

# RULES

## FOR THE CLASSIFICATION AND CONSTRUCTION OF SHIPS CARRYING LIQUEFIED GASES IN BULK

ND No. 2-020101-176-E

### RULE CHANGE NOTICE

ENTERS INTO FORCE:

01.07.2024



St. Petersburg  
2024

# **RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SHIPS CARRYING LIQUEFIED GASES IN BULK**

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The present Rule Change Notice to the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk (hereinafter — RCN) has been approved in accordance with the established approval procedure and contains information on amendments and additions, except for editorial amendments. RCN amendments come into force on 1 July 2024.

**REVISION HISTORY**

**PART I. CLASSIFICATION**

Item	Applicability	Description	Remarks
<a href="#">Section 4</a>	LG carriers Design documentation Cargo containment system Documentation for AIP and GASA	Section has been completely revised. Section has been renamed and its structure has been amended. General provisions have been introduced regarding submission of the technical documentation for review. Lists of design documentation have been significantly revised, supplemented and transformed into the table format. List of documentation for AIP (Approval in Principle) service has been introduced. Terminology in the list of documents for GASA (General Approval for Ship Application) service has been specified	Section 4

**PART IV. CARGO CONTAINMENT**

Item	Applicability	Description	Remarks
<a href="#">Para 19.2.1</a>	LG carriers Materials forming ship structure Temperature calculation	Reference to Annex 5 "Guidelines on Calculating the Temperature of Hull Structures and Cargo Boil-Off Rate" has been introduced	

**PART V. FIRE PROTECTION**

Item	Applicability	Description	Remarks
<a href="#">Para 3.3.1.4</a>	Ships carrying liquefied gases in bulk Items protected by the water-spray system  Additional cargo transfer equipment, including transfer loading arms, bunkering booms, transfer hoses, adaptors, reducers, spool pieces and transfer hose reels	Requirement has been introduced for protection of additional cargo transfer equipment by the water-spray system	IACS UI GC39 (Sep 2023 0
<a href="#">Para 3.4.1</a>	Ships carrying liquefied gases in bulk Items protected by the dry chemical powder fire extinguishing system  Additional cargo transfer equipment, including transfer loading arms, bunkering booms, transfer hoses, adaptors, reducers, spool pieces and transfer hose reels	Requirement has been introduced for protection of additional cargo transfer equipment by the dry chemical powder fire extinguishing system	IACS UI GC39 (Sep 2023)

**PART VI. SYSTEMS AND PIPING**

Item	Applicability	Description	Remarks
<a href="#">Para 4.1.2</a>	LG carriers Cargo pressure/temperature control Calculation of cargo boil-off rate	Reference to Annex 5 "Guidelines on Calculating the Temperature of Hull Structures and Cargo Boil-Off Rate" has been introduced	

**ANNEXES TO THE RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SHIPS CARRYING LIQUEFIED GASES IN BULK**

Item	Applicability	Description	Remarks
<a href="#">Annex 5</a> (new)	LG carriers Calculation of temperature of hull structures and cargo boil-off rate Analytical method Numerical method	New Annex 5 "Guidelines on Calculating the Temperature of Hull Structures and Cargo Boil-Off Rate" has been introduced	

## **PART I. CLASSIFICATION**

### **4 PLAN APPROVAL DOCUMENTATION**

**Section 4** is replaced by the following text:

#### **"4 TECHNICAL DOCUMENTATION**

##### **4.1 GENERAL**

**4.1.1** In addition to the design documentation specified in Section 3 of Part I "Classification" of the Rules for the Classification, the following technical documentation confirming fulfillment of the LG Rules shall be submitted to the Register at least in the scope specified in tables of Chapter 4.2.

The requirements of 4.2 cover the scope of documentation submitted according to the options given in 3.1.2 of Part I "Classification" of the Rules for the Classification: in the set of the plan approval documentation (PAD) or in the set of the technical design documentation (TD) with further approval of detailed (design) documentation (DD).

**4.1.2** At the early stages of design, on the customer's request, the Register may review the documentation as part of the service rendering:

Approval in Principle (AIP) of LNG containment systems;

General Approval for Ship Application (GASA) of LNG containment system with membrane tank.

The set of documentation submitted for AIP and GASA service rendering is subject to agreement between the customer and the Register in each particular case taking into account provisions of 4.3.

## 4.2 DESIGN DOCUMENTATION

Letter identification and abbreviations:

- A — Approved;
- AG — Agreed;
- FI — For information;
- TD — Technical design;
- PAD — Plan approval documentation;
- DD — Detailed (design) documentation.

### 4.2.1 Ship's general documentation.

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.1	General arrangement plan, showing location of:	FI/A	●		●	Information given in 4.2.1.1 may be submitted on separate drawings. If all necessary information concerning escape routes is stated in the plan, the general arrangement plan shall be approved
.1.1	cargo tanks with their distances from side plating and the bottom specified, fuel oil tanks, ballast tanks and other tanks					
.1.2	tank domes and openings in tanks					
.1.3	void spaces					
.1.4	doors, hatches and any other openings into gas-dangerous spaces or zones (refer to 2.1 of Part VII "Electrical Equipment")					
.1.5	vent pipes and air inlet and outlet locations of a ventilation system					
.1.6	doors, scuttles, companions, ventilating duct outlets locations and other openings in spaces of the superstructure and spaces adjacent to the cargo area					
.1.7	hazardous areas					
.1.8	airlocks between hazardous and non-hazardous areas	FI	●		●	
.2	List of cargoes to be carried onboard a ship specifying their basic chemical and physical properties, as well as hazards related to their carriage and storage					

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.3	Justification of fitness of insulating materials used in the cargo area	AG	•		•	
.4	Cargo system operation manual in accordance with the requirements of Chapter 18 of the IGC Code (preliminary)	AG	•		•	
.5	Gas testing program (preliminary)	AG	•		•	
.6	Calculation of maximum filling limit of cargo tanks	AG	•		•	

**4.2.2 Hull documentation.**

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.1	Drawings of hull structures in way of cargo tanks, including supporting arrangements, anti-flotation arrangements, deck sealing arrangements, etc.	A	•		•	
.2	Hull structures plan according to distribution of steel grades based on the hull temperature calculation in accordance with 4.2.3.3	AG	•		•	

