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RULES

FOR MEMBRANE CONTAINMENT SYSTEM FOR LIQUEFIED NATURAL GAS

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RULES FOR MEMBRANE CONTAINMENT SYSTEM FOR LIQUEFIED NATURAL GAS

Rules for Membrane Containment System for Liquefied Natural Gas by Russian Maritime Register of Shipping have been approved in accordance with the established approval procedure and come into force on 1 July 2022.

The procedural requirements, unified requirements, unified interpretations and recommendations of the International Association of Classification Societies (IACS) and the relevant resolutions of the International Maritime Organization (IMO) have been taken into consideration.

Rules are published in electronic format in English and Russian. In case of discrepancies between the Russian and English versions, the English version shall prevail.

REVISION HISTORY
(purely editorial amendments are not included in the Revision History)

For this version, there are no amendments to be included in the Revision History.

1 GENERAL

1.1 SCOPE

1.1.1   The Rules for Membrane Containment System for Liquefied Natural Gas[1] apply to membrane cargo containment systems fitted on ships assigned distinguishing marks **Gas carrier type 2G** or **LNG bunkering ship** carrying liquefied natural gas (LNG) as cargo.

1.1.2   Ships for which these Rules are not applicable shall comply with RS rules: Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk, Part IV "Cargo Containment".

1.1.3   The purpose of these Rules is to ensure the safe containment of cargo under all design and operating conditions having regard to the nature of the cargo carried. This will include measures to:

provide strength to withstand defined loads;

maintain the cargo in a liquid state;

design for or protect the hull structure from low temperature exposure;

prevent the ingress of water or air into the cargo containment system.

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[1]   Hereinafter referred to as "these Rules".

1.2 DEFINITIONS

For the purpose of these Rules, the following definitions have been adopted.

1.2.1 A c o l d s p o t is a part of the hull or thermal insulation surface where a localized temperature decrease occurs with respect to the allowable minimum temperature of the hull or of its adjacent hull structure, or to design capabilities of cargo pressure/temperature control systems required in Chapter 7 of the IGC Code (refer to 1.2.4).

1.2.2 D e s i g n v a p o u r p r e s s u r e P_0 is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

1.2.3 D e s i g n t e m p e r a t u r e f o r s e l e c t i o n o f m a t e r i a l s is the minimum temperature at which cargo may be loaded or transported in the cargo tanks.

1.2.4 T h e I G C C o d e is the International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, adopted by resolution MSC.5(48), and mandatory under SOLAS chapter VII.

1.2.5 M A R V S is the maximum allowable relief valve setting of a cargo tank (gauge pressure).

1.2.6 M e m b r a n e t a n k s are non-self-supporting tanks that consist of a thin liquid and gastight layer (membrane) supported through insulation by the adjacent hull structure. Membrane tanks are covered in Section 24.

1.2.7 For membrane tanks, the supports are provided by all elements holding the containment system such as any local supporting devices connecting to the ship inner hull as small pillars or similar elements in insulation boxes.

1.2.8 In addition to the definitions given in Chapter 1 of the IGC Code, the definitions given in these Rules shall apply.

2 APPLICATION

2.1 GENERAL

2.1.1   Unless otherwise specified in Section 24, the requirements of Sections 3 — 21 shall apply to membrane tanks, including those covered in Section 22.

3 FUNCTIONAL REQUIREMENTS

3.1 GENERAL

3.1.1 The design life of the cargo containment system shall not be less than the design life of the ship.

3.1.2 Cargo containment systems shall be designed for North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. Lesser environmental conditions, consistent with the expected usage, may be accepted by the Register (RS) for cargo containment systems used exclusively for restricted navigation. Greater environmental conditions may be required for cargo containment systems operated in conditions more severe than the North Atlantic environment.

3.1.3 Cargo containment systems shall be designed with suitable safety margins:

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

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

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

3.1.4 There are three main categories of design conditions:

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

internal pressure;

external pressure;

dynamic loads due to the motion of the ship;

thermal loads;

sloshing loads;

loads corresponding to ship deflections;

tank and cargo weight with the corresponding reaction in way of supports;

insulation weight;

loads in way of towers and other attachments; and

test loads;

.2 fatigue design conditions — the cargo containment system structure and its structural components shall not fail under accumulated cyclic loading;

.3 accident design condition:

the cargo containment system shall meet the following criteria.

Collision: the cargo containment system shall be protectively located in accordance with 2.4.1 of the IGC Code and withstand the collision loads specified in 15.2 without deformation of the supports, or the tank structure in way of the supports, likely to endanger the tank structure.

Fire: the cargo containment systems shall sustain, without rupture, the rise in internal pressure specified in 8.4.1 of the IGC Code under the fire scenarios envisaged therein.

Unfavourable static heel scenario: the cargo containment systems shall sustain, without rupture, a static angle within the range 0° to 30°.

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

3.1.6   An inspection/survey plan for the cargo containment system shall be approved by RS. The inspection/survey plan shall identify areas that need inspection during surveys throughout the cargo containment system's life and, in particular, all necessary in-service survey and maintenance that was assumed when selecting cargo containment system design parameters. Cargo containment systems shall be designed, constructed and equipped to provide adequate means of access to areas that need inspection as specified in the inspection/survey plan. Cargo containment systems, including all associated internal equipment, shall be designed and built to ensure safety during operations, inspection and maintenance (refer to 3.5 of the IGC Code).

4 CARGO CONTAINMENT SAFETY PRINCIPLES

4.1 GENERAL

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

4.1.2　　However, the size and configuration or arrangement of the secondary barrier may be reduced where an equivalent level of safety is demonstrated in accordance with the requirements of 4.1.3, as applicable.

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

failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) shall have a sufficiently long development time for remedial actions to be taken; and

failure developments that cannot be safely detected before reaching a critical state shall have a predicted development time that is much longer than the expected lifetime of the tank.

5 SECONDARY BARRIERS

5.1 GENERAL

5.1.1   A complete secondary barrier shall be provided.

6 DESIGN OF SECONDARY BARRIERS

6.1 GENERAL

6.1.1 The extent of the secondary barrier shall not be less than that necessary to protect the hull structures in unfavorable static heel scenario as described in 3.1.4 (refer to Fig. 6.1.1).
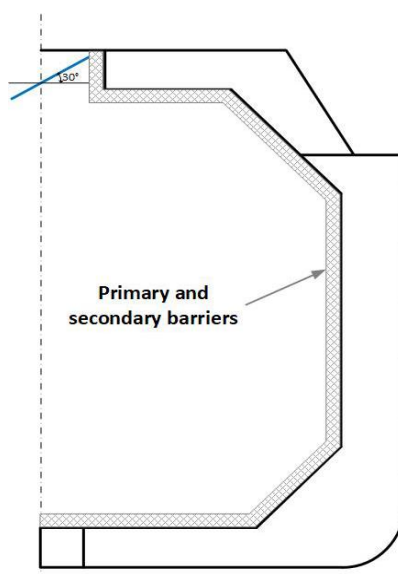

Fig. 6.1.1
Secondary barrier extension

N o t e . The "liquid level" given in Fig. 6.1.1 is considered at the maximum allowable filling level in the cargo tank

6.1.2 The design of the secondary barrier shall be such that:
.1 it is capable of containing any envisaged leakage of liquid cargo for a period of 15 days, unless different criteria apply for particular voyages, taking into account the load spectrum referred to in 18.3.6.
.2 physical, mechanical, or operational events within the cargo tank that could cause failure of the primary barrier shall not impair the due function of the secondary barrier, or vice versa;
.3 failure of a support or an attachment to the hull structure will not lead to loss of liquid tightness of both the primary and secondary barriers;
.4 it is capable of being periodically checked for its effectiveness by means acceptable to RS. This may be by means of a visual inspection or a pressure/vacuum test or other suitable means carried out according to a documented procedure agreed with RS. Requirements for tightness tests of secondary barriers are detailed in 20.4.4.
.5 the methods required in 6.1.2.4 shall be approved by RS and shall include, where applicable to the test procedure:
details on the size of defect acceptable and the location within the secondary barrier, before its liquid-tight effectiveness is compromised;
accuracy and range of values of the proposed method for detecting defects in 6.1.2.1;

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

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

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

7 PRIMARY BARRIER SMALL LEAK PROTECTION SYSTEM

7.1 GENERAL

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

8 SUPPORTING ARRANGMENT

8.1 GENERAL

8.1.1   The cargo tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in Sections 12 — 15, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

8.1.2   The supporting arrangements shall withstand the loads defined in 13.9 and Section 15, but these loads need not be combined with each other or with wave-induced loads.

9 ASSOCIATED STRUCTURE AND EQUIPMENT

9.1 GENERAL

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

10 THERMAL INSULATION

10.1 GENERAL

10.1.1   Thermal insulation shall be provided, as required, to protect the hull from temperatures below those allowable (refer to 19.2) and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in Chapter 7 of the IGC Code.

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

11 DESIGN LOADS

11.1 GENERAL

11.1.1 This Section defines the design loads to be considered with regard to the requirements in .

This includes:

load categories (permanent, functional, environmental and accidental) and the description of the loads;

the extent to which these loads shall be considered depending on the type of tank, and is more fully detailed in the following paragraphs; and

tanks, together with their supporting structure and other fixtures, that shall be designed taking into account relevant combinations of the loads described below.

