RUSSIAN MARITIME REGISTER OF SHIPPING

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RULES

FOR PLANNING AND EXECUTION OF MARINE OPERATIONS

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RULES FOR PLANNING AND EXECUTION OF MARINE OPERATIONS

Rules for Planning and Execution of Marine Operations of the Russian Maritime Register of Shipping have been approved in accordance with the established approval procedure and come into force on 1 October 2022.

The present edition of the Rules is based on the 2017 edition taking into account the amendments and additions developed immediately before publication.

REVISION HISTORY[1]

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

Amended paras/chapters/sections	Information on amendments	Number and date of the Circular Letter	Entry-into-force date
Part I, para 1.5	Editorial amendment: references to the applicable requirements of the RS rules have been specified	—	01.09.2023
Part I, para 5.2	Type and form for submission of technical documentation on design of marine operation have been brought into compliance with 3.3, Part II "Technical Documentation" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships, conditions for approval of technical documentation on design of marine operation have been specified	391-05-1673c of 01.12.2021	01.01.2022
Part II, paras 2.3, 3.4, 7.1.1, 7.1.2, 7.2.1, 7.2.6	Editorial amendment: references to the applicable requirements of the RS rules have been specified	—	01.09.2023
Part III, paras 1.1.4, 1.1.1.5, 1.1.1.7, 1.1.2, 1.1.4, 1.2.1.1.2, 1.2.1.2.2, 1.2.2.1, 1.2.2.2, 1.2.2.3, 3.2.5, 6.7.1	Editorial amendment: references to the applicable requirements of the RS rules have been specified	—	01.09.2023
Part III, Appendix 1	Part has been supplemented by Appendix 1 considering experience of practical application	391-05-1673c of 01.12.2021	01.01.2022
Part III, Appendix 2	Part has been supplemented by Appendix 2 considering experience of practical application	391-05-1673c of 01.12.2021	01.01.2022

[1] Amendments and additions introduced at re-publication or by new versions based on circular letters or editorial amendments.

Amended paras/chapters/sections	Information on amendments	Number and date of the Circular Letter	Entry-into-force date
Part III, Appendix 3	Part has been supplemented by Appendix 3 considering experience of practical application	391-05-1673c of 01.12.2021	01.01.2022

PART I. GENERAL

1 APPLICATION

1.1 The requirements of these Rules for Planning and Execution of Marine Operations[1] apply to marine operations (MO) carried out during construction, modernization and utilization of offshore oil and gas field facilities covered by the technical supervision of the Register.

1.2 The requirements of these Rules do not apply to:

works/operations which are traditional for shipping;

laying of subsea pipelines and cables, installation of subsea production systems (SPS);

installation of self-elevating units and semi-submersible units at a drilling site;

transits and towing of ships (shall be carried out in accordance with the requirements of Section 8, Part II "Carrying Out Classification Surveys of Ships" of the Guidelines on Technical Supervision of Ships in Service).

1.3 On agreement with the Register, the requirements of these Rules can be extended to MO with the objects not specified in 1.1. In this case, RS reviews the MO technical documentation; therewith, the RS technical supervision shall only include the control of implementation of the measures on the MO planning prescribed by the approved design, without the assessment of technical condition of the object. Technical supervision of MO is not carried out.

1.4 The concepts of planning and execution of other MO types not regulated by these Rules as regards the objects specified in 1.1 shall be submitted to the Register for review and agreement in each particular case. In this case, the information and documentation which allow to ascertain the efficiency and safety level of execution of the operations in question shall be submitted to the Register.

1.5 Together with the requirements of these Rules the requirements of the Rules for the Classification and Construction of Mobile Offshore Drilling Units[2], the Rules for the Classification and Construction of Fixed Offshore Platforms[3], the Rules for the Classification, Construction and Equipment of Floating Offshore Oil-and-Gas Production Units[4], the Rules for the Cargo-Handling Gear of Sea-Going Ships may be applied.

1.6 The MO designs developed according to the rules of another classification society (ACS) and other standards may be approved by the Register as alternative or additional to the requirements of these Rules.

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[1] Hereinafter referred to as "these Rules".
[2] Hereinafter referred to as "the MODU Rules".
[3] Hereinafter referred to as "the FOP Rules".
[4] Hereinafter referred to as "the FPU Rules".

2 DEFINITIONS AND EXPLANATIONS

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

Marine operations (MO) are operations for assembly, transportation, mating and in-site installation of an object for an oil and gas field or its parts or its parts (blocks, tiers, columns, modules, positioning systems, etc.) carried out when the object or any of its parts are afloat or with the use of craft, and incorporating at least two of the stages listed. Two types of operations are distinguished:

shipyard operations afloat are space-restricted MO conducted at an outfitting quay (pier) or within fully protected shipyard water area;

unrestricted marine operations are space-unrestricted MO afloat conducted within a semi-protected water area or on high seas.

Ballasting is filling of ballast tanks or compartments.

Block is an independent specially fabricated component of an object.

Towing is transportation of a self-floating object (its parts).

Short-term (Weather routed) towing is the towing restricted by weather within the limits of a favourable weather forecast — good weather "window" (within 3 days).

Unrestricted towing is the towing unrestricted by weather or time.

Module is a structural component of the object consisting of blocks and which constitutes a transport unit or a functionally completed structure intended for transportation or mounting.

Skidding/rolling is the horizontal movement of an object on guides/rails by sliding/rolling.

Object is any large-sized and/or heavy-weight product, structure, assembly handled during MO.

Positioning is a marine operation necessary to maneuver and keep the object properly oriented and precisely located over a predetermined point of seabed.

Recognized standards, reference documents, calculation and design methods are existing national, industrial, departmental standards, reference documents and also calculation methods developed by separate organizations and authors, including foreign ones approved for application by authorized bodies or the Register.

Engineering of a marine operation is substantiation of all process procedures and support means (arrangements, appliances, instruments, machinery, tugs, etc.) necessary for execution thereof, which permit to safely achieve the set objective effectively, and at the minimum cost.

Assembly is any combination of components of the unfinished object.

Launching is the dynamic operation of the floating up of an assembly, block or module in a dry dock, immersion of a floating dock or a flo-flo type heavy-lift carrier, or after sliding from the slip or down the skid beams on a barge.

Mating by float-on method is the time-restricted or weather-restricted vertical mating of objects (tiers, blocks) to each other or a substructure (floating or secured on the seabed) with a topside using a craft (barge/pontoon) through ballasting and manoeuvring.

Buoyancy pontoon (tower) is a watertight tank being temporary attached to the structure to ensure its buoyancy and stability during MO.

Point of no return (PNR) is a point during an operation that represents the final opportunity to reverse, delay or abandon the operation.

Transportation is a marine operation involving movement of an object or its separate components from a construction site (place of manufacture) to the location of the next MO.

Installation is a marine operation, which includes the procedures for submersion (if necessary), positioning and fixing the object in accordance with the design (except for positioning of self-elevating MODU and semi-submerged MODU at a drilling location).

Tier is an aggregate of horizontally joined blocks.

3 CATEGORIES OF MARINE OPERATIONS

3.1 MO covered by these Rules include:
launching of blocks, modules or objects;
outfitting, assembly and horizontal mating of blocks afloat;
lifting operations;
rolling (skidding) operations;
vertical mating of tiers by float-on method;
vertical mating of substructure and topside by float-on method;
transportation and towing (unrestricted or short-term) of the object or parts thereof;
installation of the object on site.

3.2 Depending on the risk level, MO are subdivided into the following categories (refer to Table 3.2).

Table 3.2

Category of operation	Risk description	Reference criteria
1	Simple operations	Lifting and mounting operations when the weight of the object being lifted is from 35 to 300 t
2	Well controlled operations or less weather-sensitive operations	Lifting and mounting operations hi sheltered waters when the weight of the object being lifted exceeds 300 t Launching of the object in sheltered waters Short-term towing Transportation of the object on a specialized craft
3	Complicated operations or extremely weather-sensitive operations	Lifting and mounting operations on high seas when the weight of the object being lifted exceeds 300 t Mating of blocks afloat Rolling of the object on fixed or floating foundation Unrestricted towing Launching of the object on high seas Installation of substructure on the seabed
4	Operation with high risk potential	Long-range ocean towing Erection of the topside as assembled

3.3 Depending on the reference period, MO are subdivided into:
weather-unrestricted operations with a reference period exceeding 72 h;
weather-restricted operations with a reference period less than 72 h.

MO with a reference period exceeding 72 h may be defined as weather-restricted if the operation can be interrupted during its execution and the object may be moved into a sheltered position when the metocean parameters are exceeded.

MO with reference periods less than 12 h are considered separately.

3.4 Operation reference period T_R, h, is determined by the formula

$$T_R = T_{POP} + T_C \tag{3.4}$$

where T_{POP} = planned (design) operation period, h;
T_C = estimated contingency time, h.

If the estimated contingency time T_C due to casual factors is not assessed, it may be taken equal to the planned operation period T_{POP} but not less than 6 h.

3.5 For weather-restricted MO, the design environmental conditions may be established in each particular case in the technical design assignment, proceeding from the structural particulars of the object, technical capabilities of supply vessels available, etc. The start of such operations is conditional upon existing acceptable weather conditions and their favourable forecast.

3.6 Considering instability in metocean conditions (MC) and inaccuracy in weather forecasts, the acceptable parameters of weather conditions (operation criteria) for actual beginning and performance of MO shall be assumed less than the design criteria adopted. The metocean parameters C_o for the MO performance are determined by the formula

$$C_o \leq \alpha C_D \tag{3.6}$$

where C_D = design metocean parameters;
α = reduction factor taken equal to 0,8 for an averaged (anemometric) wind velocity; for wave heights, refer to Table 3.6.

Table 3.6

Reduction factor *a* for the seas

Operation reference period T_R, in h	Design wave height with 3 % probability of exceeding level, in m		
	1,3 < $h_{3\%}$ ≤ 2,6	2,6 < $h_{3\%}$ ≤ 5,2	$h_{3\%}$ > 5,2
< 12	0,68	0,76	0,80
12 ≤ T_R < 24	0,63	0,71	0,75
24 ≤ T_R < 48	0,56	0,64	0,67
48 ≤ T_R < 72	0,51	0,59	0,63

3.7 For MO with the operation reference period exceeding 72 h, but which may be defined as weather-restricted, in establishing operation criteria the total duration of all separate stages shall be taken into account.

The metocean parameters C_o for such operations shall be separately set in each particular case.

3.8 Environmental criteria for weather-unrestricted operations afloat (exceeding 72 h) shall be based on extreme value statistics for a particular operation area. The metocean parameters C_o for operation performance may be taken equal to the design criteria.

4 TECHNICAL DOCUMENTATION

4.1 Prior to the performance of an operation, technical documentation which includes the operation plan and operation design shall be submitted to the Register for review and approval. For category 1 operations the operation plan shall be submitted, for other categories — the operation plan and operation design.

4.2 The operation plan shall describe organization of the operation performance. The operation plan shall generally include the following sections:

technical background;

organization chart;

operational schedule.

4.2.1 Technical background shall include:

design basis for development of MO;

list of reference documents;

MO stages;

description of risk factors, risk management measures.

4.3 The operation design shall describe details and procedure of the operation performance, craft, structures, arrangements and equipment involved. All essential aspects of the operation both for normal conditions of its performance and for potential critical situations shall be considered in the design.