**4.2.3 Documentation on cargo containment system.**

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.1	Cargo containment system arrangement plans including a primary and, where fitted, a secondary barrier (with indication of material and scantlings of the system elements), thermal insulation	A	•		•	
.2	Strength calculation of cargo containment system elements including fatigue analysis and crack propagation analysis (if applicable for the tank type) as well as including calculation of dynamic loads due to ship motion	AG	•		•	
.3	Temperature calculation of hull structures adjacent to the cargo containment system made in accordance with 19.2.1 of Part IV "Cargo Containment" including description of applied calculation procedures	AG	•		•	
.4	Tank domes drawings (with indication of position and scantlings of supports and seals of hull structures)	A	•		•	
.5	Calculation of boil-off rate	AG	•		•	

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.6	Drawings of ladders, fittings, pump towers and other elements of cargo containment and treatment system located inside tanks (with indication of material and scantlings of system elements)	A	•		•	
.7	Strength calculation of pump towers and other elements of cargo containment and treatment system located inside the tank	AG	•		•	
.8	Inspection/survey plan for the cargo containment system	A	•	•	•	
.9	Techniques for mechanical relief of stresses in independent cargo tanks	AG	•		•	

**4.2.4 Documentation on fire protection.**

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.1	Justification of fitness of fire extinguishing media, fire detection and extinction systems apparatus for cargoes carried	AG	•		•	
.2	Documents confirming the design time of fire extinction, application rate of fire extinguishing media and the amount of fire extinguishing media on board	AG	•		•	

**4.2.5 Documentation on systems and piping.**

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.1	Drawings and diagrams of systems and piping for cargo and cargo vapours specifying such assemblies as compensators, flange joints, stop and regulating valves and fittings	A	•	•	•	
.2	Drawings of quick-closing arrangements of the cargo containment system	A	•		•	
.3	Stress analysis in cargo and other piping containing cargo at a temperature – 110°C or lower	AG	•		•	
.4	Diagrams of cargo heating and refrigeration systems	A	•		•	
.5	Heat transfer calculation in cargo heating and refrigeration systems	AG	•		•	
.6	Drawings of relief valves and vacuum relief valves of cargo tanks	A	•		•	
.7	Diagrams of cargo pressure and temperature control systems	A	•		•	

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.8	Diagrams of the vent system with indication of all relief valve settings and relevant alarm in case the tanks are equipped with the system with variable setting pressure	A	•		•	
.9	Calculations of the vent system	AG	•		•	
.10	Drawings and descriptions of the inert gas system	A	•		•	
.11	Diagrams of bilge and ballast systems in the cargo area, pump rooms, cofferdams, pipe tunnels, spaces for independent cargo tanks, etc.	A	•		•	
.12	Calculations of bilge and ballast systems in the cargo area, pump rooms, cofferdams, pipe tunnels, spaces for independent cargo tanks, etc.	AG	•		•	
.13	Diagrams of the ventilation system of spaces in the cargo area and of other spaces to be accessible for cargo operations performance	A	•		•	The diagrams shall contain data on fitness of materials used for manufacture of fan impellers and air ducts
.14	Calculations of the ventilation system of spaces in the cargo area and of other spaces to be accessible for cargo operations performance	AG	•		•	
.15	Diagrams of piping relating to the use of cargo as fuel with indication of separate pipe joints assemblies, and of valves location and design	A	•		•	
.16	Diagrams of heating systems for hull structures (if applicable)	A	•		•	
.17	Drawings of process pressure vessels	A	•		•	
.18	Drawings of cargo pumps and compressors	A	•		•	

#### 4.2.6 Documentation on electrical equipment, instrumentation and automation systems.

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.1	Failure mode and effects analysis (FMEA) for electrical generation and distribution systems, and associated control systems	AG	•		•	refer to 2.1.4 of Part VII "Electrical Equipment"
.2	Drawings of cable laying in dangerous spaces	A	•	•	•	
.3	Drawings of earthing for electrical equipment, cables, piping located in gas-dangerous spaces	A	•	•	•	

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.4	Block diagram for all intrinsically safe circuits, including data for verification of the compatibility between the barrier and the field components	A	•		•	
.5	Diagrams of electric drives for a reliquefaction unit for cargo vapours, liquefied gas refrigeration units, cargo pumps and compressors, an inert gas generation plant, fans of dangerous spaces and air locks	A	•		•	
.6	Functional diagrams of control systems for units specified in 4.2.6.5	A	•		•	
.7	Functional diagrams of electric measurement and alarm systems including cargo temperature control system	A	•		•	
.8	Functional diagrams of automatic and remote shutdown systems for electrical equipment, remote control systems of hull structure heater valves.	A	•		•	
.9	Drawings and descriptions of all systems and devices for measurement of cargo amount and characteristics, and for gas detection	A	•		•	
.10	Calculation of maximum filling level of cargo tanks considering all values of relief valve setting if cargo tanks are equipped with the system with variable setting pressure	AG	•		•	

#### 4.2.7 Documentation on loading arms.

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.1	Arrangement plan of loading arms including their operating envelope scheme	A	•		•	
.2	Structural drawings including platforms, foundations and reinforcements	A	•	•	•	
.3	Drawing and diagram of piping with fittings including the drawing of cargo swivel	A	•		•	
.4	Drawing of quick connect/disconnect coupler (QCDC)	A	•		•	
.5	Drawing of emergency release coupling (ERC)	A	•		•	
.6	Drawings of swivel joints, ropes, blocks and counterweights	A	•		•	
.7	Diagram of purge and drain system	A	•		•	

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.8	Plan of arrangement and connection diagrams of electrical equipment (components of arm constant position monitoring system, components of automation, alarm and protection systems including local control panels, earthing, etc.)	A	•		•	
.9	Pattern of insulating coating application	A	•		•	
.10	Justification of material selection for structures and piping with loading arm fitting	AG	•		•	
.11	Strength calculation for structures and piping with loading arm fitting	AG	•		•	
.12	Bollard pull calculation when choosing the rope	AG	•		•	

#### 4.2.8 Documentation on reliquefaction unit for cargo vapours.

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.1	Technical specification of reliquefaction unit for cargo vapours	AG	•		•	
.2	Calculation of required capacity for reliquefaction unit for cargo vapours taking into account thermal flows for each cargo tank	AG	•		•	
.3	Arrangement plans of reliquefaction unit for cargo vapours and associated equipment (compressors, heat exchangers, pumps, pressure vessels, separators) on board with indication of escape routes from the compartment, where the unit is installed, and arrangement of fixed gas detection system	A	•		•	
.4	Arrangement plans for refrigerant, cooling medium and cooling water pipelines with indication of sections passing through the bulkheads, decks and platforms	A	•	•	•	
.5	Arrangement plans for electrical and automation equipment of reliquefaction unit for cargo vapours	A	•		•	
.6	Circuit diagrams of ventilation systems for spaces, where the equipment for reliquefaction unit for cargo vapours is fitted, with indication of watertight, gastight and fire-fighting bulkheads, as well as the rate of air changes	A	•		•	
.7	Circuit diagrams of refrigerant, cooling medium and cooling water systems with indication of heat-transfer properties	A	•		•	