12 PERMANENT LOADS

12.1 GRAVITY LOADS

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

12.2 PERMANENT EXTERNAL LOADS

12.2.1　　Gravity loads of structures and equipment acting externally on the tank shall be considered.

13 FUNCTIONAL LOADS

13.1 SCOPE

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

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

13.2 INTERNAL PRESSURE

13.2.1   Internal pressure should be calculated taking into account the following.

13.2.1.1   In all cases, including those specified in 13.2.1.2, P_0 shall not be less than MARVS (refer to 1.2.5).

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

lower values of ambient temperature may be accepted by RS for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required; and

for ships on voyages of restricted duration, P_0 may be calculated based on the actual pressure rise during the voyage, and account may be taken of any thermal insulation of the tank.

13.2.1.3   Subject to special consideration by RS and to the limitations given in Section 24, a vapour pressure P_h higher than P_0 may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced. Any relief valve setting resulting from this paragraph shall be recorded in the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

13.2.1.4   Where the vapour pressure in harbour conditions is greater than P_0, defined in 1.2.2, this value shall be specified in the operating instructions for the ship's Master.

13.2.1.5   The internal pressure P_{eq} results from the vapour pressure P_0 or P_h plus the maximum associated dynamic liquid pressure P_{gd}, but not including the effects of liquid sloshing loads. Guidance formulae for associated dynamic liquid pressure P_{gd} are given in 1.1 of Appendix 1.

13.2.1.6   The internal pressures to be considered for membrane tanks are defined in Section 2 of Appendix 1.

13.3 EXTERNAL PRESSURE

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

13.4 THERMALLY INDUCED LOADS

13.4.1   Transient thermally induced loads during cooling down periods shall be considered.

Stationary thermally induced loads shall be considered for cargo containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses.

13.4.2   For normal service, the upper ambient design temperature shall be:

sea: 32°C

air: 45°C.

For service in particularly hot or cold zones, these ambient design temperatures shall be increased or decreased, to the satisfaction of RS. The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere.

13.5 VIBRATION

13.5.1   The potentially damaging effects of vibration on the cargo containment system shall be considered.

13.6 INTERACTION LOADS

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

13.7 LOADS ASSOCIATED WITH CONSTRUCTION AND INSTALLATION

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

13.8 TEST LOADS

13.8.1   Account shall be taken of the loads corresponding to the testing of the cargo containment system referred to in 24.9.

13.9 STATIC HEEL LOADS

13.9.1   Loads corresponding to the most unfavourable static heel angle within the range 0° to 30° shall be considered. Guidance for calculation of static pressure for 30° heel angle is given in <u>Section 3 of Appendix 1</u>.

13.10 OTHER LOADS

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

14 ENVIRONMENTAL LOADS

14.1 SCOPE

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

14.2 LOADS DUE TO SHIP MOTION

14.2.1   The determination of dynamic loads shall take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading.

14.2.2   The ship's motion shall include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks shall be estimated at their centre of gravity and include the following components:

vertical acceleration: motion accelerations of heave, pitch and, possibly, roll (normal to the ship base);

transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll; and

longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

14.2.2   Methods to predict accelerations due to ship motion shall be approved by RS.

14.2.3   Guidance formulae for acceleration components are given in 1.2 of Appendix 1.

14.2.4   Ships for restricted service may be given special consideration.

14.3 DYNAMIC INTERACTION LOADS

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

14.4 SLOSHING LOADS

14.4.1   The sloshing loads on a cargo containment system and internal components shall be evaluated based on allowable filling levels.

When significant sloshing-induced loads are expected to be present, special tests and calculations shall be required covering the full range of intended filling levels.

14.4.2   Methodology to determine dynamic design sloshing loads on the boundaries of a membrane cargo tank at its partial filling due to the sloshing effects for all its operational filling levels shall comply with the following minimum functional requirements.

14.4.2.1   The methodology shall contain the following input data on source specifications describing the operation during the whole ship's design life, including:

the ship's main particulars including the ship lines;

the geometry of cargo tanks at the primary barrier level, the arrangement of cargo containments over the full breadth and length;

the following density and kinematic viscosity values of LNG, at −163 °C to be considered:

LNG density is equal to 470 kg/m^3;

LNG kinematic viscosity is equal to 0,2857 m^2/s;

the operational filling levels:

standard filling levels correspond to:

0 — 10 % *H*, and

70 % *H* to 98 % *V*;

partial filling levels correspond to:

10 % — 70 % *H,* where *H* — maximum height of the tank, in m, taken at the primary barrier level. If the cargo containment design does not comply with or is not checked against the partial filling levels, the partial filling levels are not allowed; this restriction of the ship operation shall be traced on ship certificate;

the ship speed and distribution law of heading;

the characteristics of ship's loading conditions (the center of gravity and center of buoyancy position, metacentric height as per the trim and stability booklet) and the corresponding roll radius of gyration for each loading condition;

statistics on irregular sea parameters (the provisions of IACS recommendation No. 34 shall be met): the environmental data for sloshing analysis shall refer to North Atlantic route with significant wave height envelope fitted to 40-year return period. North Atlantic trade route conditions are defined by Standard Wave Data (IACS Rec. No. 34);

for ice class notations, the design speed for ice condition operations shall be provided.

14.4.2.2   In general, the loads shall be determined for all the cargo tanks where the partial filling is provided. In case of the available tanks identical in terms of geometrical features, it is allowed to determine the loads for those tanks where the maximum sloshing loads are expected. In addition, the methodology shall contain substantiation for the tanks selected for calculation regarding:

geometrical features and shapes of the tanks;

tank position.

14.4.2.3   Mandatory seakeeping analysis.

A mandatory seakeeping analysis taking into account the coupling between the ship motions and the internal liquid motions within the cargo tanks shall be carried out. The calculated ship motions (6 degrees of freedom) are directly used for sloshing model tests. Methodology shall contain the ship's rolling calculations. As a result of the calculation, the characteristics of oscillating movements shall be obtained for all types of rolling at irregular seas applicable to all selected operating conditions (amplitude versus frequency response characteristics or implementation on a time scale). During the rolling calculation, the methods

may be applied based on the three-dimensional potential theory and other pitching and rolling calculation methods agreed with RS.

The input data for this seakeeping analysis are as follows:

ship lines (refer to 14.4.2.1);

ship's loading conditions and the corresponding roll radius of gyration (refer to 14.4.2.1);

LNG cargo tanks arrangement and geometry (refer to 14.4.2.1);

operational filling levels (refer to 14.4.2.1);

environmental conditions including ice condition operations (refer to 14.4.2.1).

The output of the seakeeping analysis are the ship's motions time series (6 degrees of freedom) for the sloshing model tests.

14.4.2.4 Mandatory sloshing model test.

Methodology shall contain the results of model sloshing tests in design cargo tanks. The design sloshing loads acting on the boundaries of the membrane cargo tanks shall be determined by the mandatory sloshing model tests. These design sloshing loads shall be determined for all the cargo tanks and for all operational filling levels.

The sloshing model test program shall comply with the following minimum requirements:

all assumptions used during model tests shall be specified;

the description of the used test bench and equipment used for measuring and processing the measurement results shall be provided for approval to RS;

the justification for the value of scaling load factor shall be provided;

the irregular time histories shall be considered for the ship's motions, the ship's oscillating movement at irregular seas shall be modelled (ship's motion characteristics can shall be scaled in the model test based on the Froude similarity criterion);

the duration of each model test and scope of parameters characterizing each test shall be agreed by RS.

The sloshing model test report shall include description of statistical analysis of model test results. The long-term approach shall be considered for the evaluation of the design sloshing loads. The description of statistical methods for the derivation of short-term as well as long-term sloshing loads distribution that is required to determine the maximum design loads on the boundaries of the cargo tanks shall be provided.

14.4.2.5 Sister ships.

When determining the maximum design loads, the results of model tests performed for sister ships with similar main dimensions and geometrical features of cargo tanks may be used provided the RS agreement. Feasible use of the results of earlier tests shall be justified considering the review of the compliance degree of, at least, the following characteristics:

the selected initial technical data;

the selected design cargo tanks;

the rolling and pitching seakeeping analysis results and a comparison of the initial and the target ship global accelerations results;

the main assumptions used during model tests.

As mentioned in 21.1.3, Guidance for calculation of the sloshing pressure and the corresponding areas to be checked for the ship structure supporting the membrane tanks is given in 2.2 of Appendix 1.

14.5 SNOW AND ICE LOADS

14.5.1   Snow and icing shall be considered, if relevant.

14.6 LOADS DUE TO NAVIGATION IN ICE

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

15 ACCIDENTAL LOADS

15.1 SCOPE

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

15.2 COLLISION LOADS

15.2.1   The collision load shall be determined based on the cargo containment system under fully loaded condition with an inertial force corresponding to 0,5 *g* in the forward direction and 0,25 *g* in the aft direction, where *g* is gravitational acceleration.

15.2.2   The dynamic pressure, P_W in kN/m², resulting from collision loads is the following:

$$P_W = \rho_l a_x |x - x_B|, \qquad\qquad (15.2.2\text{-}1)$$

where ρ_l –   maximum cargo density, in kg/m³, at the design temperature;
x –   X co-ordinate, in m, at the point considered.

For the case of forward acceleration:
longitudinal acceleration, in m/s², equal to

$$a_x = 0,5g, \qquad\qquad (15.2.2\text{-}1)$$

x_B — *X* co-ordinate, in m, of aft bulkhead of the tank.

For the case of aftward acceleration:
longitudinal acceleration, in m/s², equal to

$$a_x = 0,25g, \qquad\qquad (15.2.2\text{-}2)$$

x_B — *X* co-ordinate, in m, of fore bulkhead of the tank.

16 STRUCTURAL INTEGRITY

16.1 GENERAL

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

16.1.2   The structural integrity of cargo containment systems shall be demonstrated by compliance with Section 24.

16.1.3   The structural integrity of cargo containment system types that are of novel design and differ significantly from those covered by Section 24 shall be demonstrated by compliance with Section 24 to ensure that the overall level of safety provided in this Rules is maintained.