The operation design shall generally include the following sections:

MO Manual (hereinafter, the Manual)/technical background;

description of external conditions and effects;

restrictions due to external conditions;

restrictions due to strength and stability of the object and the means and structures in use;

navigational support and communications;

calculations;

general arrangement plans, general view drawings and specifications of structures, assemblies and components;

risk assessment;

environmental protection.

4.4 The Manual/technical background shall generally include:

distribution of responsibilities among the participants of the operation;

general description and main particulars of the handled objects (dimensions, weight characteristics, centre of gravity (CoG) position, etc.), general view drawings;

general arrangement plans;

operational sequence/process and operation performance plan;

contingency plans for emergency (when the standard procedure for MO is interrupted) and accident (when an accident is likely to occur) situations;

permissible loading conditions;

operational environmental criteria;

permissible draught, trim, heel and corresponding ballasting plans;

general arrangement plans with indication of principal characteristics of systems and equipment, operating manuals;

list of ships and other craft involved;

communication mode and systems;

metocean support;

life-saving appliances;

reporting forms;

list of verifications in preparation and performance of the operation;

test plans;

lists of spare parts, tools, accessories and emergency outfit.

Additional requirements for the manuals (technical documentation) on particular MO types are given in 4.9 — 4.13.

4.5 As a part of the MO design, inspection and test programs, including instrumentation calibration procedures shall be developed. The results of inspections and tests shall be documented. For operations with high-risk level, it is recommended to develop a common test program, which specifies the composition, sequence and procedure of inspections and tests for separate structures, equipment and systems. The program shall indicate controlled parameters, characteristics and their values in accordance with the design requirements.

4.6 Limiting criteria for MO or parts thereof shall be clearly stated in the Manual (technical documentation).

4.7 The documentation developed shall include the full descriptions of all procedures, equipment in use, etc. or contain references to well-known available materials containing necessary descriptions. The amount and details of the documentation shall ensure independent submission and review of drawings, procedure descriptions and calculations for all operation stages.

4.8 If any actions in the MO course are performed in accordance with the performer's standards (standard procedures), the abovementioned documents shall be submitted to the Register for review and approval.

4.9 Manuals (technical documentation) for lifting operations, skidding/rolling operations and operations on object securing during transportation shall include:

operation procedure;

general arrangement plans of the handled objects prior to loading, descriptions with indication of principal characteristics and strength calculations or calculation results of auxiliary machinery and equipment to be installed only to provide operations and/or securing;

mooring and fendering systems layouts;

general arrangement plan of the objects on craft;

general arrangement plans, strength calculations or calculation results, general view drawings of grillage and sea fastening;

global and local strength calculations for the object;

global and local strength calculations for craft, measures for load distribution (if required) and hull strengthening (if required);

calculations of trim, ballast (if required), stability, freeboard and unsinkability at all operation stages, including accident situations;

contingency plans.

4.9.1 Lifting (rigging) manual (technical documentation) shall additionally include:

technical background for selecting the cargo handling gear, appliances (means) and devices, their general arrangement plans with indication of principal characteristics, general view drawings;

slinging calculation.

4.9.2 Skidding/rolling manual (technical documentation) shall additionally include:

technical background for selecting the equipment involved;

general arrangement plans with indication of principal characteristics, general view drawings of the equipment involved;

general arrangement plans with indication of principal characteristics, general view drawings of trailers (multi wheel bogies) and hydraulic system;

general arrangement plan with indication of principal characteristics, general view drawings of traction equipment;

trailers (multi wheel bogies) and hydraulic system layout; arrangement plan of traction equipment; strength calculation of cargo track;

calculation of the object weight transfer process from support to support; seabed holding power calculation (if applicable).

4.10 Launching manual (technical documentation) shall include:
description of launching method;
technical background for selecting the launching appliances;
general arrangement plan with indication of principal characteristics, general view drawings of auxiliary equipment for position-keeping after launching;
methods and calculation of ballasting by means of solid and/or water ballast;
stability, draught and unsinkability calculations including those in damaged condition.
4.11 Towing/transportation manual (technical documentation) shall include:
technical background for craft selection, craft specifications/general description and main particulars, general arrangement plans with indication of principal characteristics, general view drawing of available standard systems, equipment and machinery and those to be installed additionally for MO, calibration tables of ballast tanks and piping and valve drawings;
calculation of towing resistance and required towing pull;
technical background for selecting the tow order ships and tugs, specifications/general description and main particulars of the towed object or transport ship (barge, pontoon) with the transported object, specifications/general description and main particulars of tugs, arrangement in the tow order (configuration in which the tugs are arranged);
general arrangement plans with indication of principal characteristics, general view drawing of towing arrangements, including emergency towing arrangements;
technical background for selecting the towlines;
specifications and general arrangement plans of life-saving appliances of the tugs;
calculation of necessary fuel, lubricating oil and fresh water reserves for the MO execution, including emergency reserve;
study of the planned route (description, extent, plot or chart);
identification of places of refuge and distance between them (coordinates of PNR and bunker ports (if any));
metocean analysis;
technical background for selecting the time for the MO execution;
hazard identification study;
schedule of transit;
metocean support;
communications;
instructions to the towmaster (refer to 4.11.1);
instructions to the tug master (refer to 4.11.2);
contingency plans (refer to 4.11.3).
4.11.1 Instructions to the towmaster (the manager responsible for towing/ transportation operation) shall include, as a minimum, the following Sections:
1. Tow/transportation route
2. Description of tow order
3. Safe towing conditions
4. Preparation for towing
5. Organization chart showing distribution of duties and responsibilities among the personnel involved, and reporting line into the project
6. Contingency measures to be taken in emergency and accident situations.
4.11.2 Instructions to the tug master shall include, as a minimum, the following Sections:
1. Tow/transportation route
2. Places of refuge
3. Coordinates of PNR
4. Specifications/general description and main particulars of the towed object
5. Safe towing/transportation conditions

6. Organization chart showing distribution of duties and responsibilities among the personnel involved, and reporting line into the project

7. Preparation and execution of towing.

4.11.3 Contingency plans shall include, as a minimum, the following Sections:

1. General

2. Organization chart showing distribution of duties and responsibilities among the personnel involved, and reporting line into the project

3. Damage control plan for the craft and towed object

4. Planned precautionary actions

5. Contingency measures to be taken in emergency and accident situations (prevention of the object shifting (during transportation) or damage to its structures/attachment, occurrence of severe weather conditions and sea states, failed leading tug, towline breakage, etc.)

6. Measures to be taken in case of any threat to human life (man overboard; emergency medical response).

4.12 Manual (technical documentation) on object installation and securing on site shall include:

pre-plan seabed inspection and soil analysis;

description of methods used for object securing on the seabed, selection of necessary means;

description of the method and means of object positioning;

ballasting calculations for the object submerging and ballasting plan;

description of the object installation on the seabed or installation of the position-keeping system;

post-installation inspection.

4.13 Environmental pollution prevention manual (technical documentation) for the MO execution shall include:

measures to prevent marine environment pollution;

measures to prevent air pollution;

measures to mitigate impact on marine biota (totality of plant, animal and microorganism species combined by a common habitat) when the object is installed on the seabed.

4.14 Depending on the MO category, the scope of documentation to be submitted may be reduced. In justified cases, the Register may require the scope of submitted documentation to be enhanced.

4.15 In cases where the MO stage is carried out within the Russian Federation inland waterways, documentation relevant to the operation stage safety shall be submitted to the Russian River Register for review and approval at least 30 days before the planned entry into the Russian inland waterways.

5 ORGANIZATION OF TECHNICAL SUPERVISION

5.1 The Register technical supervision is carried out to confirm the compliance of the design, conditions and procedure for MO execution with these Rules. The Register technical supervision includes generally:

review and approval of the MO design;

checking of readiness for the operation performance;

technical supervision while executing the marine operation during the RS technical supervision of offshore oil and gas facilities during their construction and modernization.

The scope of the technical supervision — refer to Table 5.1. The operation is referred to a particular category upon receipt of the request for technical supervision.

The Register technical supervision does not substitute the monitoring of the MO performance by the designer, performer, warranty surveyor and owner of the object.

Table 5.1

Technical supervision of marine operations

Operation category	Operation plan/design review	Technical supervision during the operation execution	Documents to be issued
1	Availability of operation plan is checked	Appointment of the operational manager having necessary qualifications is checked	Report (Form 6.3.29) (readiness to perform the operation)
2	Availability and completeness of operation plan and operation design are checked. Towing design is approved	Availability of documents on readiness to perform the operation is checked	Conclusion letter; Report (Form 6.3.29) (readiness to perform the operation)
3	Availability and completeness of operation plan and operation design are checked The Manual and towing design are checked	Readiness to perform the operation is checked. Operation performance (except for towing/transportation stage) is monitored	Conclusion letter; Reports (Form 6.3.29) (readiness to perform the operation; operation execution)
4	Availability and completeness of operation plan and operation design are checked. Operation design is approved	Preparation and performance of the operation at all stages (except for towing/ transportation stage) are monitored	Ditto

5.2 Designs for category 3 and 4 MO are subject to review and approval by the Register Head Office (RHO) or the Register Branch Offices when duly authorized by RHO. Plans/designs for category 1 and 2 MO are subject to review and approval by the Register Branch Offices without the RHO authorization. Applications for review of the MO design shall be sent to a relevant Register Branch Office or RHO Location, depending on the operation category.

The set of the MO designs together with a covering letter and the full list of documents presented shall be submitted to the Register for review. On agreement with the Register, presentation of the design by separate parts may be allowed. In so doing, the technical background and organization chart of the MO execution, as well as the full list of documentation to be developed shall be presented together with the first portion of documents, taking into account the requirements and provisions of these Rules.

Technical documentation on design of marine operation shall be submitted by the developer in any way agreed with the Register in electronic form in PDF format to ensure downloading with a view to having unrestricted off-line storage and stamping as per results of the review.

Technical documentation for MO shall be approved in full only upon fulfillment of all the comments by the designer prior to the MO commencement.

5.3 In the course of preparation for operation execution, the quality control plan (examination plan, book of presentation) with indication of the Register control points shall be agreed upon and persons responsible for its execution and maintaining shall be defined.

5.4 At the stage of preparation for operation execution, the surveys shall be carried out, or the documents shall be verified to confirm the following:

availability of approved operation plan and operation design;

completion of construction of the objects or parts thereof;

preparation of the object for operation, including installation of strengthening, buoyancy blocks and auxiliary equipment;

craft readiness;

readiness of process equipment, mounting facilities and materials necessary to carry out an operation (for welding, gas or plasma cutting, bolt tightening, underwater engineering works, pile driving and securing, hydraulic testing, ballasting, etc.);

manufacture, installation and testing of lifting arrangement and lifting appliances;

manufacture and installation of arrangements, grillage for rolling, launching or transportation of the object;

manufacture and installation of towing and mooring arrangements;

readiness of positioning means;

readiness of instrumentation and control system and non-destructive test equipment;

personnel qualifications.

Readiness of process equipment, instrumentation and control system, welding equipment and non-destructive test equipment, etc. shall be confirmed by the effective certificates, verification and calibration certificates and other documents confirming the availability of the specified equipment.

5.5 In the course of the MO execution, monitoring of operation performance shall be carried out. The results of monitoring shall be recorded in accordance with the control points in log books (plans, lists) or other documentation agreed with the performer. If the Register-approved design conditions of operation execution are violated, the causes of deviations shall be reviewed, an appropriate conclusion shall be made and the measures taken on their elimination shall be recorded. When it is needed, inspection of the MO execution conditions (determination of displacements, efforts, parameters of environmental conditions, etc.) is conducted using measuring equipment.