No.	Description of documentation	Stamp	TD	DD	PAD	Remarks
.8	Functional diagram and description of emergency shutdown system for reliquefaction unit for cargo vapours and its interaction with the emergency shutdown system for ship's cargo system	A	•		•	
.9	List of mechanisms and equipment for reliquefaction unit for cargo vapours with indication of their technical characteristics	AG	•		•	
.10	List of electrical and automation equipment for reliquefaction unit for cargo vapours with indication of type of explosion protection and equipment specification summary	AG	•		•	
.11	Failure mode and effects analysis (FMEA) for reliquefaction unit for cargo vapours (in accordance with IEC 60812 standard) performed against the level confirming intended operation of the unit after a single failure	AG	•		•	
.12	Test program of reliquefaction unit for cargo vapours	A	•		•	

### **4.3 APPROVAL IN PRINCIPLE (AIP) AND GENERAL APPROVAL FOR SHIP APPLICATION (GASA)**

#### **4.3.1 "Approval in Principle" of LNG containment system.**

**4.3.1.1** The service "Approval in Principle" of LNG containment system (hereinafter referred to as "the containment system") is rendered in accordance with 3.6 of Part II "Technical Documentation" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

**4.3.1.2** For AIP service to be rendered, the following information shall be submitted to the Register for review:

**.1** information on tank type in accordance with the types specified in Part IV "Cargo Containment" with indication of design temperature of cargo and design pressure of cargo vapours;

**.2** general arrangement plans of containment system elements specifying location and extension of barriers and thermal insulation, location of containment system elements in relation to cargo hold with indication of access areas into the tank for survey and testing;

**.3** drawings specifying the methods and fastening/mating devices of containment system elements between each other and with adjacent hull structures;

**.4** drawings specifying quantity and location of cargo temperature indicating devices;

**.5** information confirming the possibility of inert gas system functioning i.e. possibility of inerting interbarrier spaces and hold spaces of a ship depending on the type of containment system;

**.6** information on materials used for manufacture of elements of containment systems confirming fitness of applied materials with regard to their insulating, physical and mechanical properties as well as description of technology for material manufacture;

**.7** information on the process of manufacture and installation of containment system elements confirming principal possibility to manufacture elements and install tank elements on board;

**.8** general information on restrictions that may be imposed to the ship and/or special requirements for ship's design for which the containment system has been developed, if any.

#### **4.3.2 General approval for ship application of LNG containment system with membrane tank.**

**4.3.2.1** For GASA service to be rendered, the following technical documentation shall be submitted to the Register for review:

**.1** general information on ship in the scope necessary to evaluate compliance of LNG containment system with membrane tank (hereinafter referred to as "the system") with applicable requirements;

**.2** general information on system elements geometrical dimensions and location in the ship's hull;

**.3** drawings of system structures in way of flat and corner regions, in way of attachments of system elements to adjacent hull structures and in way of cargo tank dome;

**.4** drawings of pump tower including relevant equipment (pumps, pipelines, ladders, etc.) as well as its connection to ship's hull;

**.5** drawings of pump tower base support;

**.6** description of joining processes to connect system elements to each other as well as connections with adjacent hull structures;

**.7** list of materials and components used in system structures and their test results;

.8 temperature calculations of system elements and adjacent hull structures including description of applied calculation procedures;

.9 strength calculations of system elements including description of applied calculation procedures;

.10 calculation of ship's rolling and loads on the system elements with description of applied calculation procedures and results of laboratory tests;

.11 information on previously rendered AIP service by the Register, if any.

**4.3.2.2** The Register may require additional information necessary to render GASA service.

**4.3.2.3** The results of rendered GASA service are finalized by drawing up a conclusion letter (expert opinion) according to 8.5 of Part II "Technical Documentation" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships."

## **PART IV. CARGO CONTAINMENT**

### **19 MATERIALS**

#### **19.2 MATERIALS FORMING SHIP STRUCTURE**

**Para 19.2.1** is amended as follows:

"**19.2.1** To determine the grade of plate and sections used in the hull structure, a temperature calculation<sup>1</sup> shall be performed for all tank types when the cargo temperature is below  $-10\text{ }^{\circ}\text{C}$ . 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 or partial secondary 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  $5\text{ }^{\circ}\text{C}$  for air and  $0\text{ }^{\circ}\text{C}$  for seawater. Higher values may be accepted for ships operating in restricted areas and, conversely, lower values may be accepted for ships trading to areas where lower temperatures are expected during the winter months. During temperature calculation and selection of a steel grade for hull structures adjacent to the cargo containment system but not coming into direct contact with the ambient air the ambient temperature is taken in accordance with the technical documentation submitted in the scope of the ship project review<sup>42</sup>. For ice-breakers and ice class ships, the ambient temperature shall not be taken to be above that specified in 1.2.3.3, Part II "Hull" of the Rules for the Classification and Construction of Sea-Going Ships<sup>23</sup>;

.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 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 19.2.5, provided the heating arrangements are in compliance with 19.2.6;

.8 no credit shall be given for any means of heating, except as described in 19.2.5; and

.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 Section, shall be shown on the International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

<sup>1</sup> Refer to Annex 5 "Guidelines on Calculating the Temperature of Hull Structures and Cargo Boil-Off Rate".

<sup>42</sup> Additional provisions not included in the Code.

<sup>23</sup> Hereinafter referred to as "the Rules for the Classification".

## PART V. FIRE PROTECTION

### 3 FIRE FIGHTING EQUIPMENT AND SYSTEMS

#### 3.3 WATER-SPRAY SYSTEM

Para 3.3.1.4 is amended as follows:

.4 cargo liquid and vapour discharge and loading connections, including the presentation flange and the area where their control valves are situated, which shall be at least equal to the area of the drip trays provided, as well as the additional cargo transfer equipment, including transfer loading arms, bunkering booms, transfer hoses, adaptors, reducers, spool pieces and transfer hose reels that may be installed in different locations around the ship;

Note . When in use, this additional cargo transfer equipment shall comply, where applicable, with the requirements in 3.3.1.4, 3.3.1.5, 3.4.1 and 3.4.3 of this Part and 3.23.7.2 of Part VI "Systems and Piping" for fire detection and fire protection in the cargo area (ESD system functionality and fusible elements (refer to 3.17.4, Part VI "Systems and Piping"), water-spray system and dry chemical powder fire-extinguishing system protection, drip trays), including hull protection from low temperatures."