17 STRUCTURAL ANALYSES

17.1 ANALYSES

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

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

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

17.2 LOAD SCENARIOS

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

17.2.2   The most unfavourable scenarios for all relevant phases during construction, handling, testing and in service, and conditions shall be considered.

17.3 TOTAL STRESS

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

$$\sigma_x = \sigma_{x,st} \pm \sqrt{\Sigma\left(\sigma_{x,dyn}\right)^2}, \qquad\qquad\qquad (17.3.1\text{-}1)$$

$$\sigma_y = \sigma_{y,st} \pm \sqrt{\Sigma\left(\sigma_{y,dyn}\right)^2}, \qquad\qquad\qquad (17.3.1\text{-}2)$$

$$\sigma_z = \sigma_{z,st} \pm \sqrt{\Sigma\left(\sigma_{z,dyn}\right)^2}, \qquad\qquad\qquad (17.3.1\text{-}3)$$

$$\tau_{xy} = \tau_{xy,st} \pm \sqrt{\Sigma\left(\tau_{xy,dyn}\right)^2}, \qquad\qquad\qquad (17.3.1\text{-}4)$$

$$\tau_{xz} = \tau_{xz,st} \pm \sqrt{\Sigma\left(\tau_{xz,dyn}\right)^2}, \qquad\qquad\qquad (17.3.1\text{-}5)$$

$$\tau_{yz} = \tau_{yz,st} \pm \sqrt{\Sigma\left(\tau_{yz,dyn}\right)^2}, \qquad\qquad\qquad (17.3.1\text{-}6)$$

where $\sigma_{x,st}$, $\sigma_{y,st}$, $\sigma_{z,st}$, $\tau_{xy,st}$, $\tau_{xz,st}$, $\tau_{yz,st}$ are static stresses;

$\sigma_{x,dyn}$, $\sigma_{y,dyn}$, $\sigma_{z,dyn}$, $\tau_{xy,dyn}$, $\tau_{xz,dyn}$, $\tau_{yz,dyn}$ are dynamic stresses, each shall be determined separately from acceleration components and hull strain components due to deflection and torsion.

18 DESIGN CONDITIONS

18.1 SCOPE

18.1.1   All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in 18.2 — 18.4, and the load scenarios are covered by 17.2.

18.2 ULTIMATE DESIGN CONDITIONS

18.2.1 Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by the provisions of these Rules.

18.2.1.1 Plastic deformation and buckling shall be considered.

18.2.1.2 Analysis shall be based on characteristic load values as follows:

Permanent loads: expected values

Functional loads: specified values

Environmental loads: for wave loads: most probable largest load encountered during 10^8 wave encounters.

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

R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

R_m = specified minimum tensile strength at room temperature (N/mm^2).

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

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

18.2.1.4 The equivalent stress σ_c (von Mises, Huber) shall be determined by:

$$\sigma_c = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3\left(\tau_{xz}^2 + \tau_{xy}^2 + \tau_{yz}^2\right)}, \qquad (18.2.1.3)$$

where σ_x – total normal stress in x-direction;

σ_y – total normal stress in y-direction;

σ_z – total normal stress in z-direction;

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

τ_{xz} – total shear stress in x-z plane;

τ_{yz} – total shear stress in y-z plane.

The above values shall be calculated as described in 17.3.

18.2.1.5 Allowable stresses for materials other than those covered by Chapter 6 of the IGC Code shall be subject to approval by RS in each case.

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

18.3 FATIGUE DESIGN CONDITIONS

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

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

$$\sum \frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \le C_w, \tag{18.3.2}$$

where n_i – number of stress cycles at each stress level during the life of the tank;

N_i – number of cycles to fracture for the respective stress level according to the Wöhler (*S — N*) curve;

$n_{Loading}$ – number of loading and unloading cycles during the life of the tank, not to be less than 1000. Loading and unloading cycles include a complete pressure and thermal cycle;

$N_{Loading}$ – number of cycles to fracture for the fatigue loads due to loading and unloading;

C_w – maximum allowable cumulative fatigue damage ratio.

N o t e . 1000 cycles normally corresponds to 20 years of operation.

The fatigue damage shall be based on the design life of the tank but not less than 10^8 wave encounters.

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

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

The *S — N* curves shall be based on a 97,6 % probability of survival corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data up to final failure. Use of *S — N* curves derived in a different way requires adjustments to the acceptable C_w values specified in 18.3.7 — 18.3.9.

18.3.5   Analysis shall be based on characteristic load values as follows:

permanent loads:expected values;

functional loads: specified values or specified history;

environmental loads: expected load history, but not less than 10^8 cycles.

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

18.3.6   Where the size of the secondary barrier is reduced, as is provided for in 4.1.3, fracture mechanics analyses of fatigue crack growth shall be carried out to determine:

crack propagation paths in the structure;

crack growth rate;

the time required for a crack to propagate to cause a leakage from the tank;

the size and shape of through thickness cracks; and

the time required for detectable cracks to reach a critical state.

The fracture mechanics is, in general, based on crack growth data taken as a mean value plus two standard deviations of the test data.

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

Crack propagation analysis under the condition specified in 18.3.7: the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be

obtained as indicated in Fig. 18.3.6. Load distribution and sequence for longer periods, such as in 18.3.8 and 18.3.9 shall be approved by RS.

The arrangements shall comply with 18.3.7 — 18.3.9, as applicable.

Fig. 18.3.6
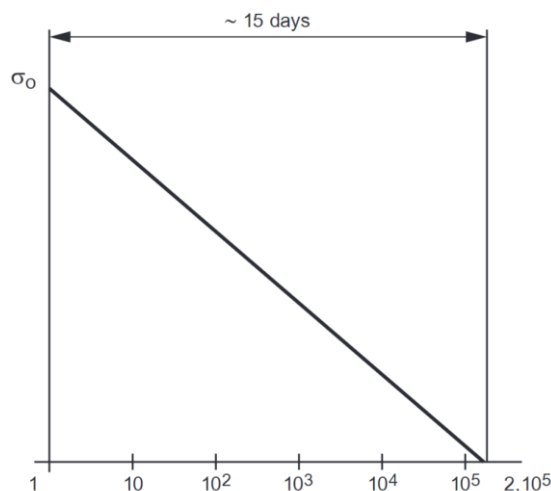Simplified load distribution

N o t e s :   1. σ_o is the most probable maximum stress over the life of the ship.
2. Response cycle scale is logarithmic; the value of $2,10^5$ is given as an example of estimate.

18.3.7   For failures that can be reliably detected by means of leakage detection, C_w shall be less than or equal to 0,5. Predicted remaining failure development time, from the point of detection of leakage till reaching a critical state, shall not be less than 15 days, unless different requirements apply for ships engaged in particular voyages.

18.3.8   For failures that cannot be detected by leakage but that can be reliably detected at the time of in-service inspections, C_w shall be less than or equal to 0,5. Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three times the inspection interval.

18.3.9   In particular locations of the tank, where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria shall be applied as a minimum: C_w shall be less than or equal to 0,1. Predicted failure development time, from the assumed initial defect until reaching a critical state, shall not be less than three times the lifetime of the tank.

18.3.10   At design stage, the fatigue assessment aims to ensure that critical details are adequately designed to reach at least the fatigue life required in 18.3.2. The associated fatigue assessment methodology is based on $S — N$ curve/cumulative damage approach as mentioned in 18.3.1.

Fatigue assessment may be performed either by means of $S — N$ curve/cumulative damage approach at design stage or for life extension for example as stated in 18.3.1 or by means of fracture mechanics analysis for repair decision when cracks are detected as mentioned in 18.3.6 — 18.3.9.

18.3.11   The following structural details shall be checked for fatigue:

.1 singular point of metallic membrane:

knots, i.e. intersections between corrugations;

corrugations or raised edges;

end of corrugations or raised edges;

.2 attachment of primary and secondary barrier on:

the corners (dihedron and trihedron);

the cargo domes;

the pump towers support;

.3 connection of the cargo dome with hull;

.4 cargo dome pipe penetrations;

.5 connection of the pump tower support with double bottom;

.6 structures of the pump tower.

In case of specific arrangement, RS may ask additional fatigue assessments for specific structural details not listed above.

18.3.12   The $S — N$ curves and the fracture mechanics material characteristics shall be validated by RS for minimal temperature that the cargo containment system elements under consideration may reach for the corresponding materials.

18.3.13   For the considered materials, the effects of corrosive environment on fatigue life shall be taken into account by means of:

increase of stress in the considered detail due to thickness decrease induced by corrosion phenomenon;

decrease of fatigue strength.

In general, for stainless steels and for aluminium alloys, no corrosion effect has to be considered for the fatigue strength.

18.3.14   The fatigue phenomenon is normally divided in two different domains:

high stress, low-cycle fatigue occurring for a low number of cycles, less than 10^4, in the range of plastic deformations;

low stress, high-cycle fatigue occurring for a large number of cycles more than 10^4, in the range of elastic deformations.

As required in 18.3.3, the low and high cycles shall be considered for the fatigue life verification.

18.3.15   The fatigue assessment of structural details at design stage shall be performed according to $S — N$ curves approach.

Fatigue assessment shall be performed for structural details in order to prevent all the fatigue failure modes possibly occurring.

The stress assessment methods for each of these fatigue failure modes shall be agreed by RS.

18.3.16   The post welded treatment of joints treated by grinding, TIG dressing or other local means are disregarded for reducing the fatigue damage.

18.3.17   When designing the cold stamping of membrane parts, it is necessary to take into account the permanent plastic deformations arising in the material.