5.6 At the stage of operation execution the following shall be monitored:

environmental conditions of operation execution;

object state and behavior;

adherence to the operation execution procedure;

compliance of the operation execution results with the characteristics and values established in the design;

intermediate acceptances of hidden work and essential structures (if applicable);

non-destructive testing;

maintaining of as-built documentation by the contractor.

5.7 The Register representatives shall be provided with a possibility of being present during the most essential tests, monitoring of equipment and structural components to confirm the compliance of their parameters with the design, and also during the MO performance at large or its particular stages to evaluate the conformity of the permissible environmental conditions for the beginning and execution of the operation. The responsibility for providing access for the Register representatives is imposed upon the organization, which has concluded an agreement with the Register on the MO technical supervision.

5.8 The technical documentation sets relating to the designs of the MO execution shall be kept by the customer. In addition to the designs, the customer shall keep the reports and minutes of operation performance supervision. All necessary documents shall be available at any phase of operation execution.

PART II. GENERAL REQUIREMENTS

1 BASIC PRINCIPLES OF MARINE OPERATION DEVELOPMENT

1.1 MO subdivision

1.1.1 MO are subdivided into two basic groups:
transportation;
construction and assembly.

Both the transportation and the construction and assembly operations may be subdivided into constituent operations the special requirements for which are given in Part III "Special Requirements".

1.1.2 The transportation operations include:
transportation of the object on a craft;
towing of the object;
load in/out operations.

1.1.3 The construction and assembly operations include:
launching of the object at the yard water area;
mating of objects or parts thereof afloat in the shipyard water area or at seat;
installation of the object on site (except for installation of self-elevating and semi-submersible MODU at a drilling site).

1.1.4 Installation of floating objects in the designed position may generally include the following number of individual operations:
launching of the object under sea conditions from a ship/barge;
upending;
positioning;
mating of the objects by float-on method;
installation of position mooring system (except for installation of semi-submersible MODU at a drilling site).

1.1.5 Installation of fixed seabed supported objects includes the following additional operations:
submersion/emersion;
righting up;
ballasting;
pile driving;
penetration into the seabed and berm building-up.

1.1.6 Other operations during object installation:
connection of the object with other structures by means of hoses, cables and piping in the field facilities construction;
establishment of safety zones.

1.1.7 Operations after object decommissioning:
dismantling of the object position mooring system;
seabed scouring near substructure, pile cutting off;
removal of a part of solid ballast;
dismantling (if necessary) of a topside (entirely or by modules);
emersion of the object to a draught ensuring its transportation.

1.2 Basic principles of MO planning and designing

1.2.1 Operations shall be planned/designed and performed regarding safety conditions.

1.2.2 The safe conditions of the MO performance afloat provide for the prevention of:

the threat to the personnel's life and health;

navigational hazard in adjacent area;

pollution and other environmental accidents;

losses and emergence of hazard for the structures of objects, ships and facilities involved in the operation.

1.2.3 Operation planning/designing shall take into account potential contingency and accident situations. When such situation occurs, the object shall remain stable and under control.

1.2.4 The MO planning/designing shall provide the possibility of their performance under safe conditions or of their suspension when environmental design parameters are exceeded and other contingency and accident situations occur. If the operation afloat enters the phase when it cannot be suspended or terminated, such phases shall be subject to special consideration in the design and safe conditions for them shall be determined.

1.2.5 The MO design shall be based, as rule, on approved principles, technology, systems and equipment. All potential contingency situations shall be reviewed during the design and the relevant action plans shall be developed. Such plans shall include a list of additional spare (consumable) equipment on board the object and supply vessels, the activities of the support personnel, the descriptions of procedures for hazard prevention, etc.

1.2.6 The MO planning/designing shall be carried out by the competent organizations meeting the applicable requirements of Section 8 and 12.2, 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[1]. The organization compliance with the specified requirements is confirmed by Report on Survey of Firm (form 6.3.19) with Annex (form 6.3.19F).

1.2.7 The MO design, organization and performance shall be carried out in accordance with the provisions of these Rules, and also with the recognized calculation methods, norms, standards (national and international) and reference documents approved by the Register. Use of the other, more effective calculation methods and technical approaches is permitted provided they ensure required safety level set by these Rules. All additional standards, norms and methods shall be submitted to the Register for review and agreement.

1.2.8 When MO are planned and designed, the following work sequence is recommended:

review and generalization of the requirements, rules and regulations, standards relating to MO under consideration;

review and generalization of the environmental conditions;

general planning of the operation including establishment of the basic principles of operation performance, equipment needed, economic factors, etc;

definition of the environmental conditions and restrictions acceptable for operation performance;

brief description of actions in operation performance;

execution of calculations and engineering developments;

development of the Manual.

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[1] Hereinafter referred to as "the RTSCS".

1.2.9 The composition of design basis and output documentation shall be determined at the early stages of design. The definition of environmental conditions and restrictions, as well as brief design descriptions shall ensure a general basis for the design of the operation, and also give a clear insight into all the stages of the MO performance and monitoring. The description of environmental conditions shall include basic parameters, characteristic conditions, design loads and reactions, load combinations, etc. The brief design descriptions shall contain planned and controlled actions, calculation, simulation[1] and design methods used, initial specifications, accepted criteria, etc.

1.2.10 The organization chart of operation performance shall describe distribution of responsibility among the persons involved in the operation and the functional duties of the key personnel.

[1] Requirements for the calculations and model tests of the object launching, tilting, floatation and setting down on the seabed are given in Appendix 2 to Part III "Special Requirements".

2 ULTIMATE STATES IN MARINE OPERATIONS

2.1 The MO performance on object transportation, positioning or installation is unsafe or prohibitive if the efforts and deformations of structures in the object or transport craft structure, securing system, towing line or the displacements of the object and supply vessels reach the relevant ultimate states.

Conducting MO, the following kinds of dangerous states of structures, arrangements and equipment of the object, transport craft and supply vessels shall be prevented:

excessive material deformations affecting operability;

loss of structure form stability;

formation of fatigue cracks;

brittle failures;

breakages of ropes, chains and other connecting elements.

2.2 During the MO performance the following are considered as ultimate states:

the first (basic) ultimate state corresponding to the formation of breaking forces in the structure of the object, in its securing system, anchor, mooring arrangements and bumpers, and also the impermissible displacements of the object and supply vessels which, if exceeded, may cause their failure or prevent the MO performance;

the second (operational) ultimate state corresponding to the formation of permissible forces and displacements in the structure and securing system, which do not cause any damages or grave disruptions of the MO normal conditions, but are borderline for the normal operating conditions;

emergency ultimate state corresponding to the damage (destruction) of any main component of the structure or its securing system;

in case of unrestricted MO and provided that the number of design loadings in the operation may reach or exceed several thousand cycles, the fatigue ultimate state wherein the braking forces corresponding to the first (basic) ultimate state are determined with due regard to fatigue conditions in the structural components of the object (securing system), shall be additionally considered taking into account the cyclic loads.

2.3 When MO is designed, all the above-mentioned ultimate states, except for fatigue one which is taken into account, if necessary, shall be considered.

It is necessary to observe the conditions that preclude the onset of the ultimate states in question specified in 2.4, Part II "Hull" of the MODU Rules or in the relevant chapters of Part II "Hull" of the Rules for the Classification and Construction of Sea-Going Ships[1].

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[1] Hereinafter referred to as "the Rules for the Classification".

3 ENVIRONMENTAL CONDITIONS, WEATHER FORECAST, INVESTIGATIONS

3.1 For MO afloat, the design recurrence of external effects is established in each particular case proceeding from the operation duration having regard to the operation area, season and potential consequences of exceeding the assumed design parameters of the effects.

3.2 For the operations afloat or their separate stages of a short-term duration (less than 72 h) defined as weather-restricted, the design values of external effects may be assumed proceeding from the actual technical capabilities of ships and equipment in use taking into account a specific weather forecast.

3.3 When establishing the design environmental conditions, their seasonal variations shall be taken into account. The design parameters shall be assumed with due regard to the specific time of the year wherein the MO performance is planned. The local environmental conditions not reflected in the generalized statistics shall be taken into account, namely: tide variations, wave and wind conditions, current variations. Sailing directions, harbour regulations, etc. shall be sources for such information.

3.4 When developing the MO design, all environmental conditions which may affect its performance shall be subject to consideration. Conditions of general importance are wind, waves and currents. It is necessary to consider ice, tide variations, temperature, visibility, precipitation, fog and other dangerous meteorological phenomena, as well as hydrographic (seabed topography, sea depth, water area dimensions) and geological conditions at the object installation area. If necessary, seismic effects during the object installation (until it is secured in a designed position) may also be considered.

The parameters of external conditions shall be assumed for the immediate areas of the MO performance.

Description, parameters and external effects calculation methods are given in 2.2, Part II "Hull" and in 2.5, Part IV "Stability" of the MODU Rules.

3.5 The design parameters of environmental conditions shall normally be adopted on the basis of generally recognized and reliable observed data of sufficient duration and investigations related to the area in question. The observed data over 3 — 4 years period, as a minimum, shall de used. If the data for a specific area under consideration are unavailable, the environmental conditions parameters may be established on the basis of calculations according to the methods recognized by the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). The information on collection and origin of environmental conditions data shall be submitted to the Register for review and approval.

3.6 In order to describe environmental conditions, the generally accepted parameters used in determination of external effects, loads and structure reactions shall be applied. When describing external effects of casual character, long and short-term statistics shall be used. Special emphasis shall be placed on the assessment of reliability of statistical techniques and their results. The long-term (condition) functions of variation in such environmental conditions as wind, waves, currents, etc. shall be primarily described by certain statistical distributions. When evaluating extreme values of external effect parameters, the recognized extrapolation techniques may be used.

3.7 The design parameters of environmental conditions, statistical distributions of their values and directions adopted in the MO design shall be submitted to the Register for review and approval.

3.8 The scope and composition of investigations in the MO areas associated with essential change of the structure draught (mating by float-on method, upending, installation on the seabed) are adopted in accordance with the type, dimensions, importance of the object and available information on environmental, including geological, hydrographic and other conditions in the areas under consideration. The selection of techniques and the range of investigations shall be compatible with environmental conditions of the area in question. When selecting the range of investigations, the following shall be taken into account:

errors in positioning of craft used for investigations;

errors of navigation equipment used in the MO performance;

possible deviations of the object during the MO performance under actual conditions.

3.9 The results of investigations shall be submitted to the Register for review. Such reports shall include:

information on the time of investigation and on the performer;

comprehensive description of the equipment used and of the procedure of field and laboratory studies;

investigation results;

evaluation of the errors and restrictions in application of investigation results.

3.10 The topographic survey of the seabed shall be conducted at the object installation site.

Depth-sounding accuracy at the object installation area shall be within ± 0,1 m. For other MO types (towing, etc.) the sounding accuracy is determined in each particular case of the MO performance. Special emphasis shall be placed on potential seabed movements. In addition to the generally accepted depth-sounding techniques, it is recommended to scan the seabed with a side-scan sonar or other similar device in areas of potential underwater obstructions (boulders, anchors, debris, etc.).

3.11 Geological investigations are conducted for the immediate area of the object installation. The scope and composition of geological investigations at the object installation site may be determined on the basis of the documents of the object general design as its amount of information exceeds required minimum for the MO performance. The investigation documents shall contain data obtained from the field and laboratory investigations of the seabed as well as geotechnical sections with data on bedding of soils and design values of their physical and mechanical properties. Particular attention shall be given to geological conditions needed for evaluation of the holding capacity of piles and ship anchors or the anchors of roads facilities during the object positioning. The results of detailed geological investigations may also be required while handling the problems of the object installation, in particular, for setting down the object on the seabed. Seabed properties shall be defined for planned anchorages during the operation.