#### 3.4 DRY CHEMICAL POWDER FIRE EXTINGUISHING SYSTEM

Para 3.4.1 is amended as follows:

**3.4.1** Ships in which the carriage of flammable products is intended shall be fitted with fixed dry chemical powder fire-extinguishing systems, approved by IMO circular MSC.1/Circ.1315/Rev.1 "Revised Guidelines for the Approval of Fixed Dry Chemical Powder Fire-Extinguishing Systems for the Protection of Ships Carrying Liquefied Gases in Bulk" for the purpose of firefighting on the deck in the cargo area, including any in the areas of location of cargo liquid and vapour discharge and loading connections, including the additional cargo transfer equipment (transfer loading arms, bunkering booms, transfer hoses, adaptors, reducers, spool pieces and transfer hose reels) that may be installed in different locations around the ship, as well as connections located on deck and, in bow or stern cargo handling areas.

Note . When in use, this additional cargo transfer equipment shall comply, where applicable, with the requirements in 3.3.1.4, 3.3.1.5, 3.4.1 and 3.4.3 of this Part and 3.23.7.2 of Part VI "Systems and Piping" for fire detection and fire protection in the cargo area (ESD system functionality and fusible

elements (refer to 3.17.4, Part VI "Systems and Piping"), water-spray system and dry chemical powder fire-extinguishing system protection, drip trays), including hull protection from low temperatures."

## **PART VI. SYSTEMS AND PIPING**

### **4 CARGO PRESSURE/TEMPERATURE CONTROL**

**Para 4.1.2** is amended as follows:

**4.1.2** Use of at least two units for control of cargo pressure and temperature, capable of operating in every ship's mode, shall be provided onboard the ship. The capacity of each system for control of cargo pressure and temperature shall correspond to the maximum possible intensity of cargo vaporization from all LNG tanks during the normal ship's operation at the maximum design ambient temperature<sup>1</sup> stated in 4.1.3, and the pressure in cargo tank not exceeding MARVS.

<sup>1</sup> Refer to Annex 5 "Guidelines on Calculating the Temperature of Hull Structures and Cargo Boil-Off Rate".

## **ANNEXES TO THE RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SHIPS CARRYING LIQUEFIED GASES IN BULK**

**New Annex 5** is introduced reading as follows:

*"ANNEX 5*

### **GUIDELINES ON CALCULATING THE TEMPERATURE OF HULL STRUCTURES AND CARGO BOIL-OFF RATE**

#### **1 GENERAL**

##### **1.1 Main definitions.**

For the purpose of the Guidelines on Calculating the Temperature of Hull Structures and Cargo Boil-Off Rate<sup>1</sup>, the following definitions have been adopted.

Cargo boil-off rate, *BOR*, % is the amount of liquefied cargo that is evaporating from a cargo tank due to heat leakage and expressed in percentage of total initial cargo volume reduction per day.

Finite element method is a method for numerically solving differential equations of heat transfer where the continuous variable approximates with a discrete model consisting of numerous piecewise continuous functions. The specified functions are determined on a finite number of elementary areas which the examined structure is divided in, and function values are determined by means of temperature values at the limit number of points of the examined area — nodes of the finite element model.

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<sup>1</sup> Hereinafter referred to as "these Guidelines".

**Design compartment** is a closed theoretical compartment in the ship's hull the walls of which are formed by plate structures located at mutually perpendicular directions.

**Steady heat transfer process** is a type of heat transfer when the temperature and heat flux do not change with time.

**Thermal convection** is a mechanism of heat transfer that occurs in fluids and gases and is performed by means of flows of the substance itself. There are two types of heat convection: natural (free) convection and forced convection. Natural convection occurs in still air and water conditions. Forced convection occurs in wind and current conditions.

**Heat flow**,  $Q$ ,  $W$ , is the amount of heat transferred via isothermal surface per a time unit.

**Thermal conductivity** is a mechanism of heat transfer from more heated parts of body to less heated ones by means of chaotic movement of body particles.

**Grashof number**,  $Gr$ , is a similarity criterion of heat processes that characterizes the heat exchange process at convection within buoyancy force.

**Nusselt number**,  $Nu$ , is a similarity criterion of heat processes that characterizes the ratio between heat exchange rate by means of thermal conductivity and heat exchange rate by means of thermal convection.

**Prandtl number**,  $Pr$ , is a similarity criterion of heat processes that characterizes influence of physical properties of the heat agent on the heat transfer.

**Rayleigh number**,  $Ra$ , is a similarity criterion of heat processes that characterizes fluid behavior under influence of temperature gradient.

## **1.2 Application.**

**1.2.1** These Guidelines describe minimum requirements for temperature calculations of hull structures and cargo boil-off rate.

**1.2.2** The requirements of these Guidelines cover calculations applied when fulfilling the following RS requirements:

requirements of 19.2.1, Part IV "Cargo Containment" regarding determination of design temperatures of hull structures in cargo area;

requirements of 4.1.2, Part VI "Systems and Piping" regarding determination of maximum possible cargo boil-off rate during normal operation.

## **1.3 Basic assumptions.**

**1.3.1** These Guidelines provide calculations by means of two methods:

analytical calculation method;

numerical calculation method.

The analytical method is assumed to be applied when determining the temperature of hull structures, cargo boil-off rate as well as when determining boundary conditions of the specified temperature and specified convection when calculating by numerical method.

It is also assumed that the numerical method applies when determining the temperature of hull structures.

**1.3.2** These Guidelines assume the necessity to consider following heat transfer mechanism:

thermal conductivity;

thermal convection.

The heat transfer process is considered to be steady. The cargo temperature is constant and equal to the design temperature at design pressure of cargo vapours in tank.

Materials of hull, cargo containment as well as liquid and gaseous substances are a homogenous medium. Materials do not absorb liquid cargo and do not affect its chemical composition.

**1.3.3** These Guidelines assume that the heat transfer due to thermal conductivity is performed in the following cases as schematically shown in Fig. 1.3.3:

heat transfer through ship's hull structures: shell plates, plating of decks and platforms, bulkhead plating, etc.;

heat transfer through thermal insulation and barriers of cargo containment tanks: hard, soft and loose insulating materials.