18.4 ACCIDENT DESIGN CONDITION

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

18.4.2 Analysis shall be based on the characteristic load values as follows.

Permanent loads: Expected values.

Functional loads: Specified values.

Environmental loads: Specified values.

Accidental loads: Specified values or expected values.

18.4.3 Loads mentioned in 13.9 and Section 15 need not be combined with each other or with wave-induced loads.

19 MATERIALS

19.1 GENERAL

19.1.1 The purpose of this Section is to ensure that the cargo containment system, the thermal insulation, adjacent ship structure and other materials in the cargo containment system are constructed from materials of suitable properties for the conditions they will experience, both in normal service and in the event of failure of the primary barrier, where applicable.

19.2 MATERIALS FORMING SHIP STRUCTURE

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

.1   the primary barrier of all tanks shall be assumed to be at the cargo temperature;

.2   in addition to 19.2.1.1, where a complete barrier is required, it shall be assumed to be at the cargo temperature at atmospheric pressure for any one tank only;

.3   for worldwide service, ambient temperatures shall be taken as 5 °C for air and 0°C for seawater. Higher values may be accepted for ships operating in restricted areas and, conversely, lower values may be fixed by RS or ships trading to areas where lower temperatures are expected during the winter months. For the temperature calculation performed in view of the selection of steel grade for hull structures adjacent to the cargo containment system but not directly subject to the outside air temperature shall be taken in accordance with the technical documentation submitted in the scope of the ship project review. For ice class ships, the ambient temperature shall not be taken above that specified in the RS requirements;

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

.5   degradation of the thermal insulation properties over the design life of the ship due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations, as defined in 19.4.6 and 19.4.7, shall be assumed;

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

.7   credit for hull heating may be taken in accordance with 19.2.4, provided the heating arrangements are in compliance with 19.2.5;

.8   no credit shall be given for any means of heating, except as described in 19.2.4.

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

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

19.2.2   The shell and deck plating of the ship and all stiffeners attached thereto shall be in accordance with recognized standards. If the calculated temperature of the material in the design condition is below –5 °C due to the influence of the cargo temperature, the material shall be in accordance with Table 6.5 of the IGC Code.

19.2.3   The materials of all other hull structures for which the calculated temperature in the design condition is below 0 °C, due to the influence of cargo temperature and that do not form the secondary barrier, shall also be in accordance with Table 6.5 of the IGC Code. This includes hull structure supporting the cargo tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

19.2.4   Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in Table 6.5 of the IGC Code. In the calculations required in 19.2.1, credit for such heating may be taken in accordance with the following:

.1 for any transverse hull structure;

.2 for longitudinal hull structure referred to in 19.2.2 and 19.2.3 where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of +5 °C for air and 0 °C for seawater with no credit taken in the calculations for heating;

.3 as an alternative to 19.2.4.2, for longitudinal bulkhead between cargo tanks, credit may be taken for heating, provided the material remains suitable for a minimum design temperature of –30 °C, or a temperature 30 °C lower than that determined by 19.2.1 with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with SOLAS regulation II-1/3-1 for both when those bulkhead(s) are considered effective and not.

19.2.5 The means of heating referred to in 19.2.4 shall comply with the following requirements:

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

.2 the heating system shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with 19.2.4.1 shall be supplied from the emergency source of electrical power; and

.3 the design and construction of the heating system shall be included in the approval of the containment system by RS;

4 with reference to application of 19.2.5.1 — 19.2.5.3, the following requirements shall be considered:

where the above requirements are met by duplication of the system components, i.e., heaters, glycol circulation pumps, electrical control panel, auxiliary boilers etc., all electrical components of at least one of the systems shall be supplied from the emergency source of electrical power;

where duplication of the primary source of heat, e.g., oil-fired boiler is not feasible, alternative proposals can be accepted such as an electric heater capable of providing 100 % of the theoretical heat requirement provided and supplied by an individual circuit arranged separately on the emergency switchboard. Other solutions may be considered towards satisfying the requirements of 19.2.5 provided a suitable risk assessment is conducted to the satisfaction of RS. The requirement of the previous paragraph continues to apply to all other electrical components in the system.

19.2.6 Where a hull heating system complying with 19.2.4 is installed, this system shall be contained solely within the cargo area or the drain returns from the hull heating coils in the wing tanks, cofferdams and double bottom shall be led to a degassing tank. The degassing tank shall be located in the cargo area and the vent outlets shall be located in a safe position and fitted with a flame screen.

N o t e . In the case of an indirect heating system applied to the heating of cofferdams, degassing tank is not mandatory.

19.2.7 The RS requirements regarding the satisfactory operation of the heating plant that shall be ascertained during the first full loading and the subsequent first unloading of ships.

19.3 MATERIALS OF PRIMARY AND SECONDARY BARRIERS

19.3.1   Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with Tables 6.1, 6.2 or 6.3 of the IGC Code.

19.3.2   Materials, either non-metallic or metallic but not covered by Tables 6.1, 6.2 and 6.3, used in the primary and secondary barriers may be approved by RS, considering the design loads that they may be subjected to, their properties and their intended use.

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

compatibility with the cargoes;

ageing;

mechanical properties;

thermal expansion and contraction;

abrasion;

cohesion;

resistance to vibrations;

resistance to fire and flame spread;

resistance to fatigue failure and crack propagation.

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

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

19.3.6   Guidance on the use of non-metallic materials in the construction of primary and secondary barriers is provided in Appendix 4 of the IGC Code.

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

19.4 THERMAL INSULATION AND OTHER MATERIALS USED IN CARGO CONTAINMENT SYSTEM

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

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

compatibility with the cargoes;

solubility in the cargo;

absorption of the cargo;

shrinkage;

ageing;

closed cell content;

density;

mechanical properties, to the extent that they are subjected to cargo and other loading effects, thermal expansion and contraction;

abrasion;

cohesion;

thermal conductivity;

resistance to vibrations;

resistance to fire and flame spread;

resistance to fatigue failure and crack propagation.

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

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

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

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

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

19.4.8 The materials for insulation shall be approved by RS.

The approval of bonding materials, sealing materials, lining constituting a vapour barrier or mechanical protection shall be considered by RS on a case-by-case basis. In any event, these materials shall be chemically compatible with the insulation material

19.4.9 Before applying the insulation, the surfaces of the tank structures or of the hull shall be carefully cleaned.

19.4.10 Where applicable, the insulation system shall be suitable to be visually examined at least on one side.

19.4.11   When the insulation is sprayed or foamed, the minimum steel temperature at the time of application shall not be less than the temperature given in the specification of the insulation.

19.5 CERTIFICATION OF MATERIALS AND PRODUCTS

19.5.1   The certification of materials and products used in the cargo containment system shall comply with the general procedures for the certification of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships of Russian Maritime Register of Shipping taking into account the provisions of Table 19.5.1.

This Chapter provides minimum requirements to the certification of materials and components.

In case of materials or products are operated in unusual conditions not covered by this rule, RS may impose additional requirements. Such requirements could cover chemical composition, mechanical properties, testing, etc.

T a b l e 19.5.1
Certification of materials and products

No	Materials and Products	Certification Scheme		Nomenclature code[1]
		RC/TAC/DA	Product Certification C/W	
MEMBRANE CARGO CONTAINMENT SYSTEM WITH FOAM INSULATION IN GENERAL USE				
1	Stainless steel plates	RC	C	17011110
2	Aluminium for reinforcement elements	RC	C	17011120
3	Staples	N/A	W	17011131
4	Inner hull studs, nuts, and washers	N/A	W	17011132
5	Stainless steel studs, nuts, and washers	N/A	W	17011133
6	Expansion rivets	N/A	W	17011134
7	Stainless steel corners prefabricated elements	DA	C	17011135
8	Anchor strips for primary barrier	DA	C	17011136
9	Primary barrier components (e.g. membrane sheets and elements)	DA	C	17011137
10	Plywood	TAC	W	17011211
11	Glass wool	TAC	W	17011221
12	Glass cloth	TAC	W	17011222
14	Low density foam (LDF) panel	TAC	W/C	17011233
13	Reinforced polyurethane foam (R-PUF, HD R-PUF) panel	TAC	C	17011231
15	Load bearing mastic	TAC	W	17011241
16	Insulating panel adhesive	TAC	W	17011242
17	Adhesive for secondary barrier	TAC	W	17011243
18	Paint for inner hull protection	TAC	W	17011251
19	Thermal protection	N/A	W	17011261

[1] In accordance with the Nomenclature of Items of the Register Technical Supervision (Appendix 1 to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

No	Materials and Products	Certification Scheme		Nomenclature code[1]
		RC/TAC/DA	Product Certification C/W	
20	Secondary barrier components (e.g. rigid and flexible material)	TAC	C	17011262
21	Primary block assembly prefabricated elements	DA	C	17011263
22	Flat wall panels prefabricated elements	DA	C	17011264
23	Top bridge pads prefabricated elements	DA	C	17011265
24	Flat joints based on glass wool	N/A	W	17011266
25	Corner panels prefabricated elements	DA	C	17011267
26	Single legs prefabricated elements	N/A	W	17011268
MEMBRANE CARGO CONTAINMENT SYSTEM WITH PLYWOOD BOXES INSULATION IN GENERAL USE				
1	Fe-Ni alloy (36% Nickel) strips	RC	C	17012110
2	Fe-Ni (36% Nickel) welding filler metal	TAC	W	17012120
3	Staples	N/A	W	17012131
4	Collar stud	N/A	W	17012132
5	Self-locked nuts	N/A	W	17012133
6	Spring washers	N/A	W	17012134
7	Wood screws	N/A	W	17012135
8	Coupler base socket	N/A	W	17012136
9	Plywood	TAC	C	17012211
10	Glass wool	TAC	W	17012221
11	Glass cloth	TAC	W	17012222
12	Glass wool (for insulating box)	TAC	W	17012223
13	Reinforced polyurethane foam (R-PUF)	TAC	C	17012231
14	Load bearing mastic	TAC	W	17012241
15	Insulating panel adhesive	TAC	W	17012242
16	Glue	TAC	W	17012243
17	Anti-sticking film	N/A	W	17012251
18	Thermal protection	N/A	W	17012261
19	Insulating material	TAC	W	17012262
20	Insulating boxes prefabricated elements	DA	C	17012263
21	Flat wall panels	DA	C	17012264
22	Plywood cleat	DA	C	17012265
23	Perlite	TAC	W	17012270

N o t e .   Definitions.