3.12 The MO design shall include arrangements for receiving weather forecasts prior to and during the operation. Such weather forecasts shall be based on reliable sources and shall consider the nature and duration of the planned operation. The weather forecast shall be in writing.

In addition to the general description of the weather situation and its predicted development, the weather forecast shall include:

wind velocity and direction;

height, mean and maximum period and direction of wind and long-period waves;

information on precipitations, lighting, ice conditions, etc.;

data on sea level variations (tide variations, storm surges, etc.);

visibility;

temperature;

barometric pressure.

The listed parameters shall be predicted for a period of 12, 24, 48 and 72 h. A forecast for several days shall also be provided.

Special emphasis in weather forecasts shall be placed on the accuracy and reliability of determination of such predictable parameters as average wind velocity, wave parameters (height and period).

The weather forecast shall take into account the worst scenario of weather conditions development. This is of primary importance for areas with unstable weather and for forecasts of poor reliability. The weather forecast may be regarded as favourable for the MO start if all the above-listed parameters do not exceed acceptable metocean parameters.

3.13 Depending on the extent to which the performance of different MO types is affected by weather conditions, it is recommended to discern three levels of weather prediction: A, B and C.

Level A covers MO most sensitive to weather conditions. Among these are mating of a substructure with an object topside on high seas, long-range ocean towing under severe environmental conditions, positioning and installation of the object (category 4 operations).

Level B covers weather sensitive operations the violation of which may result in significant financial losses. Among these are launching or mounting operations on high seas, long-term towing, etc. (category 3 operations).

Level C covers operations less sensitive to weather conditions and operations carried out on a regular basis. Among these are shipyard operations: lifting and mounting operations when the object weight does not exceed 300 t, towing in sheltered waters and others (category 1 and 2 operations).

3.14 Depending on the prediction level, the weather forecasts shall meet the requirements of Table 3.14.

Table 3.14

Weather Forecast Levels

Weather Forecast Level	Is availability of environmental conditions data for the operation performance needed?	Number of the independent weather forecast sources	Maximum weather forecast interval, in h.
A	Yes	2	4[1)]
B	No[2)]	2[3)]	4
C	No	1	12

[1)] Smaller intervals may be required for the operations most sensitive to weather conditions.
[2)] The need for metocean data for the particular operation site is considered and determined separately in each particular case.
[3)] When properly justified, the weather forecast may be based on one source only.

3.15 For MO particularly sensitive for certain environmental conditions such as waves, swell, current, tide etc., systematically monitoring of these conditions prior to and during the operation shall be arranged. Monitoring shall be systematic. Responsibilities, monitoring methods and intervals shall be described in a procedure. Essential monitoring system shall have back up systems. Predicted variations of theses parameters during the MO execution shall be based on monitored variations, tabulated values and forecasted variations. Any unforeseen monitoring results shall be reported without delay.

Tidal variations shall additionally be monitored a period with the same lunar phase as for the planned operation.

4 ORGANIZATION AND MANAGEMENT OF MARINE OPERATIONS

4.1 MO shall be conducted in accordance with the plan and design developed as a part of the structure design or with the independent design approved by the Register and also with due regard to good seamanship that prevents unnecessary risk. The responsibility for the observance of necessary conditions, rules and requirements of the MO design rests with the operational manager.

4.2 The MO design/plan shall describe in detail organization of the operation execution and establish responsibility of the key personnel involved in MO, and in possible emergency and accident situations.

4.3 The organizations involved in the operation (performers) shall have necessary licenses and certificates in accordance with the existing legislation. The organizations shall comply with the general requirements listed in Section 8 and 12.2, Part I "General Regulations for Technical Supervision" of RTSCS. The organization compliance with the specified requirements is confirmed by Report on Survey of Firm (form 6.3.19) with Annex (form 6.3.19F).

In addition, the firms involved in underwater surveys shall comply with the applicable requirements of 9.2 and 9.3.3, Part I "General Regulations for Technical Supervision" of RTSCS. The organization compliance with the specified requirements is confirmed by Report on Survey of Firm (form 6.3.19) with Annex (form 6.3.19SS).

4.4 The operational manager and personnel involved in the operation shall possess adequate qualification and competence, have an appropriate experience and knowledge within the area of their responsibility.

4.5 The representatives of the supervisory organizations and state supervision bodies shall familiarize themselves with all aspects of the planned operations and possess a thorough knowledge with respect to limitations and assumptions for the design. A briefing regarding responsibility, communication, work procedures, safety, etc. shall be performed for the representatives of the supervisory organizations and state supervision bodies.

4.6 For operations with a planned duration exceeding 12 h the work of the personnel shall be arranged in several shifts and an appropriate number and composition of the personnel shall be provided.

4.7 Particular emphasis shall be placed on ensuring reliable communication in the MO organization. Communication lines, primary and secondary means of communication shall be clearly defined in the special section of the MO design. The planned flow of information, a communication language, etc. shall be also presented in the design.

4.8 In the MO course, the direct designer's supervision shall be carried out or a procedure for the designer's prompt approval of the results of essential work performance during the operation and agreement of alterations to be made shall be established. A procedure for amending the plan and design which ensures agreement with the parties concerned and informing the participants shall be established.

4.9 Prior to MO, all craft, structures, equipment, systems, instrumentation used during MO shall be inspected, calibrated and tested in accordance with the design and existing standards. Both primary and secondary structures, equipment, systems, components and assemblies shall be tested.

4.10 The control over the operational procedure shall be carried out in compliance with the Quality Control Plan, which defines points, scope and methods of control for all the participants in the operation, as well as the supervisory organizations and supervision bodies.

4.11 The actual conditions of particular MO performance afloat shall not be different from the conditions specified in the design of relevant operations.

4.12 The MO preparation and step-by-step execution shall be recorded. It is recommended to include model forms of the relevant reports into the Manual.

5 ENVIRONMENTAL PROTECTION

5.1 General

5.1.1 Protection of the environment during the MO execution shall be ensured through the development and implementation of a set of measures and arrangements aimed at mitigation and prevention of unfavourable impact on the environment in compliance with the provisions of the International Convention for Prevention of Pollution from Ships[1] and Annexes I — VI thereto, and the Guidelines on the Application of Provisions of the International Convention MARPOL 73/78.

5.1.2 Within the inland waters, territorial sea, on continental shelf and in the exclusive economic zone of the Russian Federation MO shall be performed meeting the environmental protection requirements in compliance with the Federal Law "On Environmental Protection", other normative legal acts of the Russian Federation and subjects of the Russian Federation.

5.1.3 Due account shall be taken of the environmental limitations for the MO area.

5.1.4 The environmental protection shall include:

organizational arrangements;

measures to prevent marine environment pollution;

measures to prevent air pollution;

measures to mitigate impact on the marine biota;

engineering and environmental monitoring.

5.1.5 Organizations involved in preparation of the objects and craft for MO are responsible for observing the decisions relevant to the environmental protection made in the design, as well as for observing the national legislation and international environmental agreements.

5.1.6 Regulations, procedures and policy of the object owner in the field of environmental protection shall be brought to the notice of the whole personnel involved in MO.

5.1.7 All violations of standards and regulations, as well as deviations from the MO procedure, which may be considered as potential sources of environmental risk, shall be recorded.

5.1.8 The operational manager is responsible for the personnel and ships' crew adherence to health, safety and environment (HSE) requirements specified in these Rules.

5.2 Basic activities aimed at environmental impact mitigation

5.2.1 Organizational arrangements include:

checking availability of ship's documentation on environmental protection;

availability of the Shipboard Oil Pollution Emergency Plan and Garbage Management Plan;

checking of the technical facilities designed for the prevention of oil, sewage and garbage pollution, as well as air pollution;

ensuring of oil, oily and sewage water, and garbage intake from craft used in MO;

establishment of a procedure for handling the industrial waste;

briefing and examination of crew members and personnel involved in MO regarding environmental protection.

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[1] Hereinafter referred to as "MARPOL 73/78".

5.2.2 Measures to prevent marine environment pollution shall include:

regular examinations and maintenance of pumps, machinery, piping, shut-off fittings and hoses;

installation of coamings and drip trays to prevent spillages;

observation of safety measures during pumping, intake/discharge of fuel, bilge and sewage waters, storage and discharge of oily waste and garbage.

5.2.3 Measures to prevent air pollution may include:

use of low-sulphur fuels, catalysts and filters;

fine adjustment of engines and boilers;

use of antismoke fuel additives;

installation of silencers and spark arresters of exhaust gas pipes and uptakes;

installation of filters in smoke ventilation and ventilation systems, timely cleaning and replacement thereof.

5.2.4 Impacts on marine biota occur during installation of supporting structures and anchors on the seabed, performance of underwater engineering works, as well as during anchoring of auxiliary vessels and manifest themselves in the following:

increase in water turbidity due to rise of the near-bottom suspended matter and seabed moving;

transition of the harmful contaminants which are a constituent part of long-term sedimentation into a dissolved state;

forced migration of fish, marine mammals and birds from the working area caused by the presence of the object, craft and personnel and associated with noise, sea water movement, artificial lighting, emission of environmentally harmful substances.

5.2.5 Measures to mitigate impact on marine biota shall provide for:

selection of environmentally safe period throughout a year for the MO execution and lay out of safe towing/transportation routes;

prohibition of work performance and craft movement in areas not stipulated by the MO design;

exclusion, in general, of explosive works (underwater seabed ripping and other underwater engineering works are permitted to be performed by explosive method only if the construction management plan includes a feasibility study, which excludes the possibility of performing these works by any other methods).

5.2.6 To reduce the amount of waste provision shall be made for repeated use of water during bore cleaning and hydraulic testing of process piping. Water displaced from the pipeline shall not be discharged into the sea without pre-cleaning.

5.2.7 Incoming inspection of engineering structures and materials shall establish conformity of material quality to the design in respect of the content of toxic substances hazardous to marine biota.

5.2.8 Engineering and environmental monitoring shall ensure:

measurements, monitoring and control over the emissions of contaminants to atmosphere and discharges of untreated sewage into marine environment from the object and craft;

monitoring the established indicators of water content and properties at the border of processing discharge zone of the water area adjacent to the object;

waste storage monitoring on-site;

check for compliance with the standards for ultimate discharges and emissions.

6 NAVIGATIONAL SAFETY OF MARINE OPERATION

6.1 Navigational safety during towing/transportation

6.1.1 Navigational safety of MO is achieved through adequate operation management, proper organization of watch keeping and communication, thorough preparation for transit at sea and/or through inland waterways, regular receipt of navigational information by marine or landline transmission, by radio in the form of NAVAREA warnings in accordance with the World-Wide Navigational Warning Service, NAVIP navigational warnings concerning the information not included in NAVAREA, PRIP (COASTAL WARNINGS) in accordance with the regional systems of navigational warnings and LOCAL WARNINGS for harbour water areas, receipt of navigational information through publications (Notices to Mariners of the Head Department of Navigation and Oceanography of the Ministry of Defense of the Russian Federation and hydrographic offices of fleets) and weather forecasts, through uninterrupted operation of electrical and radio navigational devices, as well as compliance with the requirements of Annex 28 "Guidelines for Safe Ocean Towing" of the Annexes to the Guidelines on Technical Supervision of Ships in Service and due to compliance with the requirements/regulations of good seamanship.