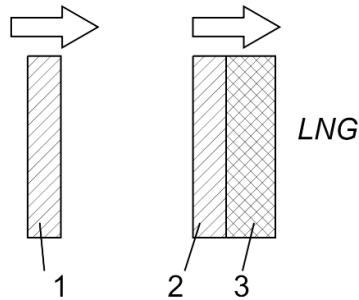


Fig. 1.3.3  
Heat transfer due to thermal conductivity  
(1, 2 — ship's hull structures, 3 — thermal insulation)

**1.3.4** These Guidelines assume that the heat transfer due to natural convection is performed in the following cases (refer to Fig. 1.3.4):

heat transfer to the ship's hull from the ambient still air and water;

heat transfer in the area between sides, bottoms and decks, in cofferdams, hold spaces without forced air circulation.

These Guidelines assume that the heat transfer due to forced convection is performed in the following cases (refer to Fig. 1.3.4):

heat transfer to the ship's hull from the ambient air and water with wind or current;

heat transfer in the area between sides, bottoms and decks, in cofferdams, hold spaces in case of forced air circulation.

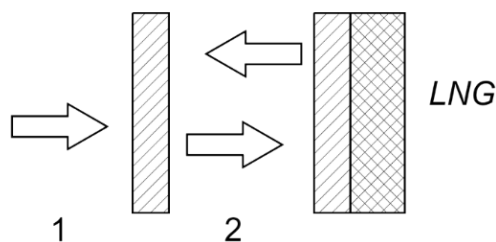


Рис. 1.3.4  
Heat transfer due to convection  
(1 — outside environment, air or water; 2 — atmosphere inside ship's hull)

**1.3.5** These Guidelines assume determination of convective heat transfer coefficient based on analytical methods and similarity criteria of heat processes. As agreed with the Register, it is allowed to apply experimental and numerical methods for fluid and gas flow dynamics (CFD) to calculate convective heat transfer rate.

**1.3.6** The ambient temperature (of air, sea water) and conditions to perform temperature calculations of hull structures shall be taken in accordance with the requirements of 19.2, Part IV "Cargo Containment".

The ambient temperature (of air, sea water) and conditions to perform the calculation of maximum possible cargo boil-off rate during normal operation shall be taken in accordance with the requirements of 4.1.2, Part VI "Systems and Piping".

**1.3.7** When calculating, it is necessary to consider heating devices of hull structures meeting the requirements of 19.2.6, Part IV "Cargo Containment". The temperature of heated structures shall be constant in accordance with parameters of installed heating devices.

**1.3.8** The calculations are performed at as-built scantlings of structural members of hull structures and cargo containment system.

The design temperature of structure is a value equal to the arithmetic mean between the temperature values on the structural surface. The design temperature of framing members and stiffeners is taken equal to the design temperature of plate structure that it is connected with.

## 2 DETERMINATION OF HEAT FLUX PARAMETERS

### 2.1 Heat flux value.

**2.1.1** In general, the value of heat flux  $Q$  between points with temperatures  $T_1$  and  $T_2$ , °C, shall be determined according to the formula

$$Q = A \cdot U \cdot (T_1 - T_2) \quad (2.1.1)$$

where  $A$  = area of heat transfer, in  $m^2$ ;  
 $U$  = heat transfer coefficient determined in compliance with the requirements of 2.1.2 and 2.1.3, in  $W/(m^2 \text{ } ^\circ\text{C})$ .

**2.1.2** The heat transfer coefficient  $U$  when transferring the heat through the plane wall due to thermal conductivity shall be determined according to the formula

$$U = \frac{k}{t} \quad (2.1.2-1)$$

where  $k$  = coefficient of thermal conductivity of material that is determined in compliance with the requirements of 2.2, in  $W/(m \text{ } ^\circ\text{C})$ ;  
 $t$  = thickness of structure through which passes the heat flux, in m.

Schematically the mechanism of heat transfer through the plane wall due to thermal conductivity is shown in Fig. 2.1.2.

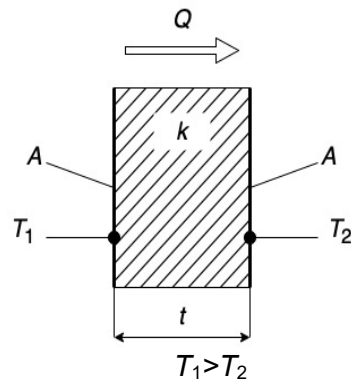


Fig. 2.1.2

For multi-layer structure, the thermal conductivity coefficient  $U$  is determined based on the following expression:

$$\frac{1}{U} = \sum_{i=1}^m \frac{1}{U_i} \quad (2.1.2-2)$$

where  $m$  = number of structure layers;  
 $U_i$  = heat transfer coefficient for each  $i$ -th layer of structure.

**2.1.3** The heat transfer coefficient  $U$  at heat transfer due to thermal convection is determined based on the formula

$$U = h \cdot \Phi \quad (2.1.3)$$

where  $h$  = convective heat transfer coefficient determined in accordance with requirements of 2.3, in  $W/(m^2 \text{ } ^\circ C)$ ;  
 $\Phi$  = coefficient of fin effect;  
 $\Phi = 1$  = for plate surface of stiffeners;  
 $\Phi > 1$  = for surface with stiffeners in accordance with provisions of 2.5.

Schematically the mechanism of heat transfer due to thermal convection is shown in Fig. 2.1.3.

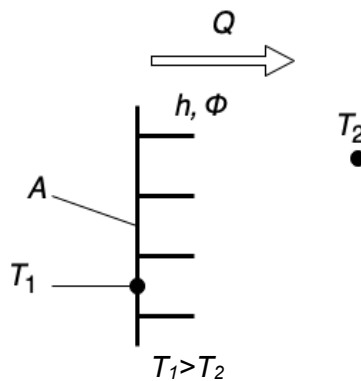


Fig. 2.1.3

**2.2 Thermal conductivity coefficient.**

**2.2.1** The value of thermal conductivity coefficient  $k$  of metal materials for hull structures and structures of cargo tanks shall be determined based on reference data or results of material tests. The determination procedure shall be agreed with the Register and shall consider amendment of the thermal conductivity coefficient from the temperature.

The value of thermal conductivity coefficient  $k$  of non-metal materials for thermal insulation of cargo tank shall be determined upon test results in compliance with the requirements of Appendix 4 to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

As agreed with the Register at the early stages of design, it is allowed to use approximate values of thermal conductivity coefficient in accordance with 2.2.2.

