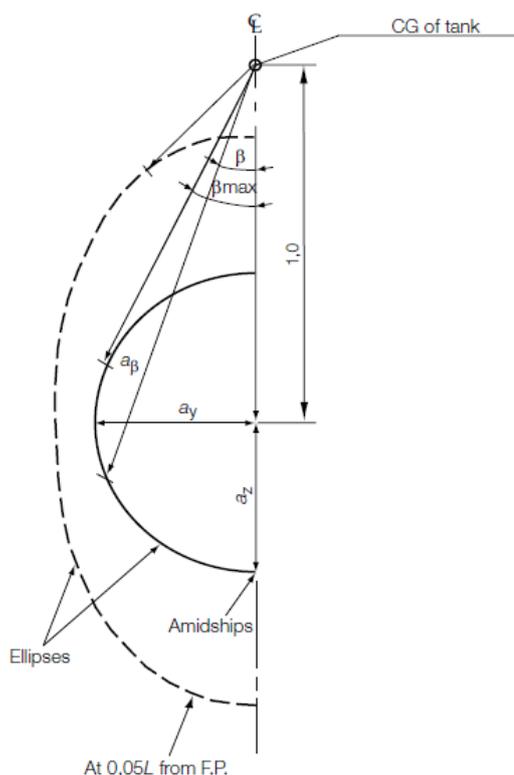
a_β = resulting acceleration (static and dynamic) in arbitrary direction β
a_y = transverse component of acceleration
a_z = vertical component of acceleration
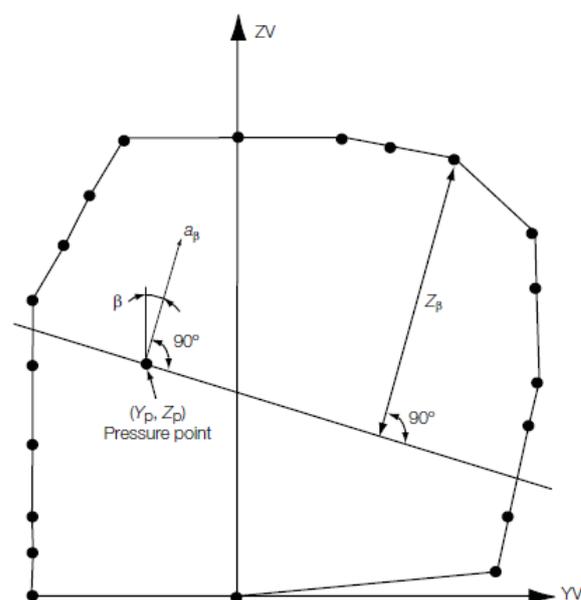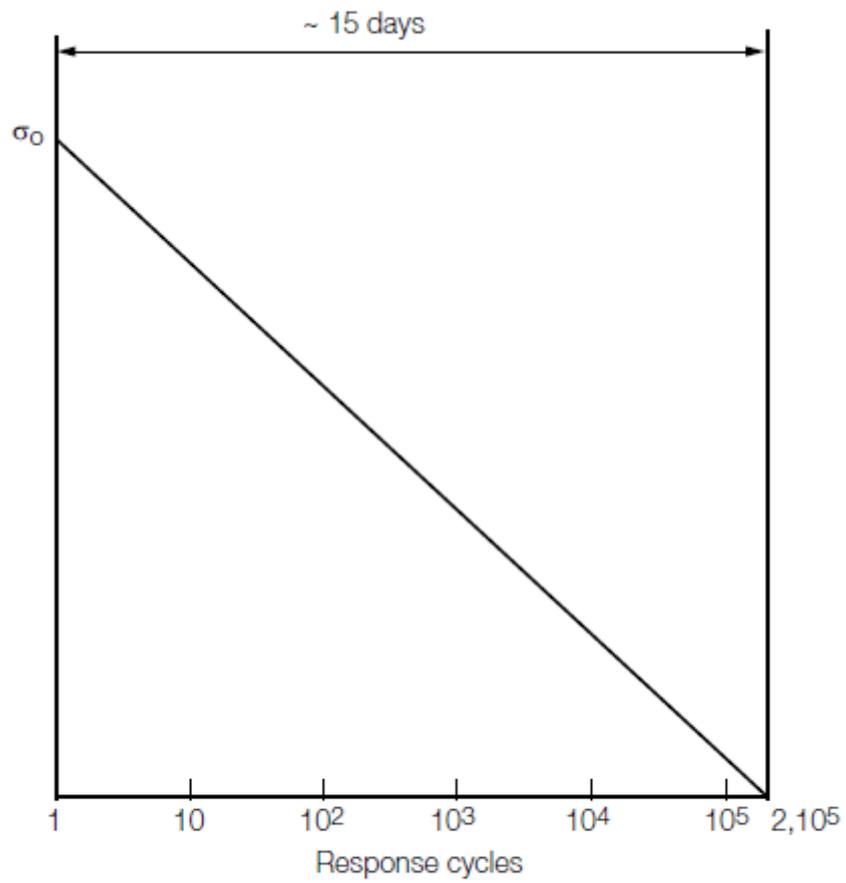
Fig.1 Acceleration ellipse   **Fig.2 Determination of internal pressure heads**