R C (R e c o g n i t i o n C e r t i f i c a t e) is an RS document certifying compliance of a manufacturer of materials and/or products complies with the relevant RS Rules.

T A C (T y p e A p p r o v a l C e r t i f i c a t e) is an RS document certifying compliance of materials and/or products with the relevant RS Rules based on the positive results of examination and testing.

D A (D e s i g n A p p r o v a l) , refer to 19.5.2.

C (C e r t i f i c a t e) is an RS document certifying compliance of materials and/or products with the relevant RS Rules.

W (W o r k i n g d o c u m e n t i s s u e d b y t h e m a n u f a c t u r e r) is a document conforming the compliance of materials and/or products with relevant RS Rules.

N / A not applicable.

19.5.2   The design approval (DA) corresponds to a review of technical documentation for a specific unit in compliance with RS requirements and/or the agreed requirements. DA is a step within the classification process which is followed by construction survey activities, as applicable to the concerned ship's part, equipment or component.

20 CONSTRUCTION PROCESSES

20.1 GENERAL

20.1.1   The purpose of this Section is to define suitable construction processes and test procedures in order to ensure, as far as reasonably practical, that the cargo containment system will perform satisfactorily in service in accordance with the assumptions made at the stage design.

20.2 WELD JOINT DESIGN

20.2.1 Where applicable, all the construction processes and testing, except that specified in 20.4, shall be done in accordance with the applicable provisions of Chapter 6 of the IGC Code.

20.3 DESIGN FOR GLUING AND OTHER JOINING PROCESSES

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

20.4 TESTING

20.4.1 All cargo tanks shall be subjected to testing in accordance with 24.9.

20.4.2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 20.4.1.

20.4.3 Requirements with respect to inspection of secondary barriers shall be decided by RS in each case, taking into account the accessibility of the barrier (refer to 6.1.2).

20.4.4 For containment systems with glued secondary barriers:

at the time of construction, a tightness test should be carried out in accordance with approved system designers' procedures and acceptance criteria before and after initial cool down. Low differential pressures tests are not considered an acceptable test;

if the designer's threshold values are exceeded, an investigation shall be carried out and additional testing such as thermographic or acoustic emissions testing should be carried out;

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

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

20.4.5 RS may require that for ships fitted with tanks designed according to Section 22 at least one prototype tank and its supporting structures shall be instrumented with strain gauges or other suitable equipment to confirm stress levels.

20.4.6 The overall performance of the cargo containment system shall be verified for compliance with the design parameters during the first full loading and discharging of the cargo, in accordance with the survey procedure and requirements in 1.4 of the IGC Code, and the RS requirements. Records of the performance of the components and equipment essential to verify the design parameters, shall be maintained and be available to RS.

20.4.7 Heating arrangements, if fitted in accordance with 19.2.4 and 19.2.5, shall be tested for required heat output and heat distribution.

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

20.4.9 If the tests are performed while cargo tanks are filled or partially filled, they are to be performed at the minimum service temperature, as far as practicable.

20.4.10 All operating data and temperatures read during the first voyage of the loaded ship shall be sent to RS.

Attention is drawn to the RS requirements regarding the cold spots examination that shall be carried out on ships carrying liquefied natural gases (LNG) in bulk during the first loaded voyage.

20.4.11 All data and temperatures read during subsequent voyages shall be kept at RS disposal for a suitable period of time.

21 HULL SCANTLINGS

21.1 GENERAL

21.1.1   The hull scantling of the ship shall comply with RS requirements.

21.1.2   Specific allowable hull girder stresses and/or deflections, indicated by the cargo containment Designer, shall be taken into account for the determination of the hull scantlings.

21.1.3   The hull structure, plating and stiffeners, subject to sloshing pressure shall be checked in compliance with RS requirements using the pressures given in 2.2 of Appendix 1.

Areas to be checked for sloshing pressure are defined in 2.2.3 of Appendix 1.

21.1.4   For ordinary stiffeners located below the upper deck level and subject to sloshing loads, cut-outs made in inner hull and cofferdam bulkhead for their passage through the vertical webs shall be closed by collar plates welded to the inner hull or cofferdam bulkhead plating.

Where deemed necessary, adequate reinforcements shall be fitted in the double hull and transverse cofferdams at connection of the cargo containment system to the hull structure. Details of the connection shall be submitted to RS for approval.

22 CARGO CONTAINMENT SYSTEMS OF NOVEL CONFIGURATION

22.1 LIMIT STATE DESIGN FOR NOVEL CONCEPTS

22.1.1 Cargo containment systems that are of a novel configuration that cannot be designed using Section 24 shall be designed using this Chapter and Sections 3 — 5, and also Sections 16 — 20 as applicable. Cargo containment system design according to this section shall be based on the principles of limit state design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed using Section 24.

22.1.2 The limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in 3.1.4. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the requirements.

22.1.3 For each failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states. The limit states are divided into the three following categories:

Ultimate limit states (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain or deformation; under intact (undamaged) conditions.

Fatigue limit states (FLS), which correspond to degradation due to the effect of time varying (cyclic) loading.

Accident limit states (ALS), which concern the ability of the structure to resist accidental situations.

22.1.4 The procedure and relevant design parameters of the limit state design shall comply with the Standards for the Use of limit state methodologies in the design of cargo containment systems of novel configuration (LSD Standard), as set out in Appendix 5 of the IGC Code.

23 STRESS DEFINITIONS

23.1 DEFINITIONS

23.1.1   For the purpose of stress evaluation, stress categories are defined in this Section as follows:

N o r m a l   s t r e s s is the component of stress normal to the plane of reference.

M e m b r a n e   s t r e s s is the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

B e n d i n g   s t r e s s is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

S h e a r   s t r e s s is the component of the stress acting in the plane of reference.

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

P r i m a r y   g e n e r a l   m e m b r a n e   s t r e s s is a primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding.

P r i m a r y   l o c a l   m e m b r a n e   s t r e s s arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress, although it has some characteristics of a secondary stress. A stress region may be considered as local, if:

$$S_1 \leq 0{,}5\sqrt{Rt}, \tag{23.1.1-1}$$

$$S_2 \leq 2{,}5\sqrt{Rt}, \tag{23.1.1-2}$$

where S_1 – distance in the meridional direction over which the equivalent stress exceeds 1,1f;
S_2 – distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded;
R – mean radius of the vessel;
t – wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded;
f – allowable primary general membrane stress.

S e c o n d a r y   s t r e s s is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur.

24 MEMBRANE TANK

24.1 DESIGN BASIS

24.1.1   The design basis for membrane containment systems is that thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.

24.1.2   A systematic approach based on analysis and testing shall be used to demonstrate that the system will provide its intended function in consideration of the events identified in service as specified in 24.2.1.

24.1.3   The design vapour pressure P_o shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value, but less than 0,07 MPa.

24.1.4   The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or where membranes are included or incorporated into the thermal insulation.

24.1.5   The thickness of the membranes shall not normally exceed 10 mm.

24.1.6   The circulation of inert gas throughout the primary insulation space and the secondary insulation space, in accordance with 9.2.1 of the IGC Code, shall be sufficient to allow for effective means of gas detection.

24.2 DESIGN CONSIDERATION

24.2.1   Potential incidents that could lead to loss of fluid tightness over the life of the membranes shall be evaluated. These include, but are not limited to:

.1   Ultimate design events:

tensile failure of membranes;

compressive collapse of thermal insulation;

thermal ageing;

loss of attachment between thermal insulation and hull structure;

loss of attachment of membranes to thermal insulation system;

structural integrity of internal structures and their supporting structures;

failure of the supporting hull structure.

.2   Fatigue design events:

fatigue of membranes including joints and attachments to hull structure;

fatigue cracking of thermal insulation;

fatigue of internal structures and their supporting structures;

fatigue cracking of inner hull leading to ballast water ingress.

.3   Accident design events:

accidental mechanical damage (such as dropped objects inside the tank while in service);

accidental overpressurization of thermal insulation spaces;

accidental vacuum in the tank;

water ingress through the inner hull structure.

Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable.

24.2.2   The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the cargo containment system shall be established during the design development in accordance with 24.1.2.

24.3 LOADS AND LOADS COMBINATIONS

24.3.1　　Particular consideration shall be given to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the cargo tank, the sloshing effects, hull vibration effects, or any combination of these events.

24.4 STRUCTURAL ANALYSIS

24.4.1　Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the cargo containment and associated structures, e.g. structures as defined in Section 9, shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the cargo containment system.

24.4.2　Structural analyses of the hull shall take into account the internal pressure as indicated in 13.2. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

24.4.3　The analyses referred to in 24.4.1 and 24.4.2 shall be based on the particular motions, accelerations and response of ships and cargo containment systems.