**2.2.2** Approximate values of the thermal conductivity coefficient  $k$  for metal materials are given in Table 2.2.2-1. Approximate values of the thermal conductivity coefficient  $k$  for non-metal materials applied during manufacture of thermal insulation for cargo tanks are given in Table 2.2.2-2.

Table 2.2.2-1

Material	Thermal conductivity coefficient $k$ , W/m °C		
	0 °C	-100 °C	-163 °C
Steel of a normal and higher strength	59		
Steel with 2,5 % Ni	38	33	–
Steel with 3,5 % Ni	34	29	21
Steel with 9 % Ni	28	23	16
Austenitic steel of type 304	14,5	12	–
Aluminium alloy of type 5083	115	92	70

Table 2.2.2-2

Material	Thermal conductivity coefficient $k \cdot 10^2$ , W/m °C		
	10 °C	-70 °C	-163 °C
FRP-reinforced polyurethane foam	4,0	2,9	2,0
Birch plywood	11,8	9,5	6,2
Glass wool	3,6	3,4	3,2
Expanded perlite	5,2	3,6	1,8

**2.2.3** In case when the thermal insulation of tanks is made of thermally insulating boxes, the thermal conductivity coefficient of a box shall be determined according to the formula

$$k = \frac{\sum_i V_i k_i}{\sum_i V_i} \quad (2.2.3)$$

where  $i$  = ordinal number of structural member of thermally insulating box (refer to Fig. 2.2.3);  
 $V_i$  = volume of  $i$ -th structural member within the insulating box, in m<sup>3</sup>;  
 $k_i$  = thermal conductivity coefficient of  $i$ -th structural member within the insulating box, in W/(m °C).

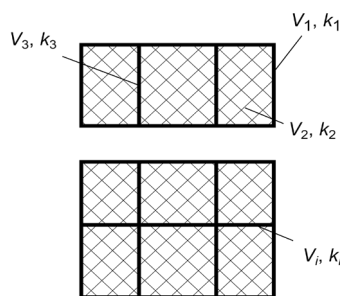


Fig. 2.2.3

**2.3 Convective heat transfer coefficient.**

**2.3.1** Convective heat transfer coefficient  $h$ , W/(m<sup>2</sup> °C), is determined by the formula

$$h = \frac{k_{liq}}{L_s} \cdot Nu \quad (2.3.1)$$

where  $k_{liq}$  = heat transfer coefficient of atmosphere or water determined in accordance with 2.3.2, in Вт/(m °C);  
 $L_s$  = characteristic length of heat transfer surface determined in accordance with 2.3.3, in m;  
 $Nu$  = Nusselt number determined in accordance with 2.4.

**2.3.2** The value of coefficient  $k_{liq}$  shall be taken for water environment in accordance with Table 2.3.2-1, and for air environment – in accordance with Table 2.3.2-2.

Table 2.3.2-1

Sea water temperature	30 °C	20 °C	10 °C	0 °C
$k_{liq} \cdot 10^2$ , W/(m °C)	61,5	59,8	58,0	56,1

Table 2.3.2-2

Air temperature	60 °C	40 °C	20 °C	0 °C	-50 °C	-100 °C	-150 °C
$k_{liq} \cdot 10^3$ , W/(m °C)	28,5	27,1	25,7	24,3	20,4	16,0	11,6

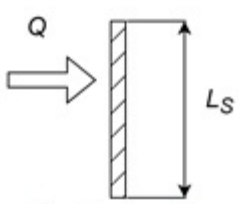
**2.3.3** The value  $L_s$  shall be determined depending on the position of heat transfer area:

for vertical heat transfer surface in accordance with Table 2.4.1-1;  
 for horizontal heat transfer surface in accordance with Table 2.4.2;  
 for inclined heat transfer surface in accordance with Table 2.4.3.

**2.4 Similarity criterion of heat processes.**

**2.4.1** The value of Nusselt number  $Nu$  at natural convection and vertical heat transfer surface are determined in compliance with the requirements of Table 2.4.1-1.

Table 2.4.1-1

Scheme of heat flux	Range $Ra$	Value $Nu$
 <p>Vertical surface</p>	$Ra \leq 10^9$	$Nu = 0,68 + \frac{0,67Ra^{1/4}}{[0,825 + (0,492/Pr)^{9/16}]^{4/9}}$
	$Ra > 10^9$	$Nu = \left\{ 0,825 + \frac{0,387Ra^{1/6}}{[1 + (0,492/Pr)^{9/16}]^{8/27}} \right\}^2$

The value of Rayleigh number  $Ra$  is determined according to the formula

$$Ra = Gr \cdot Pr \tag{2.4.1-1}$$

where  $Gr$  = Grashof number determined according to the formula (2.4.1-2);  
 $Pr$  = Prandtl number determined for water environment in accordance with Table 2.4.1-2, and for air environment in accordance with Table 2.4.1-3;

$$Gr = \frac{g \cdot \beta \cdot \Delta T \cdot L_s^3}{\nu^2} \tag{2.4.1-2}$$

where  $g$  = gravitational acceleration, in  $m/s^2$ ;  
 $\beta$  = thermal expansion coefficient determined for water environment in accordance with Table 2.4.1-2, and for air environment in accordance with Table 2.4.1-3, in  $1/^\circ C$ ;  
 $\Delta T$  = temperature difference between heat transfer surface and ambient temperature, in  $^\circ C$ ;  
 $L_s$  = refer to 2.3.3, in  $m$ ;  
 $\nu$  = kinematic viscosity determined for water environment in accordance with Table 2.4.1-2, and for air environment in accordance with Table 2.4.1-3, in  $m^2/s$ .

Table 2.4.1-2

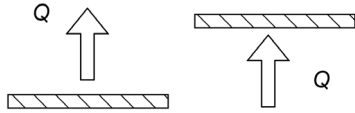
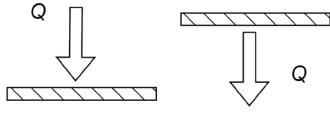
Water temperature	30 °C	20 °C	10 °C	0 °C
$\beta \cdot 10^7, 1/^\circ C$	3413	2489	1668	526
$\nu \cdot 10^8, m^2/s$	6,2	6,0	5,9	5,7
$Pr$	5,4	7,0	9,5	13,5

Table 2.4.1-3

Air temperature	60 °C	40 °C	20 °C	0 °C	-50 °C	-100 °C	-150 °C
$\beta \cdot 10^3, 1/^\circ\text{C}$	3,0	3,2	3,4	3,7	4,5	5,8	8,2
$\nu \cdot 10^6, \text{m}^2/\text{s}$	18,9	17,0	15,1	13,3	9,6	6,0	3,1
$Pr$	0,71			0,72	0,73	0,74	0,76

**2.4.2** The value of Nusselt number  $Nu$  at natural convection and horizontal heat transfer surface shall be determined in compliance with the requirements of Table 2.4.2.