6.1.2 Preparation for MO includes:

completing of the established ship folio with nautical charts, manuals and nautical publications;

receipt of materials for updating the ship folio;

selection of nautical charts, manuals and nautical publications for the scheduled transit, updating thereof;

preparation of navigational systems and equipment and, if necessary, repair thereof, replenishment of spare parts and tools, determination (testing) their parameters and corrections;

receipt of information on mine, ice and MC (if necessary, conclusion of an agreement on hydrometeorological center(s) pilotage;

study of navigation area, route selection and route planning — input of route points and other navigational information into the receivers of the global navigation satellite system (GNSS) and radio navigation system;

study of the selected transit route with officers;

checking availability of information on ship's maneuvering characteristics;

checking of general alarm system operability, expiring dates of pyrotechnic signal means.

6.1.3 When studying the area of unrestricted MO, the following shall be taken into account:

general navigational-hydrographical characteristic of the area, remoteness from shore, presence of navigational hazards, seabed topography and depth, presence of shoals, distinguishing depths and their proximity to the planned route;

specific metocean criteria: prevailing winds, cyclone paths, wave conditions, probability of reduced visibility, ice conditions and limits of floating ice and icebergs, possible icing areas, active currents;

availability of radio navigation systems, the receivers of which are provided for the MO participants, their operating modes, accuracy, possible restrictions on use;

pilotage restrictions recommended by hydrometeorological centers(wave height, wind velocity, wave direction, etc.);

broadcasting for different areas of navigation the weather forecasts, storm and ice warnings, navigational information.

6.1.4 When studying an area with restricted navigation conditions and port approaches, the following shall be considered additionally:

navigational and hydrographic features of the area: recommended paths and routes, fairways and channels, length and width of their tracks; hazardous and forbidden zones, zones prohibited for navigation and restricted areas of navigation, areas of heavy ship and ferry traffic, fishing, development and production of oil and gas; traffic separation schemes; possible anchorage and characteristics thereof;

hydrological features: tidal and surging phenomena; characteristics and degree of wind waves; water desalination; influence of all these factors on allowable draught and speed when passing through shallow waters;

occurrence of heave of sea;

availability of navigational equipment in the navigation area, operating mode and restrictions on use of the equipment; the applicability of radars for positioning of the ship; distinctive signs to identify navigational references and warning markers;

possible methods and necessary frequency of positioning in order to be kept within the limits of fairways or channels;

zone of operation, types of maintenance of the Vessel Traffic Service (VTS);

local regulations applied in ports and areas constrained by navigation conditions.

6.1.5 When preparing passage through the most difficult areas, it is necessary to resort to mathematic simulation, modeling on simulator or testing in model basin.

6.1.6 After studying the navigation areas, the towmaster of this MO phase together with the tug(s) master(s) shall select the transit route by the general nautical chart(s) dividing the entire route into sections depending on situation and MC, shall plan arrangements to ensure safety of navigation. Route planning shall be made on small and large-scale navigational charts of a scale which is the most favourable for the area concerned. In so doing, the information from large-scale charts and plans, which may contain important navigation data, shall be used. Development of transit through the RF inland waterways shall be performed using the Atlas of the Unified Deep Water System of Russia.

6.1.7 Simultaneously with route planning, preparation of the small and large-scale navigational charts and plans shall be carried out. If necessary, safety contour shall be plotted and isolated dangers shall be defined; the visibility range of lighthouses and signs (taking into account the height of observer's eye) and lighting intensity shall be marked, the lighthouse sectors indicating the hazards, boundaries of zones prohibited for navigation, zone of operation the VTS shall be more clearly defined. When planning the route, the course at safe distances from the navigational hazards shall be plotted, and the points of no return (PNR) and, if the chart scale permits, the PNR start/end points shall be marked, check bearings to selected reference points and/or distances thereto shall be measured and plotted; beams and control four-point-bearings shall be marked. When the alterations of course are frequent, the length of each route section shall be measured and indicated at the beginning of the section, duration of the route on each section at designed speed shall be calculated and indicated on the same section.

On sections where the ship's course runs close to the hazards, it is preferable to plot the safety isolines of the navigational parameters on the chart. The PNR coordinates, boundaries of fairways, hazardous and forbidden zones, allowable cross-track deviations from the selected route and PNR, coordinates of the reference points and other necessary information shall be input into the receivers of GNSS and radio navigation system.

6.1.8 When the equipment is rendered operative, its technical parameters shall be checked. The equipment is considered operative, if its operating parameters comply with the manufacturer's specification. The navigational equipment operability shall be checked as follows:

for gyrocompass — by steadiness of landmark bearings if it was not switched off during the ship's anchorage;

for GNSS receiver — by availability of indication of last observations data;

for a radio navigation system receiver — by steadiness of the navigational parameter readings.

6.1.9 Printers shall be subject to checking for the availability of paper, toggle switches of sensors and printing types shall be switched on, verification printout shall be made, selected print interval for the port waters shall be set. Moreover, time readings of the reverse recorder shall be set, verification printout shall be made, time shall be marked on the course recorder. Echo sounder shall be subjected to checking for the availability of paper and, if necessary, depth alarm shall be installed. Information sensors of the navigation system or video plotter shall be selected. The automatic alarm for traffic ship monitoring shall be activated.

6.1.10 Watch keeping shall be so organized as to ensure reliable safety of navigation. Throughout the passage, the watch-keeping personnel shall meet actual navigational conditions and circumstances. When appointing the watch-keeping personnel, the following shall be taken into consideration:

ensuring of continuous watch;

weather conditions, visibility, day time;

navigation area characteristics, including vicinity of navigational hazards, traffic density, possible presence of small craft with poor discernibility, high-speed craft, ferries, etc, which require discharge of specific duties by the watch officer;

possibility and practicability of using the shipboard navigational equipment, and technical condition thereof;

any other requirements for watch keeping stipulated by special operating conditions.

6.2 Navigational safety at the installation site

6.2.1 The object owner is obliged to inform Head Department of Navigation and Oceanography of the Ministry of Defense of the Russian Federation for publication in the Notices to Mariners:

not later than 120 days in advance — about commencement of installation and dismantling works;

immediately — about commencement and completion of works, as well as about the results of inspection at the installation site after dismantling, with the reports enclosed.

6.2.2 At the work performance area a safety zone extending over 500 m from the outer edge of the object shall be established.

6.2.3 If the primary warning alarm and navigational equipment of the object are inoperative, the work performance area shall be provided with IALA[1] buoyage, Region A, and secondary warning alarm and navigational equipment shall be installed on the object. The composition and characteristics of the secondary warning alarm and navigational equipment shall be defined by the Hydrographical Services of the Fleet on the basis of materials presented by the organization qualified for installation of the object.

6.2.4 To designate the existing underwater dangers, it is recommended for the time of work performance to deploy buoys fitted with visual alarm and radar reflectors.

6.2.5 For operations performed at the installation site, the MO organization chart shall provide for monitoring center for navigation situation in the work performance area, located on one of the craft involved in the operation.

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[1] The International Association of Marine Aids to Navigation and Lighthouse Authorities formerly called the International Association of Lighthouse Authorities (IALA) adopted in 1980. The IALA defines one system of marks specifying the shapes, colours and characteristic lights of buoys depending on their purpose.

7 REQUIREMENTS FOR STRUCTURES, SYSTEMS AND EQUIPMENT FOR MARINE OPERATIONS SUPPORT

7.1 Arrangements, equipment and systems

7.1.1 Object arrangements and equipment used in MO include towing, anchor, mooring, bumper and lifting arrangements, positioning system, ballast system, arrangements for on-site installation, as well as electrical, mechanical, instrumentation, navigation and other specially installed systems, devices and equipment which are essential for movement, positioning and installation of the object in a design position. The listed arrangements, and equipment shall ensure complete monitoring of the object throughout MO.

Systems, arrangements and associated equipment shall be designed, fabricated, installed and tested in accordance with the relevant standards and provisions Part III "Equipment, Arrangements and Outfit" of the MODU Rules, Part III "Equipment, Arrangements and Outfit" of the FOP Rules and Part III "Equipment, Arrangements and Outfit" of the Rules for the Classification. The above requirement does not apply to process systems and equipment installed and used only during performance of the operation, and which operating conditions differ from those observed during the object operation. Selection of systems and equipment shall be based on a thorough consideration of their conformity to functional and operational requirements for MO. Emphasis shall be placed on operation reliability and resistance in contingencies.

The issues of ensuring the object course-keeping qualities and the relevant equipment are subject to special consideration by the Register.

7.1.2 Towing, anchor, mooring and bumper arrangements shall be designed for all relevant loads specified in 2.3, Part II "Hull" of the MODU Rules, 2.3, Part II "Hull" of the FOP Rules or in relevant chapters of Part II "Hull" of the Rules for the Classification. When designing the towing, anchor, mooring and bumper arrangements the "weak link" principle shall be applied which prevents the damage of the main components of the structure (arrangement) under occasional overloads exceeding the design ones. The structure shall withstand local loads without the loss of overall strength and stability.

7.1.3 Depending on the MO complexity and duration, particularly close control over the operation conditions and functioning of various systems both in normal and critical situations is needed to ensure its safe execution. It is generally recommended to consider the following electrical and mechanical systems:

propulsion plant;
back-up propulsion plant for power supply in extreme situations;
machinery monitoring systems;
valve (slide valve) monitoring systems;
ballast arrangements;
instrumentation systems;
fuel system;
power lines;
compressor systems;
fire extinguishing systems;
navigation systems;
communication systems.

7.1.4 All systems, devices and equipment shall be checked and tested prior to the start of operations in accordance with the acceptance list.

7.1.5 The instrumentation systems and equipment shall generally ensure monitoring of:
loads and deformations of structures, separate components and arrangements;
environmental conditions;
ballasting and stability conditions;
heel, trim and draught of floating objects;
object position (navigational parameters);

object under keel clearance;
object penetration into the seabed.

7.1.6 The most important systems and equipment including computer networks, etc. shall be duplicated. The reliability of power supply to arrangements and equipment shall be ensured by availability of standby and emergency sources of power, which will be activated when the main source of power fails. All systems shall be tested in accordance with the RTSCS. In the Manual, the time necessary for change-over or substitution of the system shall be assessed. The requirements for design and manufacture of primary and back-up systems shall the same. Back-up systems may be used as an integral part of primary system. For systems consisting of multiple independent units, the back-up may be provided by having a sufficient number of available spare units. Automatic control systems shall be provided with a possibility for manual overriding.

7.1.7 Non-traditional arrangements and equipment specially installed on the object (joining elements, etc.) shall be properly designed and calculated for loads applied to the object in the MO course.

For review and approval of such arrangements, the following documentation shall be submitted to the Register:
equipment description;
general arrangement plan;
strength calculations;
material specifications;
specifications (procedures, processes) for manufacture and installation.

7.1.8 In some cases, in the MO course, the temporary reinforcement or disassembly of separate parts of the object structure, arrangements and equipment may be needed, which shall be properly reflected in the design of the MO performance.

7.1.9 Besides the requirements of this Section, the arrangements, equipment and systems for the MO support are covered by the requirements of 1.3, Part III "Special Requirements".

7.2 Structures

7.2.1 All loads on the object structure, arrangements and equipment and the object displacements shall not exceed the allowable levels set in the design of operation performance. The loads in the MO course shall be determined in accordance with the requirements of 2.3, Part II "Hull" of the MODU Rules, 2.3, Part II "Hull" of the FOP Rules and relevant chapters of Part II "Hull" of the Rules for the Classification.