24.5 ULTIMATE DESIGN CONDITION

24.5.1   The structural resistance of every critical component, subsystem or assembly shall be established, in accordance with 24.1.2, for in-service conditions.

24.5.2   The choice of strength acceptance criteria for the failure modes of the cargo containment system, its attachments to the hull structure and internal tank structures, shall reflect the consequences associated with the considered mode of failure.

24.5.3   The inner hull scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as indicated in 13.2 and the specified appropriate requirements for sloshing load as defined in 14.4.

24.6 FATIGUE DESIGN CONDITION

24.6.1   Fatigue analysis shall be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.

24.6.2   The fatigue calculations shall be carried out in accordance with 18.3, with relevant requirements depending on:

the significance of the structural components with respect to structural integrity;

availability for inspection.

24.6.3   For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, C_w shall be less than or equal to 0,5.

24.6.4   Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in 18.3.8.

24.6.5   Structural element not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in 18.3.9.

24.7 ACCIDENT DESIGN CONDITION

24.7.1   The containment system and the supporting hull structure shall be designed for the accidental loads specified in Section 15. These loads need not be combined with each other or with environmental loads.

24.7.2   The structure of the tank shall be checked for collision loads using pressure defined in 15.2.

The yielding check of the structural members of transverse bulkhead up to the first adjacent web frame, as shown in Fig. 24.7.2 shall be carried out as follows.

Plating: the net thickness of the plating shall comply with the RS requirements, all the partial safety factors to be taken equal to 1.

Stiffeners: the net section modulus and the net shear sectional area of the stiffeners, including longitudinals, shall comply with the RS requirements, all the partial safety factors to be taken equal to 1.

Primary supporting members: the net section modulus and the net shear sectional area of the primary supporting members shall comply with the RS requirements, all the partial safety factors to be taken equal to 1.
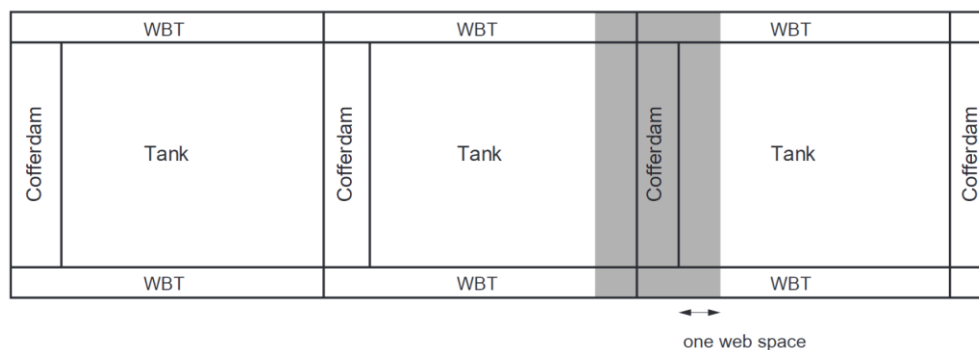

Fig. 24.7.2
Extent for structural assessment for collision condition

24.7.3   Additional relevant accident scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside tanks.

24.8 DESIGN DEVELOPMENT TESTING

24.8.1   The design development testing required in 24.1.2, shall include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. This will culminate in the construction of a prototype-scaled model of the complete cargo containment system. Testing conditions considered in the analytical and physical models shall represent the most extreme service conditions the cargo containment system will be likely to encounter over its life. Proposed acceptance criteria for periodic testing of secondary barriers required in 6.1.2 may be based on the results of testing carried out on the prototype-scaled model.

24.8.2   The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.

24.9 TESTING

24.9.1 All tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.

24.9.2 All hold structures supporting the membrane shall be tested for tightness before installation of the cargo containment system.

24.9.3 Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

24.9.4 The testing of membrane shall comply with the RS requirements.

GUIDANCE FOR PRESSURES AND ACCELERATION CALCULATIONS

1 GUIDANCE FOR THE INTERNAL PRESSURE FOR STATIC DESIGN PURPOSE

1.1 CALCULATION OF DYNAMIC LIQUID PRESSURE

1.1.1 This Appendix provides guidance for the calculation of the associated dynamic liquid pressure for the purpose of static design calculations. This pressure may be used for determining the internal pressure referred to in 13.2.1.5, where P_{eq} is the greater of the greater of P_{eq1} and P_{eq2}, in MPa, calculated as follows:

$$P_{eq1} = P_0 + \left(P_{gd}\right)_{\max},$$
$$P_{eq2} = P_h + \left(P_{gdsite}\right)_{\max},$$

where $\left(P_{gd}\right)_{\max}$ — associated liquid pressure, in MPa, determined using the maximum design accelerations;

$\left(P_{gdsite}\right)_{\max}$ — associated liquid pressure, in MPa, determined using site specific accelerations;

P_0 — design vapour pressure, in MPa, defined in 1.2.2;

P_h — vapour pressure, in MPa, referred in 13.2.

1.1.2 The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the cargo due to the motions of the ship referred to in 14.2. The value of internal liquid pressure P_{gd}, in MPa, resulting from combined effects of gravity and dynamic accelerations should be calculated as follows:

$$P_{gd} = a_\beta Z_\beta \frac{\rho}{1,02 \times 10^5},$$

where a_β — dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary β direction (refer to Fig. 1.1.2-1).

For large tanks, an acceleration ellipsoid taking account of transverse vertical and longitudinal accelerations, should be used. Methods for the calculation of acceleration in upright ship conditions and inclined ship conditions are given in 1.2;

Z_β — largest liquid height, in m, above the point where the pressure is to be determined measured from the tank shell in the β direction (refer to Fig. 1.1.2-2). The liquid heights Z_β are to be calculated in accordance with Fig. 1.1.2-4 at each calculation point of the tank.

At each calculation point, the maximum internal pressure $(P_{gd})_{max}$ is to be obtained for the β direction which gives the maximum value of P_{gd} (refer to Fig. 1.1.2-3).

Tank domes, V_d in m³, considered to be part of the accepted total tank volume shall be taken into account when determining Z_β, unless the total volume of tank domes V_d does not exceed the following value:

$$V_d = V_t \frac{100 - FL}{FL},$$

where V_t — tank volume, in m³, without any domes; *FL* — filling limit, i.e. maximum liquid volume in a cargo tank relative to the total tank volume when the liquid cargo has reached the reference temperature;

ρ — maximum cargo density, in kg/m³, at the design temperature. Where the maximum mass density of the liquid carried is not given, $\rho = 500$ kg/m³ is to be considered for methane.

The direction that gives the maximum value $(P_{gd})_{max}$ or $(P_{gdsite})_{max}$ should be considered. The above formula applies only to full tanks. Equivalent calculation procedures may be applied.

a_β resulting acceleration (static and dynamic)
in arbitrary direction β
a_X longitudinal component of acceleration
a_Y transverse component of acceleration
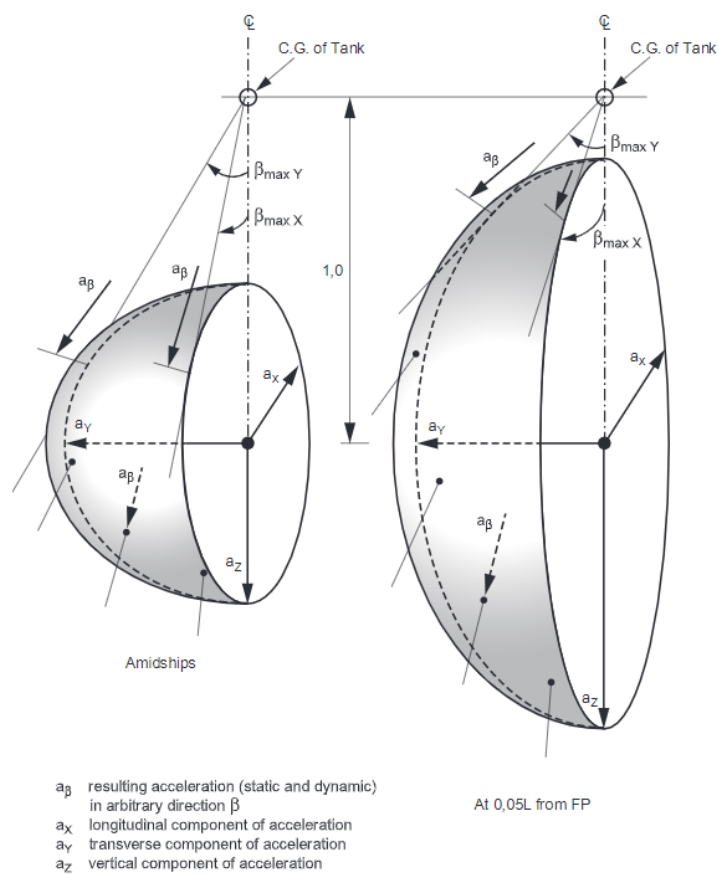a_Z vertical component of acceleration
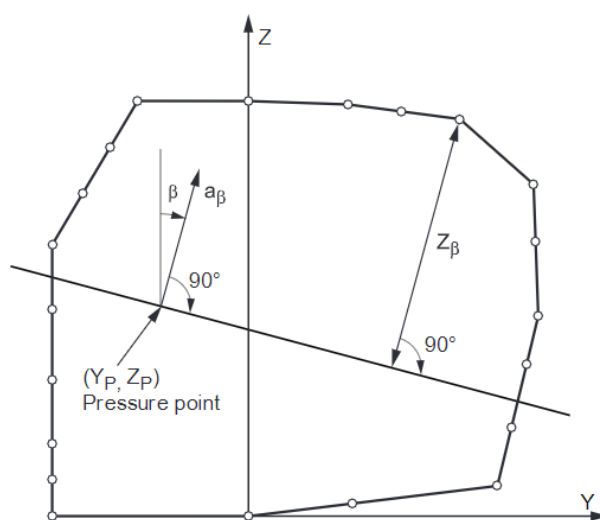
Fig. 1.1.2-1
Acceleration ellipsoid