Table 2.4.2

Scheme of heat flux	Range $Ra$	Value $Nu$
 <p>Heat flux in reverse direction from the gravity force</p>	$Ra = 10^4 \sim 10^7$	$Nu = 0,54 \cdot Ra^{1/4}$
	$Ra = 10^7 \sim 10^{11}$	$Nu = 0,15 \cdot Ra^{1/3}$
 <p>Heat flux in the direction of gravity force</p>	$Ra = 10^4 \sim 10^{11}$	$Nu = 0,27 \cdot Ra^{1/4}$
<p>Notes:</p> <ol style="list-style-type: none"> <li>The value <math>Ra</math> is determined in accordance with formula (2.3.3-1).</li> <li>The value <math>L_s</math> is determined as follows:  <math display="block">L_s = \frac{A}{P}</math>                     where <math>A</math> = heat transfer surface, in <math>\text{m}^2</math>;  <math>P</math> = perimeter of heat transfer surface, in m.</li> </ol>		

**2.4.3** The value of Nusselt number  $Nu$  at natural convection and inclined heat transfer surface is determined in compliance with the requirements of 2.4.1. Herewith, the value of Rayleigh number determined according to formula (2.4.1-1) shall be multiplied by value  $\cos\theta$  where  $\theta < 60^\circ$  (refer to Fig. 2.4.3). In case if  $\theta \geq 60^\circ$ , the heat transfer surface shall be assumed to be located horizontally.

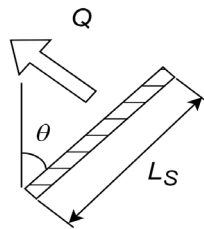


Fig. 2.4.3

**2.4.4** The value  $Nu$  at forced convection shall be determined according to formula

$$Nu = 0,037 \cdot Re^{4/5} \cdot Pr^{1/3} \quad (2.4.4-1)$$

where  $Re$  = Reynolds number determined according to the formula (2.4.4-2);  
 $Pr$  = refer to 2.4.1;

$$Re = \frac{V_p \cdot L_s}{\nu} \quad (2.4.4-2)$$

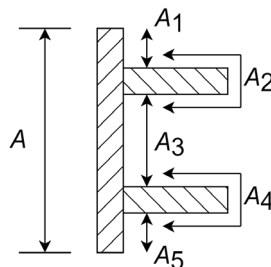
where  $V_p$  = speed of fluid or gas, in m/s;  
 $L_s$  = refer to 2.3.3, in m;  
 $\nu$  = refer to 2.4.1, in m<sup>2</sup>/s.

**2.5 Fin effect coefficient.**

**2.5.1** Fin effect coefficient  $\Phi$  in case if stiffeners are installed on the heat transfer surface, are determined according to the formula

$$\Phi = \frac{A_u}{A} + \eta_f \cdot \frac{A_f}{A} \quad (2.5.1)$$

where  $A_u, A, A_f$  = area values determined in accordance with the provisions in Fig. 2.5.1 without considering flanges of built-up stiffeners, in m<sup>2</sup>;  
 $\eta_f$  = fin efficiency coefficient determined in accordance with 2.5.2.



$$A_f = A_2 + A_4; A_u = A_2 + A_4$$

Fig. 2.5.1

**2.5.2** Fin efficiency coefficient  $\eta_f$  is determined according to the formula

$$\eta_f = \frac{\tanh(m \cdot L_f)}{m \cdot L_f} \quad (2.5.2)$$

where  $m = \sqrt{\frac{2 \cdot h \cdot (w_f + t_f)}{k_f \cdot w_f \cdot t_f}}$ ;

$L_f, w_f, t_f$  = geometrical parameters of stiffener determined in accordance with provisions in Fig. 2.5.2 without considering flanges of built-up stiffeners, in m;

$h$  = coefficient of convective heat transfer surface without considering stiffeners (refer to 2.3.1), in  $W/(m^2 \text{ } ^\circ\text{C})$ ;

$k_f$  = coefficient of stiffener material thermal conductivity determined in accordance with provisions in 2.2, in  $W/(m^2 \text{ } ^\circ\text{C})$ .

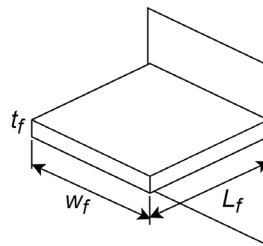


Fig. 2.5.2

### 3 FUNCTIONAL REQUIREMENTS FOR CALCULATION

#### 3.1 Analytical calculation method.

**3.1.1** The Guidelines assume that the analytical calculation method is based on review of thermal equilibrium of each design compartment in cargo area.

When dividing the cargo area into design compartments it is necessary to be guided by the following (refer to Fig. 3.1.1):

for double side structure the walls of design compartments are formed by the intersection of shell plating, web frames, second side and side stringers;

for structure of double bottom the walls of design compartments are formed by the intersection of bottom, web floors, inner bottom plating and side girders;

for structure of double deck the walls of design compartments are formed by the intersection of upper deck plating, deck transverses, trunk deck and deck girders;

cargo hold and cofferdam are considered as design compartments bounded by transverse bulkheads along the length.

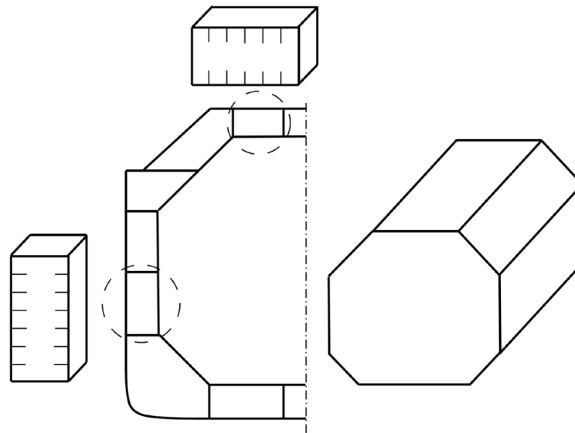


Fig. 3.1.1

**3.1.2** The temperature of hull structures shall be determined in accordance with the following condition of thermal equilibrium for each design compartment:

$$\sum_{i=1}^n Q_i = 0 \quad (3.1.2)$$

where  $Q_i$  =  $i$ -th heat flux in design compartment of ship's hull the value of which is determined in accordance with 2.1;

$n$  = number of heat fluxes to the design compartment of ship's hull, refer to Fig. 3.1.2.