7.2.2 Structural elements and components used in MO shall be as far as possible flexible and pliable within the prescribed limits. It is not recommended to use an increased air pressure in floating components or underwater air caissons to improve safety in the event of structural damages to the object. This may, however, be permitted in special cases upon thorough consideration of some systems like a drain system, etc. with due regard to the damage consequences, operation duration, etc.

7.2.3 When developing structure components for MO, transmission of tensile stresses through the thickness of rolled steel elements (plates, beams, etc.) shall, as far as possible, be avoided. Transmission of concentrated loads to plate structures shall only be arranged through the intermediate stiffening elements (reinforcements).

7.2.4 Appendages of the structure located above the waterline shall be designed or protected so as to prevent trapping of water when submerged into water during the object motions, etc.

7.2.5 Structural elements and their connections are recommended to group according to the following indications:
type of stresses;
presence of cyclic loading;
presence of stress concentrations;
presence of contraction;

loading rate;

consequences of failures.

It is recommended to consider the following categories of structural elements:

special — the most essential parts of primary structural elements, which define their strength, carry main loads, undergo stress concentration, etc.;

primary — structural elements, which define overall integrity of the structure whose damage may result in the hazard to human life, etc.;

secondary — structural elements of less importance whose damage does not threaten human life or does not result in significant economic consequences.

The listed categories define requirements for materials and extent of inspection and examination.

7.2.6 The material quality shall meet the design operational conditions, ensure necessary properties (strength, ductility, toughness, weldability, corrosion resistance), and meet the requirements of current standards specified in 1.4 — 1.7, Part II "Hull" of the MODU Rules, 1.4 — 1.7, Part II "Hull" of the FOP Rules.

7.2.7 Besides the requirements of this Section, the requirements of 1.3, Part III "Special Requirements" cover the structures supporting MO.

PART III. SPECIAL REQUIREMENTS

1 REQUIREMENTS FOR BUOYANCY AND STABILITY OF OBJECT, STRUCTURE AND THEIR COMPONENTS DURING MARINE OPERATIONS

1.1 General requirements for buoyancy and stability

1.1.1 General.

1.1.1.1 The requirements of these Rules specified for the buoyancy, stability and damage stability of any floating components of the structure and the whole object at large shall be fulfilled at all MO stages.

1.1.1.2 When stability is calculated, it is not recommended to take into account the object structure parts located above the deck, which may occasionally (during significant motions) submerge into water. The effect of such structures on object stability may be admitted in specially specified cases if properly justified. Where additional solid ballast or loads are used to improve stability, reliable sea fastening of the solid ballast or loads shall be ensured.

1.1.1.3 Drainage openings to avoid unacceptable accumulation of water on the object shall be provided in its structure. Where such openings are impracticable, the object stability shall be estimated with due regard to the potential additional volume of water.

1.1.1.4 In the calculations of stability and reserve buoyancy, due allowance shall be included to account for possible changes in mass, displacement of the object center of mass, density of ballast and sea water. Correction for free surface effects in ballast tanks and other compartments containing liquids shall be included.

1.1.1.5 When estimating stability, wind and wave effects shall be assumed in accordance with 2.5, Part IV "Stability" of the MODU Rules or 2.1, Part IV "Stability" of the Rules for the Classification.

1.1.1.6 Inclining tests of floating modules shall be normally performed during construction of the object and prior to MO.

1.1.1.7 The inclining test procedure shall take into account the requirements given in 1.5, Part IV "Stability" of the MODU Rules. The Register may waive the inclining test provided that the requirements of 1.5.7, Part IV "Stability" of the Rules for the Classification.

1.1.2 Stability and freeboard.

The specified requirements apply to floating structures whose blocks are launched, outfitted and mated afloat.

The freeboard of intact structures and the substructure when afloat or during local towing shall not be less than 2 m or be equal to a significant wave height (with 13 % probability of exceeding level) plus 0,5 m, whichever is greater. Upon agreement with the Register, the application of the requirements specified in 1.2.2.2 is permitted.

For a damaged substructure, when water enters one of the tanks or compartments, the substructure shall remain afloat. In this case, the requirements for the damage waterline specified in 2.5.1, Part V "Subdivision" of the MODU Rules shall be complied with.

1.1.3 Initial metacentric height.

For an intact structure during the long period of being afloat (construction, unrestricted towing), the initial metacentric height (corrected for free surface effects and effects of air cushions in tanks) shall be at least 1,0 m.

For a damaged structure (with a compartment or tank flooded) the initial metacentric height shall be positive.

Where positioning systems: anchor system, tow lines, mooring lines (from ships and buoys), slings are available, the initial metacentric height shall be calculated with regard to the effect of the above link systems.

1.1.4 Stability curves.

For structures, while being afloat, within the whole range of draughts, i.e. from the initial draught (at the beginning of construction) till the one corresponding to the mass when floating out from the shipyard, stability curves with respect to the most unfavourable inclination axes shall be plotted.

The arms of the righting moment curve shall be positive within the range from zero till the angle corresponding to the second intersection of the above curve with the heeling moment curve or till the angle of heel corresponding to the second intersection of the above curve with the heeling moment curve or till the angle of heel corresponding to the entry into water of the nearest opening considered to be open (as defined in 1.4.2, Part IV "Stability" of the MODU Rules).

1.2 Additional requirements for buoyancy and stability

1.2.1 Self-floating structure.

1.2.1.1 For intact structure:

.1 the cross-curves of stability shall remain positive to the next inclination angle beyond equilibrium:

$$\vartheta \geq (\vartheta_{max} + 15 + 15/h), \text{ max } 40° \qquad (1.2.1.1.1)$$

where ϑ_{max} = maximum dynamic inclination due to wind and waves, in deg;
h = initial metacentric height, in m.

For MO of a short duration covered by a reliable weather forecasts (short-term towing, installation on site) a relaxation of the requirement (1.2.1.1.1) may be accepted when the inclination angle may be $\vartheta \geq 20°$;

.2 relationship between the areas formed at the intersection of the righting moment curve with the wind heeling moment curve

$$(A + B) \geq 1{,}4\,(B + C) \qquad (1.2.1.1.2)$$

where areas *A*, *B* and *C* are formed as specified in Part IV "Stability" of the MODU Rules.

1.2.1.2 For damaged structure:

.1 the relationship shall be fulfilled

$$(A + B) \geq (B + C); \qquad (1.2.1.2.1)$$

.2 a structure with one tank or tower flooded shall remain afloat and the requirements for damage waterline specified in 2.5.1, Part V "Subdivision" of the MODU Rules shall be complied with.

1.2.2 Transportation and towing.

1.2.2.1 Barge transporting.

Relationships (1.2.1.1.1) and (1.2.1.1.2) shall be fulfilled for an intact barge.

During loading the object on a barge, the latter shall have a metacentric height value of at least 1,0 m.

The transverse metacentric height of the barge during transportation shall not be less than 0,3 m with regard to free surface effect.

The range of the righting lever curve shall generally exceed 40°.

The range of the righting lever curve less than 30° is not permitted. Where the range of stability is more than 30° but less than 40°, it shall be shown that the maximum design angle of roll is less than the angle corresponding to the maximum righting arm.

Barge stability calculations shall take into account changes in the design CoG position ± 1 m in vertical direction and shall also consider the reserve of stability adopted by the shipowner.

When damaged, the barge shall remain afloat with one compartment flooded and the requirements for damage waterline specified in 2.5.1, Part V "Subdivision" of the MODU Rules shall be complied with.

When evaluating transport barge stability, the righting moment due to the cargo (structure blocks) entering into water shall not be considered. On the contrary, it shall be allowed for the possibility of barge compartment or cargo flooding. For a damaged barge, relationship (1.2.1.2.1) shall be fulfilled.

1.2.2.2 Towing afloat.

All the requirements specified in 1.2.1 apply to a structure or module floating either on its own or with the use of temporary buoyancy towers.

A damaged structure, where water enters into one of its compartments or tanks or towers, shall remain afloat, and the requirements for damage waterline specified in 2.5.1, Part V "Subdivision" of the MODU Rules shall be complied with.

The towed object shall have a corrected initial metacentric height not less than 0,3 m and freeboard not less than 1 m at all stages of towing.

The heeling and righting moments shall be calculated with due regard to the wind, wave, current, icing effects and tug efforts.

1.2.2.3 Launching.

For launching methods with a considerable dynamic component (longitudinal launching from a barge, launching from inclined slipway) the minimum design freeboard of a structure after launching shall meet the requirements of 1.1.2. In addition, the buoyancy reserve shall ensure a launching trajectory the lowest point of which shall be not less than 5 m above seabed including allowance made for a possibility to damage one compartment during launching. When launching by means of crane assistance, by emersion in the dock, by submersion of a flo-flo ship, the freeboard may be reduced in accordance with the requirements of 1.2.2.2. Following launching, the initial metacentric height shall be positive at the moment of the greatest deepening and thereafter, in equilibrium position, the stability shall meet the requirements of 1.2.1.1.2 and 1.2.1.2.1. In this case, the initial metacentric height for the short-term MO of a duration less than one day (launching, short-term towing) shall be at least 0,3 m.

When evaluating buoyancy and stability in launching, the emergency flooding of any one compartment or tank or tower shall be taken into account. After damage, the requirements for damage waterline specified in 2.5.1, Part V "Subdivision" of the MODU Rules shall be complied with and the structure shall have a positive metacentric height.

1.2.3 Buoyancy and stability during vertical mating by float-on method, installation on site and upending.

1.2.3.1 In the process of emersion during vertical mating by float-on method and of submersion during installation on site, the metacentric height calculated with due regard to the effect of the buoyancy towers (pontoons) and anchor and mooring lines (and slings if a floating crane is used for supporting) shall be positive within the entire range of draughts and shall also meet the requirements for stability according to 1.2.1, including the case of one compartment, tank or tower flooded.

Installation of a gravity or piled structure on the seabed calls for ensuring stability during submersion. Stability therewith shall be ensured at the expense of the initial metacentric height being at the end of the submersion not less than 1 m (1 — 2 m above the seabed).

1.2.3.2 During upending, the reserve of buoyancy of the object shall be not less than 10 % of the full volume at any stage.

The longitudinal and transverse metacentric heights of the intact and damaged structure shall be at least 1 m.

1.2.3.3 Dynamic parameters evaluation.

In order to obtain hydrodynamic initial data and to confirm the results of stability calculations, the execution of model tests is recommended for all specified dynamic cases including launching, mating by float-on method, object setting on the seabed.

1.3 Requirements for arrangements, equipment, systems and structures affecting buoyancy and stability

1.3.1 Special attention shall be paid to ensuring object structure watertightness during MO. The number of openings in watertight bulkheads and decks shall be kept to a minimum. Where piping, ventilation ducts and electrical cable pass through decks, outer walls and bulkheads, appropriate arrangements shall ensure their watertightness.

The requirements of the International Convention on Load Lines, 1966 shall be followed with respect to air pipes, overboard and inlet pipes, watertight doors, hatch covers and other openings. Temporary closing devices of the object, such as hatches, blind flanges, plugs and other accessible openings that may be exposed to slamming, flooding, etc. shall be designed for appropriate loads. Where necessary, special protection of such devices shall be provided. Consideration shall be given to possible displacements of the closing devices and supporting structures.

1.3.2 For a damaged object, the strength of watertight bulkheads and tower walls under a hydrostatic pressure corresponding to the submersion of the structure at trim after an accident shall be ensured. When the transport craft is damaged, the strength of the watertight bulkheads and sufficient strength margin of cargo sea fastening (structure or parts thereof) shall be ensured.