Fig. 1.1.2-2
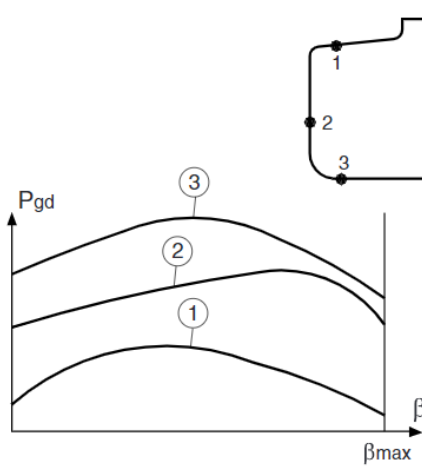Determination of internal pressure heads

Fig. 1.1.2-3
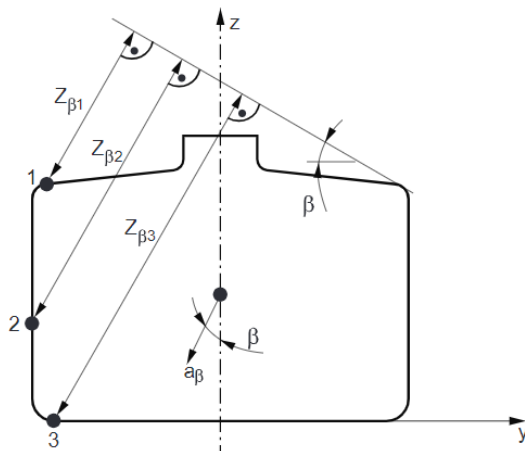Determination of internal pressure for pressure points *1*, *2* and *3*

Fig. 1.1.2-4
Determination of liquid height Z_β for pressure points *1*, 2 and 3

1.2 CALCULATION OF ACCELERATION COMPONENTS

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

vertical acceleration, as defined in :

$$a_z = \pm a_0 \sqrt{1 + \left(5{,}3 - \frac{45}{L_0}\right)^2 \left(\frac{x}{L_0} + 0{,}05\right)^2 \left(\frac{0{,}6}{C_b}\right)^2 + \left(\frac{0{,}6 y K^{1,5}}{B}\right)^2};$$

transverse acceleration, as defined in :

$$a_y = \pm a_0 \sqrt{0{,}6 + 2{,}5 \left(\frac{x}{L_0} + 0{,}05\right)^2 + K\left(1 + 0{,}6K\frac{z}{B}\right)^2};$$

longitudinal acceleration, as defined in :

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

where $a_0 = 0{,}2 \frac{V}{\sqrt{L_0}} + \frac{34 - \frac{600}{L_0}}{L_0}$;

L_0 — length of the ship, in m;

C_B — block coefficient;

B — greatest moulded breadth of the ship, in m;

x — longitudinal distance, in m, from amidships to the centre of gravity of the tank with contents; x is positive forward of amidships, negative aft of amidships;

y — transverse distance, in m, from centreline to the centre of gravity of the tank with contents;

z — vertical distance, in m, from the ship's actual waterline to the centre of gravity of tank with contents; z is positive above and negative below the waterline;

$K = 1$ — in general. For particular loading conditions and hull forms, determination of K according to the following formula may be necessary:
$K = 13 \ GM / B,$
where $K \geq 1$; *GM* — metacentric height, in m.

$A = \left(0{,}7 - \frac{L_0}{1200} + \frac{5z}{L_0}\right)\left(\frac{0{,}6}{C_b}\right)$;

V — service speed, in knots;

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

2 INTERNAL PRESSURE FOR MEMBRANE TANKS

2.1 GENERAL

2.1.1   The inertial internal liquid pressure is to be calculated according to the RS rules.

2.2 SLOSHING PRESSURE AND TANK AREAS TO BE CHECKED

2.2.1 The sloshing pressure shall to be considered with regards to the number and size of membrane tanks.

The sloshing pressure in membrane tanks of ships having a total capacity over 180000 m³ is to be specially considered by RS.

The ship structural members, i.e. plating, stiffeners and primary supporting members, supporting the membrane tanks are to be checked against the sloshing pressure defined in 2.2.2 for the tanks areas defined in 2.2.3.

2.2.2 The standard filling levels for membrane tanks of ships having a capacity less than 180000 m³ shall be taken as follows:

full load condition: the liquid height in the cargo tank is comprised between 70 % of the cargo tank height to 98 % of the cargo tank volume;

ballast condition: the liquid height in the cargo tank is comprised between 0 % and 10 % of the cargo tank height. In case of specific arrangement and tank dimensions, the value of 10 % may be adapted on case by case basis.

For the standard filling levels, the sloshing pressure, in kN/m², shall be obtained from the following formula:

$$p_{sl} = p_{wi} + p_{pv},$$

<div style="margin-left:2em">

where p_{wi} –   quasi static pressure, in kN/m², taken equal to 240 kN/m². If duly justified (for example by numerical analysis and/or model tests), another value of p_{wi} can be considered RS;

p_{pv} –   design vapour pressure, in kN/m², not taken less than 25 kN/m².

</div>

For filling levels other than standard filling levels, the sloshing pressure shall be specially considered by RS.

2.2.3 The areas of the tanks to be checked for sloshing are described in Fig. 1.2.2.3. For small tanks, the dimensions of those areas may be adapted on a case by case basis.
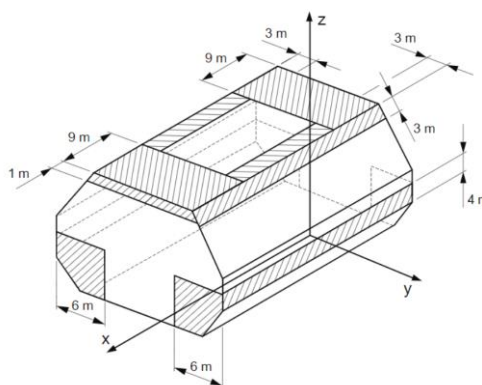
Fig. 2.2.3
Areas to be checked for sloshing

3 GUIDANCE FOR PRESSURE CALCULATION
FOR A STATIC HEEL ANGLE OF 30°

3.1 INTERNAL PRESSURE CALCULATION

3.1.1   The components of accelerations to be used for this calculation are the following:

positive roll angle case:

$$a_y = g \sin \frac{\pi}{6};$$

$$a_z = -g \cos \frac{\pi}{6};$$

negative roll angle case:

$$a_y = -g \sin \frac{\pi}{6};$$

$$a_z = -g \cos \frac{\pi}{6}.$$

3.1.2   This highest point is then shall be used as a reference for calculation of internal pressure as following:

$$p_{gd} = \rho g \left[a_y (y_H - y) + a_z (z_H - z) \right],$$

where y_H and z_H –   are the coordinates of the highest point in the tank.

CORRESPONDENCE WITH THE IGC CODE

1 GENERAL

1.1 CORRESPONDENCE TABLES

1.1.1 Table 1.1.1 provides the correspondence between the provisions of these Rules and those of Chapter 4 of the IGC Code.

1.1.2 Table 1.1.2 provides the correspondence between the provisions of Chapter 4 of the IGC Code and those of these Rules.

Table 1.1.1

Correspondence between these Rules and Chapter 4 of the IGC Code

Ref. of Rules	Ref. of IGC, Ch. 4	Ref. of Rules	Ref. of IGC, Ch. 4	Ref. of Rules	Ref. of IGC, Ch. 4	Ref. of Rules	Ref. of IGC, Ch. 4
(1.1.1]	/	(13.7.1)	4.13.7	(18.4.2)	4.18.3.2	(20.4.8)	4.20.3.7
(1.1.2)	/	(13.8.1)	4.13.8	(18.4.3)	4.18.3.3	(20.4.9)	/
(1.1.3)	Ch 4 Goal	(13.9.1)	4.13.9	(19.1.1)	4.19 Goal	(20.4.10)	/
(1.2.1)	4.1.1	(13.10.1)	4.13.10	(19.2.1)	4.19.1.1	(21.1.1)	/
(1.2.2)	4.1.2	(14.1.1)	4.14	(19.2.2)	4.19.1.2	(21.1.2)	/
(1.2.3)	4.1.3	(14.2.1)	4.14.1	(19.2.3)	4.19.1.3	(21.1.4)	/
(1.2.4)	/	(14.3.1)	4.14.2	(19.2.4)	4.19.1.5	(22.1.1)	4.27.1
(1.2.5)	Ch 1, 1.2.34	(14.4.1)	4.14.3	(19.2.5)	4.19.1.6	(22.1.2)	4.27.2
(1.2.6)	4.1.5	(14.4.2)	/	(19.2.6)	/	(22.1.3)	4.27.3
(1.2.7)	/	(14.5.1)	4.14.4	(19.2.7)	/	(22.1.4)	4.27.4
(1.2.8)	4.1.8	(14.6.1)	4.14.5	(19.3.1)	4.19.2.1	(23.1.1)	4.28.3
(2.1.1)	4.2	(15.1.1)	4.15	(19.3.2)	4.19.2.2	(24.1.1)	4.24.1.1
(3.1.1)	4.3.1	(15.2.1)	4.15.1	(19.3.3)	4.19.2.3	(24.1.2)	4.24.1.2
(3.1.2)	4.3.2	(15.2.2)	/	(19.3.4)	4.19.2.4	(24.1.3)	4.24.1.4
(3.1.3)	4.3.3	(16.1.1)	4.16.1	(19.3.5)	4.19.2.5.1	(24.1.4)	4.24.1.5
(3.1.4)	4.3.4	(16.1.2)	4.16.2	(19.3.6)	4.19.2.5.2	(24.1.5)	4.24.1.6
(3.1.5)	4.3.5	(16.1.3)	4.16.3	(19.3.7)	4.19.2.6	(24.1.6)	4.24.1.7
(3.1.6)	4.3.6	(17.1.1)	4.17.1	(19.4.1)	4.19.3.1	(24.2.1)	4.24.2.1
(4.1.1)	4.4.1	(17.2.1)	4.17.2	(19.4.2)	4.19.3.2	(24.2.2)	4.24.2.2
(4.1.2)	4.4.2	(17.3.1)	4.17.3	(19.4.3)	4.19.3.3	(24.3.1)	4.24.3
(4.1.3)	4.4.3	(18.1.1)	4.18	(19.4.4)	4.19.3.4	(24.4.1)	4.24.4.1
(5.1.1)	4.5	(18.2.1)	4.18.1.1 — 4.18.1.6	(19.4.5)	4.19.3.5	(24.4.2)	4.24.4.2
(6.1.1)	/	(18.3.1)	4.18.2.1	(19.4.6)	4.19.3.6	(24.4.3)	4.24.4.3
(6.1.2)	4.6.2	(18.3.2)	4.18.2.2	(19.4.7)	4.19.3.7	(24.5.1)	4.24.5.1
(7.1.1)	4.7.3	(18.3.3)	4.18.2.3	(19.4.8)	/	(24.5.2)	4.24.5.2
(8.1.1)	4.7.4	(18.3.4)	4.18.2.4.1 — 4.18.2.4.2	(19.4.9)	/	(24.5.3)	4.24.5.3
(8.1.2)	4.7.6	(18.3.5)	4.18.2.5	(19.4.10)	/	(24.6.1)	4.24.6.1