When determining the number of heat fluxes it is necessary to consider input and output fluxes from the design compartment as specified in examples in Fig. 3.1.2.

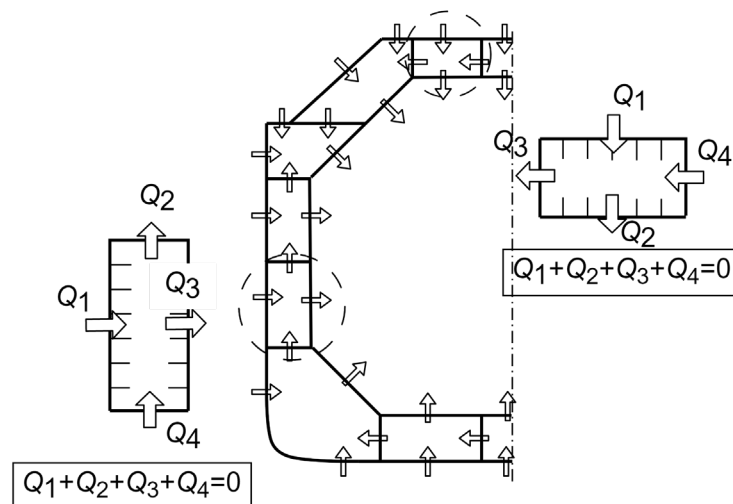


Fig. 3.1.2

**3.1.3** The temperature of hull structures shall be calculated in accordance with 3.1.2 by method of successive approximations considering dependence of heat flux value and

thermal conductivity coefficient (refer to 2.1) from the temperature of hull structures and temperature of thermal insulation of tank.

**3.1.4** The value of maximum possible cargo boil-off rate *BOR* at normal operation shall be determined according to the formula

$$BOR = \frac{Q_{max}}{\rho \cdot V \cdot H} \cdot 3600 \cdot 24 \cdot 100 \% \quad (3.1.4-1)$$

where  $Q_{max}$  = maximum possible total heat flux to the cargo tank at normal operation, refer to the formula (3.1.4-2), in W;

$\rho$  = cargo density determined at design cargo temperature and design pressure of cargo vapours in tank, in kg/m<sup>3</sup>;

$V$  = maximum permissible amount of cargo in tank considering 3.22, Part VI "Systems and Piping", in m<sup>3</sup>;

$H$  = heat of cargo vaporization determined at design cargo temperature and design pressure of cargo vapours in tank, in J/kg;

$$Q_{max} = \sum_{i=1}^m Q_i \quad (3.1.4-2)$$

where  $Q_i$  = *i*-th heat flux to the cargo tank the value of which is determined in accordance with 2.1;

$m$  = number of heat fluxes to the cargo tank at normal ship operation (refer to Fig. 3.1.4).

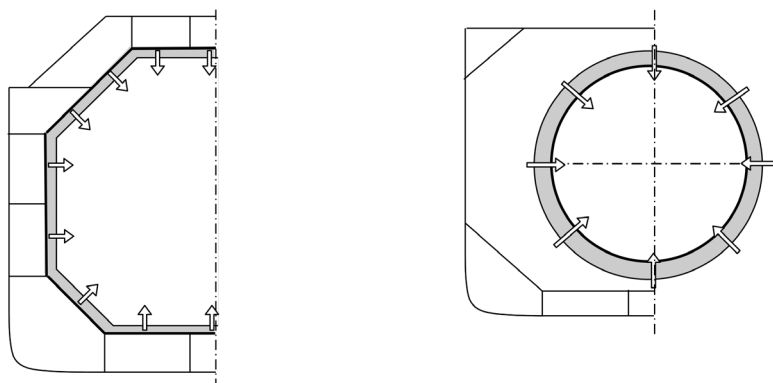


Fig. 3.1.4

### 3.2 Numerical calculation method.

**3.2.1** These Guidelines assume application of finite element method as a numerical method for temperature calculation of hull structures. Calculation results are temperature values in nodes of finite element model.

**3.2.2** When selecting the type of finite elements applied for calculations, one shall be guided by the following:

plates and stiffeners of ship's hull structures shall be modelled by shell-type finite elements;

stiffeners on plate elements shall be modelled without considering the flange;

thermal insulation of cargo tank shall be modelled by volume finite elements;

if thermal insulation of tanks is made of thermally insulating boxes, walls and bulkheads of the box shall be modelled by shell-type finite elements.

**3.2.3** It is allowed not to include stiffeners into finite element model provided the fin effect coefficient of plate structures is considered in accordance with 2.3.2.

**3.2.4** Values of material heat conductivity coefficients shall be taken in accordance with the requirements of 2.2.

**3.2.5** These Guidelines assume the necessity of application of the following boundary conditions to the finite element model:

boundary conditions of specified temperature;

boundary conditions of specified convection.

**3.2.6** Boundary conditions of specified temperature shall be applied to the nodes of finite element model in areas where the temperature of structures may be deemed as known considering the following:

temperature on boundaries of finite element model shall be taken in accordance with the results of calculations made by analytical method in accordance with 3.1;

temperature in nodes of finite elements in contact with the cargo shall be taken equal to the design cargo temperature.

**3.2.7** Boundary conditions of the specified convection shall be applied to the surface of finite elements in contact with air or water environment considering the following:

value of convective heat transfer coefficient shall be equal to value  $U$  obtained according to the formula (2.1.3);

fin effect coefficient  $\Phi = 1$  in case if the stiffeners are included in the finite element model. The fin effect coefficient  $\Phi > 1$  in accordance with the requirements of 2.5, if stiffeners are not included in the finite element model;

ambient temperature for elements shall be taken in accordance with the results of calculations made by analytical method in accordance with 3.1 depending on the location of examined structure;

for elements in contact with ambient air and sea water, the ambient temperature shall be taken in accordance with 1.3.6."

Russian Maritime Register of Shipping

**Rule Change Notice  
to the Rules for the Classification and Construction  
of Ships Carrying Liquefied Gases in Bulk**

Endorsed: 24-87473

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