1.3.3 All openings between the object compartments, which may contribute to progressive flooding of the object during operation execution, shall be closed. Regular inspections of compartments tightness, checks of water level in compartments and tanks, checks of the object draught, heel, trim, etc. in search of possible leakage shall be carried out during the operation.

1.3.4 Requirements for water ballast system to ensure submersion/emersion stability shall include the following items (but not limited thereto):

ballasting system capacity shall ensure the specified time of MO;

in order to prevent the loss of stability due to simultaneous opening of outboard flooding valves (sea valves) of several tanks or towers, the use of those valves is undesirable;

system description shall include instructions on the calculation of a stability curve with due regard to the change of the waterline, centres of gravity and buoyancy, and for corrections for free surface effects in tanks while handling the ballast in its various states.

2 FLOATING CRAFT AND TECHNICAL FACILITIES, CREWS AND PERSONNEL INVOLVED IN A MARINE OPERATION

2.1 All the floating craft and technical facilities involved in MO, their equipment, machinery, machines and arrangements shall meet the requirements of international conventions, authorized state supervision bodies and classification societies for the conformity to which they are designed.

2.2 All the floating craft and technical facilities involved in MO, their equipment, machinery, machines and arrangements shall have valid certificates to be effective until the predicted time of completion of the operation and taking into account potential delays.

2.3 Characteristics of all floating craft and technical facilities involved in MO shall be consistent with those specified in the MO design or be superior to those characteristics that enable to perform MO in accordance with the requirements of these Rules.

2.4 Equipment that is inconsistent with the characteristics specified in the MO design or does not comply with the requirements of these Rules shall be interlocked unless its presence affects the normal operation of any other equipment and threatens the safety of the personnel. Otherwise, this equipment shall be dismantled.

2.5 All crew members of the floating craft intended for operation at sea shall possess adequate qualifications, fully meet the requirements and have all the necessary valid diplomas, certificates and other documents in accordance with the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978[1], as amended. The crew members of craft flying the RF flag shall also have documents in accordance with the Merchant Shipping Code of the Russian Federation and valid orders of the Ministry of Transport of the Russian Federation. Experience in the MO execution is recommended.

2.6 All the crew members of craft intended to operate on the Russian Federation's inland waterways shall possess adequate qualifications, fully meet the requirements and have necessary valid diplomas, certificates and other documents in accordance with the Regulations for Certification of Crew Members of Inland Navigation Vessels, 2005, and orders of the Ministry of Transport of the Russian Federation. Experience in the MO execution is recommended.

2.7 Personnel involved in MO shall possess adequate qualifications and experience, have all necessary valid documents confirming their qualification and approval for the works performed during MO.

2.8 All the crew members and personnel involved in MO shall be briefed about the MO performance, including emergency actions. For operations with complex communication systems and for the most important systems, provision shall be made for preliminary instructing and training of the personnel under conditions similar to those which are expected during the actual operation. Key personnel participating in the operation shall be familiarized in detail with the procedure of the operation to the extent they are concerned. Other personnel participating in the operation shall be briefed, generally about the operation and specially about safety, damage control, and assigned tasks/responsibilities.

2.9 For all crew members, in accordance with the normative documents, lessons, training and drills shall be arranged to maintain and enhance the qualifications.

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[1] Hereinafter referred to as "STCW Convention 78".

3 OBJECT TRANSFER OPERATIONS

3.1 General

3.1.1 Among the transfer operations are load in/out operations and other operations (mating, launching, installation) performed by the object lifting or skidding/rolling.

3.1.2 Prior to operation, a check for readiness shall be carried out, which consists in the following:

equipment and technical facilities are suited to their designed purpose and tested;

the Object Transfer Manual is approved by the Register;

weather forecast for the duration of the operation allowing for the contingencies fits the established restrictions;

results of the object weighing or weight control are satisfactory and accepted by all the participants.

3.1.3 For operations consisting of several, previously defined phases, the decision on commencement of the operation based on similar principles shall be taken prior to the commencement of each phase.

3.1.4 To control preparation for the operation it is recommended to use check lists.

3.1.5 The operation schedule shall take into account the time of high/low tide beginning, as well as time spent for ballasting and object sea fastening (releasing/cutting sea fastening).

3.1.6 If load out supports were previously installed on a craft, their reliability shall be previously checked prior to commencement of loading operation in order to verify that the object can be safely loaded out with the agreed allowances being agreed.

If the load out supports belong to the object, their consistency with the frames and bulkheads of the craft shall be evaluated by measurements prior to loading.

3.1.7 The operations shall be mainly performed in the daytime. For operations carried out in darkness sufficient lighting shall be arranged.

3.1.8 Prior to loading in, all the preparations for sea fastening shall be completed. Sea fastening shall commence as soon as possible after lowering the object and in such a sequence as to make it possible to keep it in horizontal position when stowed for sea in a minimum of time and prevent inadmissible stresses in the object structures.

3.2 Structural analysis

3.2.1 Object structure and rigging shall be so designed as to ensure all phases of the operation.

If tilt (turnover) of the object is planned, at least three critical intermediate positions between the horizontal and vertical shall be investigated.

For skidding/rolling operations, strength calculations of the object and support structure during object transfer from the quay onto craft/stability block shall be made.

3.2.2 In analyzing operations with a partially submerged object, consideration shall be given to the effect of its parts resistance in water.

3.2.3 Every time when the results of weighing (if provided) show that the actual weight exceeds the maximum expected weight and/or an excessive CoG shift, the calculations shall be revised and, if required, the structure shall be strengthened accordingly.

3.2.4 To confirm reliability and safety of the operation with an object of inadequately rigid structure (e.g. topside module), it is recommended to develop a three-dimensional elastic model of the object including its cargo handling rigging allowing for appropriate restrictions and assumptions. The model shall include all primary and secondary elements essential for modeling.

Loads incorporated into the model shall be determined with regard to 3.3.

3.2.5 Safety factors used in strength calculations of the object shall not exceed the values given in Table 2.4.2.5, Part II "Hull" of the MODU Rules for transportation mode. Recommendations for design of lifting equipment are given in Appendix 1 to Part III "Special Requirements".

3.3 Load analysis during object lifting

3.3.1 For lifting operations strength calculations of the lifting equipment and object shall be made in accordance with the recommendations of this Chapter.

3.3.2 Calculation stages of the object lifting by means of one/two cranes assistance are shown in Figs. 3.3.2-1 and 3.3.2-2, respectively.

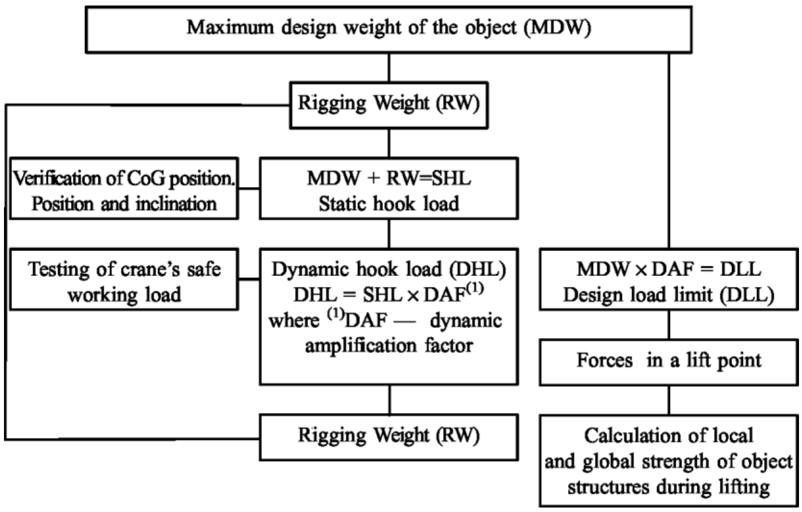

Fig. 3.3.2-1
Calculation stages of the object lifting by one crane

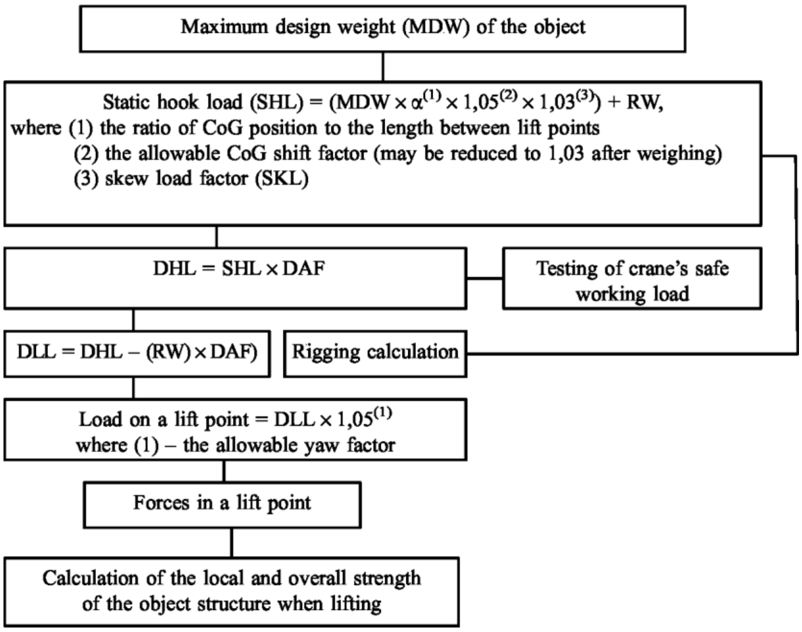

Fig. 3.3.2-2
Calculation stages of the object lifting by two cranes

3.3.3 Maximum design weight (MDW) of the object shall take account of the mass margin.

When calculating the MDW value at the design stage, the weight of the object shall be determined separately for the following elements:

weight of structural steel with allowances assumed for thicknesses, painting, welds, inaccuracy of linear dimensions and other additions increasing the design weight. For this group, it is recommended to assume the mass margin to be equal to 10 % of the total mass of the elements included into this group;

weight of the equipment and ancillary elements that takes account of the allowable inaccuracies in evaluating weight of the essential and additional equipment and steel structures (foundations and working platforms). For this group, the design weight shall be increased by 20 %.

Upon completion of construction, the object shall be weighed using agreed weighing methods and the value obtained, considering inaccuracies in weighing, shall be increased by total error of all devices used for weighing but at least 3 %. The fact that such value of error may be admissible shall be confirmed in the operation technical documentation. If the object is partially finished, the design weight of the object being lifted may be determined by approved weighing method with allowance made for permissible inaccuracies in weighing. Weight of components which are not installed yet shall be determined with allowance made for inaccuracies and possibilities of further alterations.

If the weight of constructed object plus mass margin exceed the design weight of the object the calculations associated with the lifting design shall be checked.

3.3.4 The weight of rigging is the total weight of the rigging arrangement, i.e. equipment such as shackles, slings, spreader bars or frames, eyes, etc. At the preliminary stage of the design, the total weight of rigging may be taken equal to 5 % of the weight of the object being lifted (7 % if spreader beams are used). At the final design stage, the weight of rigging shall be determined by summing up the estimated weight of all the rigging elements.

The value e in Fig. 3.3.4 shall not exceed 0,02 of the vertical distance from the crane hook to the CoG of the lifted object.

In case when this distance is initially unknown, the value e shall not exceed 600 mm.