Ref. of Rules	Ref. of IGC, Ch. 4	Ref. of Rules	Ref. of IGC, Ch. 4	Ref. of Rules	Ref. of IGC, Ch. 4	Ref. of Rules	Ref. of IGC, Ch. 4
(9.1.1)	4.9.1	(18.3.6)	4.18.2.6.1 — 4.18.2.6.4	(19.4.11)	/	(24.6.2)	4.24.6.2
(10.1.1)	4.10.1	(18.3.7)	4.18.2.7	(19.5.1)	/	(24.6.3)	4.24.6.3
(10.1.2)	4.10.2	(18.3.8)	4.18.2.8	(19.5.2)	/	(24.6.4)	4.24.6.4
(11.1.1)	4.11	(18.3.9)	4.18.2.9	(20.1.1)	4.20 Goal	(24.6.5)	4.24.6.5
(12.1.1)	4.12.1	(18.3.10)	/	(20.2.1)	4.20.1.3	(24.7.1)	4.24.7.1
(12.2.1)	4.12.2	(18.3.11)	/	(20.3.1)	4.20.2	(24.7.2)	/
(13.1.1)	4.13.1	(18.3.12)	/	(20.4.1)	4.20.3.1	(24.7.3)	4.24.7.2
(13.2.1)	4.13.2	(18.3.13)	/	(20.4.2)	4.20.3.2	(24.8.1)	4.24.8.1
(13.3.1)	4.13.3	(18.3.14)	/	(20.4.3)	4.20.3.3	(24.8.2)	4.24.8.2
(13.4.1)	4.13.4	(18.3.15)	/	(20.4.4)	/	(24.9.1)	4.24.9.1
(13.4.2)	Ch 7, 7.2	(18.3.16)	/	(20.4.5)	4.20.3.4	(24.9.2)	4.24.9.2
(13.5.1)	4.13.5	(18.3.17)	/	(20.4.6)	4.20.3.5	(24.9.3)	4.24.9.3
(13.6.1)	4.13.6	(18.4.1)	4.18.3.1	(20.4.7)	4.20.3.6	(24.9.4)	/

Table 1.1.2

Correspondence between Chapter 4 of the IGC Code and these Rules

Ref. of IGC, Ch4	Ref. of Rules	Ref. of IGC, Ch4	Ref. of Rules	Ref. of IGC, Ch4	Ref. of Rules	Ref. of IGC, Ch4	Ref. of Rules
Ch 1, 1.2.34	(1.2.5)	4.13.6	(13.6.1)	4.18.3.3	(18.4.3)	4.24.1.2	(24.1.2)
Ch 4 Goal	(1.1.3)	4.13.7	(13.7.1)	4.19 Goal	(19.1.1)	4.24.1.4	(24.1.3)
4.1.1	(1.2.1)	4.13.8	(13.8.1)	4.19.1.1	(19.2.1)	4.24.1.5	(24.1.4)
4.1.2	(1.2.2)	4.13.9	(13.9.1)	4.19.1.2	(19.2.2)	4.24.1.6	(24.1.5)
4.1.3	(1.2.3)	4.13.10	(13.10.1)	4.19.1.3	(19.2.3)	4.24.1.7	(24.1.6)
4.1.5	(1.2.6)	4.14	(14.1.1)	4.19.1.5	(19.2.4)	4.24.2.1	(24.2.1)
4.1.8	(1.2.8)	4.14.1	(14.2.1)	4.19.1.6	(19.2.5)	4.24.2.2	(24.2.2)
4.2	(2.1.1)	4.14.2	(14.3.1)	4.19.2.1	(19.3.1)	4.24.3	(24.3.1)
4.3.1	(3.1.1)	4.14.3	(14.4.1)	4.19.2.2	(19.3.2)	4.24.4.1	(24.4.1)
4.3.2	(3.1.2)	4.14.4	(14.5.1)	4.19.2.3	(19.3.3)	4.24.4.2	(24.4.2)
4.3.3	(3.1.3)	4.14.5	(14.6.1)	4.19.2.4	(19.3.4)	4.24.4.3	(24.4.3)
4.3.4	(3.1.4)	4.15	(15.1.1)	4.19.2.5.1	(19.3.5)	4.24.5.1	(24.5.1)
4.3.5	(3.1.5)	4.15.1	(15.2.1)	4.19.2.5.2	(19.3.6)	4.24.5.2	(24.5.2)
4.3.6	(3.1.6)	4.16.1	(16.1.1)	4.19.2.6	(19.3.7)	4.24.5.3	(24.5.3)
4.4.1	(4.1.1)	4.16.2	(16.1.2)	4.19.3.1	(19.4.1)	4.24.6.1	(24.6.1)
4.4.2	(4.1.2)	4.16.3	(16.1.3)	4.19.3.2	(19.4.2)	4.24.6.2	(24.6.2)
4.4.3	(4.1.3)	4.17.1	(17.1.1)	4.19.3.3	(19.4.3)	4.24.6.3	(24.6.3)
4.5	(5.1.1)	4.17.2	(17.2.1)	4.19.3.4	(19.4.4)	4.24.6.4	(24.6.4)
4.6.2	(6.1.2)	4.17.3	(17.3.1)	4.19.3.5	(19.4.5)	4.24.6.5	(24.6.5)
4.7.3	(7.1.1)	4.18	(18.1.1)	4.19.3.6	(19.4.6)	4.24.7.1	(24.7.1)
4.7.4	(8.1.1)	4.18.1.1 — 4.18.1.6	(18.2.1)	4.19.3.7	(19.4.7)	4.24.7.2	(24.7.3)
4.7.6	(8.1.2)	4.18.2.1	(18.3.1)	4.20 Goal	(20.1.1)	4.24.8.1	(24.8.1)
4.9.1	(9.1.1)	4.18.2.2	(18.3.2)	4.20.1.3	(20.2.1)	4.24.8.2	(24.8.2)
4.10.1	(10.1.1)	4.18.2.3	(18.3.3)	4.20.2	(20.3.1)	4.24.9.1	(24.9.1)

Ref. of IGC, Ch4	Ref. of Rules	Ref. of IGC, Ch4	Ref. of Rules	Ref. of IGC, Ch4	Ref. of Rules	Ref. of IGC, Ch4	Ref. of Rules
4.10.2	(10.1.2)	4.18.2.4.1 — 4.18.2.4.2	(18.3.4)	4.20.3.1	(20.4.1)	4.24.9.2	(24.9.2)
4.11	(11.1.1)	4.18.2.5	(18.3.5)	4.20.3.2	(20.4.2)	4.24.9.3	(24.9.3)
4.12.1	(12.1.1)	4.18.2.6.1 to 4.18.2.6.4	(18.3.6)	4.20.3.3	(20.4.3)	4.27.1	(22.1.1)
4.12.2	(12.2.1)	4.18.2.7	(18.3.7)	4.20.3.4	(20.4.5)	4.27.2	(22.1.2)
4.13.1	(13.1.1)	4.18.2.8	(18.3.8)	4.20.3.5	(20.4.6)	4.27.3	(22.1.3)
4.13.2	(13.2.1)	4.18.2.9	(18.3.9)	4.20.3.6	(20.4.7)	4.27.4	(22.1.4)
4.13.3	(13.3.1)	4.18.3.1	(18.4.1)	4.20.3.7	(20.4.8)	4.28.3	(23.1.1)
4.13.4	(13.4.1)	4.18.3.2	(18.4.2)	4.24.1.1	(24.1.1)	Ch 7, 7.2	(13.4.2)
4.13.5	(13.5.1)						

Russian Maritime Register of Shipping

Rules for Membrane Containment System for Liquefied Natural Gas

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