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

Response cycle scale is logarithmic; the value of $2,10^5$ is given as an example of estimate

Fig.3 Simplified load distribution

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G1.4 Structural analysis
(1974)
(Rev. 1 1979)

G1.4.1 Integral tanks

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

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 the Classification Society 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 the Classification Society 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 the Classification Society 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 the Classification Society for deep tanks taking into account the internal pressure as indicated in G1.3.2 and any corrosion allowance required by G1.5.2.

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(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 the Classification Society, 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:

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

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 ≤ 0,5, except that the Classification Society 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.

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G1.5 Allowable stress – corrosion allowance
(1974)
(Rev. 1 1979)

G1.5.1   Allowance stresses

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

(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 $0,75\sigma_F$ or $0,38\sigma_B$ 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 the Classification Society; 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:

$\sigma_m \leq f$

$\sigma_L \leq 1,5f$

$\sigma_b \leq 1,5F$

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

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

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

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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, the Classification Society 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:

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

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

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

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

$\sigma_{x.dyn}$, $\sigma_{xy.dyn}$ and $\tau_{xy.dyn}$ 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

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consideration by the Classification Society, advantage may be taken of enhanced yield stress and tensile strength at low temperature.

(i)   Allowable stresses for materials other than those covered by 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, the Classification Society may require a suitable corrosion allowance.

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

G1.6 Supports
(1974)
(Rev. 1 1979)

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.

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G1.7 Secondary barrier
(1974)
(Rev. 1 1979)

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 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.

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Table 1

Cargo temperature t_b at atmospheric pressure	t_b > –55°C	–10°C < t_b ≥ –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 the Classification Society 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 the Classification Society. Procedures for the periodic checking of the secondary barrier during the life of the ship are to be submitted to the Classification Society as a condition of the approval of the cargo containment system.

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G1.8 Insulation
(1974)
(Rev. 1 1979)

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 the Classification Society 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 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 the Classification Society.

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.

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G1.9 Materials
(1974)
(Rev. 1 1979)

G1.9.1   The shell and deck plating of the ship, and all stiffeners attached thereto, are to be in accordance with the Rules of the Classification Society 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 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 W1.

G1.9.3   Material used in the construction of cargo tanks are to be in accordance with Tables 1, 2, or 3 of 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 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 the Classification Society.

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.

G1
(cont)

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
(1974)
(Rev. 1 1979)

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, the Classification Society 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 the Classification Society. Inspection of welds including non destructive testing are to be in accordance with 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 the Rules of the Classification Society. 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 the Classification Society. 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

G1
(cont)

by the Classification Society 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 the Classification Society.

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.

G1
(cont)

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

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.

G1
(cont)

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

$$K \geq 1,0$$

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.

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