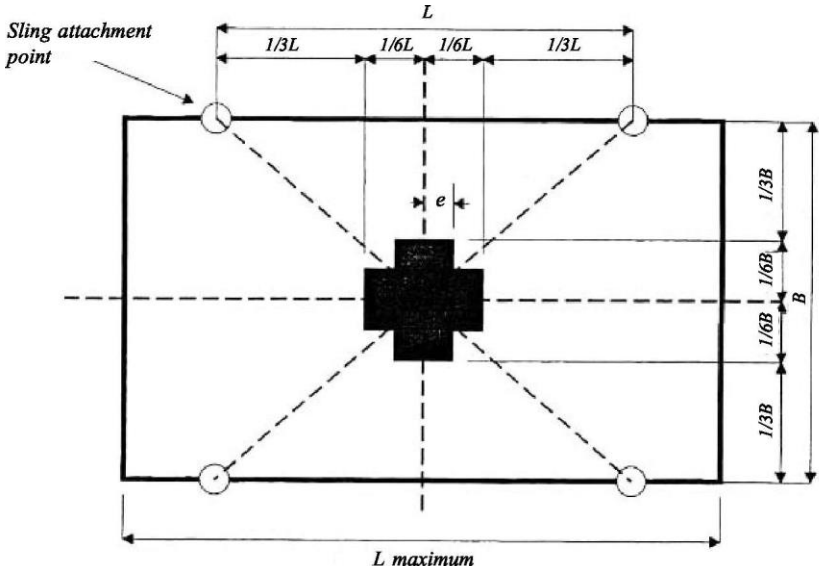

Fig. 3.3.4
Allowable CoG position

If the CoG of the lifted object is located outside the shaded zone, as shown in Fig. 3.3.4, the possibility of lifting shall be confirmed by appropriate calculations.

The length of the lift sling shall be selected proceeding from the minimization of inclinations of the object axes during lifting. Unless expressly provided otherwise, the object tilt shall not exceed 2°.

In case when the object was weighed, its static tilt shall be calculated with due account of measurement of the CoG position and sling length. In this case, the shift between the position of the hook center and the CoG of the lifted object shall be not exceed 600 mm.

3.3.5 Particular attention in designing the lifting operation shall be given to selection/confirmation of the CoG position with respect to the point of the object suspension from the crane hook.

Along with that, consideration shall be given to the fact that the main influence on this position is exerted by:

the number and length of slings;

the crane hook load value;

the allowable tilt the lifted object.

3.4 Static hook load

3.4.1 The static hook load (SHL) shall be determined by Formula (3.4.1-1) for a lift by one crane, and by Formula (3.4.1-2) for a lift by two cranes:

$$SHL = MDW + RW; \quad (3.4.1\text{-}1)$$

$$SHL = MDW + \alpha \times 1{,}05 \times 1{,}03 + RW. \quad (3.4.1\text{-}2)$$

SHL be tested with respect to the crane safe working load at the maximum design arm of crane. In case of lifting through water and lifting by two cranes, the buoyancy and hydrodynamic loads can change the load distribution between two hooks. These effects shall be taken into consideration when determining individual hook loads.

3.4.2 The dynamic hook load (DHL) can be determined by multiplying SHL by the dynamic amplification factor (DAF) (refer to Table 3.4.2):

$$DHL = SHL \times DAF.$$

DAF induces a correction for dynamic loads arising from crane ship and/or cargo barge motions during lifting operations.

DHL shall also be tested for correspondence to the crane safe working load at the maximum design arm of crane.

Where lifting is performed in air, the dynamic load is generally regarded as the greatest load at the time when the object takes off the system of cross members. This load and the relevant DAF shall be determined by design analysis wherein consideration is given to the maximum transfer of the lifted object in relation to the barge from which it has been offloaded. The calculations shall take account of the elasticity of crane ropes, booms and cargo-gripping devices.

Table 3.4.2

Relationship between DAF and lifting conditions

Object weight W, t	≤ 100	$100 < W \leq 1000$	$1000 < W \leq 2500$	$2500 < W \leq 10000$
Inshore lifts	1,0	1,0	1,0	1,0
Column-stabilized floating crane				
Offshore lifts in air	1,30	1,20	1,15	1,10
Offshore lifts from deck	1,15	1,10	1,05	1,05
Onshore lifts in air	1,15	1,10	1,05	1,05
Floating crane/crane ship				
Offshore lifts in air	1,50	1,40	1,30	1,20
Onshore lifts in air	1,30	1,20	1,15	1,10

Based on the results of such analysis, weather restrictions (primarily, wave heights and periods) shall be established. If the DAF design value is found to be critical for execution of the operation, then during lifting it will be necessary to monitor weather conditions, and the operation performance period shall be selected on the basis of the analysis of weather condition statistics in the lifting operation area.

3.4.3 Attachment points for slings shall be provided on the object.

Loads on sling attachment points (lift points) shall be determined by calculation of design lifting loads (DLL) and by consideration of the geometry of load-gripping device and of the CoG position of the object for a single crane using Formula (3.4.3-1) and for two cranes using Formula (3.4.3-2):

$$DLL = MDW \times DAF; \qquad (3.4.3\text{-}1)$$

$$DLL = DHL - (RW \times DAF). \qquad (3.4.3\text{-}2)$$

To confirm safety of lifting, the analysis of load distribution between the diagonally opposite pair of lift points with due account for the object rigidity and sling elasticity shall be made. Where the information on the errors of the object manufacturing and slinging is lacking, it is recommended to take into account the following assumptions in such analysis:

each lift point is located 12 mm from its design position (account shall be taken of the integral effect due to position errors of all lift points in relation to their design position);

two shackles, each one being 6 mm shorter than its standard size, are secured to the diagonally opposite attachment points, whereas two shackles that are 6 mm longer than the standard size are secured along another diagonal;

slings that 0,25 % shorter than the specified nominal length are secured to two diagonally opposite lift points while the slings that 0,25 % longer than their nominal length are secured to two remaining lift points.

The load on the lift point shall be increased by 5 % to account for rotation/swinging of the lifted object.

3.4.4 When the object is lowered from the surface down to its final position on seabed, the object buoyancy and center of buoyancy (CoB) shall be established on the basis of accurate hydrostatic analysis.

When evaluating impact loads on the object being submerged, due to the impacts during setting down or lowering onto the seabed the object submersion rate shall not be taken less than 1 m/s.

Environmental loads acting on the object shall be evaluated and used to obtain the loads pulling the object away from the crane and the lateral forces applied perpendicular to the crane arm axis.

At the preliminary design stage, the DAF value may be taken equal to 1,4 for lifting of small structures from the water. For large-sized objects, DAF may be taken equal to 1,2.

3.4.5 Asymmetrical distribution of loads in the slings shall be taken into account in every object slinging diagram. Such asymmetry may be evaluated through the skew load factor (SKL) considering relative rigidity and weigh of the lifted object and slings, mismatch and deviations of the sling lengths within the tolerances and other inaccuracies of force distribution in slings.

SKL shall be taken into account in the design of the whole structure, lift points, slings, connecting shackles and spreader bars or frames.

For the statically indeterminate four lift points with one of the following slinging arrangements:

four slings directly from four lift points to hook;

four slings to hook with intermediate spreader frame;

four slings to hook with two intermediate spreader bars

SKL shall be taken from Table 3.4.5.

Table 3.4.5

Load distribution and SKL

Statically indeterminate four lift points	Rigid structure	Non-rigid structure
SKL	1,50	1,33
Asymmetrical load distribution in any set of diagonally opposite slings	75/25 %	67/33 %

For statically determinate four lift points with one of the following slinging arrangements SKL equal to 1,10, i.e., asymmetrical load distribution in any set of diagonally opposite slings 55/45 %:

four slings to hook with two intermediate unsecured spreaders;

two slings to hook with one intermediate spreader.

For statistically determinate three lift points the SKL is equal to 1.

3.5 Cranes and crane ships

3.5.1 The dynamic hook load shall be consistent with the crane capacity chart. The crane shall be equipped with a load measuring device.

3.5.2 If the lifted object is gripped at several points, consideration shall be given to the effect of rotation about horizontal axis and tilts which may result from displacement of the hooks from their ideal relative positions.

In the absence of a significant load due to wind or tension of auxiliary winch ropes a minimum yaw effect factor (YEF) equal to 1,05 shall be used.

If cranes are installed on the same ship the above factor shall be calculated for a tilt equal to 3°, and if cranes are installed on separate ships it shall be calculated for a tilt equal to 5°.

These factors shall be taken into account for in the design of lift points, slings, connecting shackles and spreader or frames.

3.5.3 If the design hook load is less than 80 % of the crane safe working load, and the ship performs lifting at an operating draught, no submission of stability calculation is required. However, if the load is close to allowable maximum for the ship or the ship's draught is beyond the normal operating range, the stability calculation shall be submitted for review.

Where lift is carried out by two cranes, documentation shall be submitted to prove that the crane ship is capable to ensure safe change in the hook load which arises at tilt angles and yaw factors under environmental impact, especially considering allowable transverse angles for crane arms.

3.5.4 The crane shall have sufficient capacity and the crane barge — sufficient stability at all stages of the operation.

3.5.5 Arrangement of slings on the hook shall be symmetrical to avoid tilt of cargo and angle between the ropes and sheaves. Unsymmetrical arrangement shall be considered with due regard to the hook strength and its displacement, and shall be approved by the crane manufacturer.

3.5.6 During all stages of lifting the following minimum clearances shall be ensured:

under the object — 3 m;

between the object and the arm of crane — 3 m;

between the spreader bar and the arm of crane — 3 m;

between the crane ship and the object — 3 m (crane ship is lying at anchor);

between the crane ship and the object — 10 m (crane ship uses dynamic positioning system).

3.6 Load in/out operations

3.6.1 Prior to operation the seabed area shall be examined to verify that the under-keel clearance both during load out and thereafter is sufficient, and that there are no underwater obstructions for operation.

Number of the sounding points shall be sufficient to exclude undetected obstructions. When substantiating sufficiency of depth, consideration shall be given to tidal conditions, waves, swell, barometric pressure and the lowest possible low water.

In this case, mud thickness shall be measured. The results of measurements shall be plotted on a chart with the date of measurements marked.

The minimum under-keel clearance (vertical clearance) throughout the loading operation shall be not less than 0,5 m taking account of the craft heel and trim.

3.6.2 The transport craft shall be kept at a design location during performance of a load out operation until sea fastening is completed.

3.6.3 Selection of the restricting conditions with respect to wind velocity and wave height shall take account of the quay position, operation duration and operation peculiarities, range of sea level variations due to tidal conditions. If the quay is protected against wave impacts, the effect of the latter may be considered as insignificant. If the quay is exposed to the effect of the long-period swell waves, the design value of the wave period shall be approved by the Register.

3.6.4 The following load out monitoring facilities shall be installed:

barge draught, heel and trim;

water level in barge ballast tanks;

tide level;

displacement of the object on barge.

When deflections of the barge from the quay and alignment of the barge with the quay are critical, the monitoring thereof shall be provided using geodetic equipment.

3.6.5 A possibility shall be provided to verify valid certificates for constituent parts of rigging, especially for slings, thimbles and shackles, as well as the documentation on the results of weld inspection at lift points. If the object was lifted more than once, prior to the second and next lifts a detailed visual examination of the welds at lift points shall be carried out by a competent expert in the presence of the surveyor to the Register.

3.6.6 The final position of the object on load out supports shall be clearly marked.

3.6.7 When approaching the specified position, the deflections in the object position shall not exceed:

vertical: ± 0,75 m;

horizontal: ± 1,50 m in any direction;

inclination: 2°;

turning around vertical axis: 3°.

3.6.8 Upon completion of load out operation, regular monitoring of the reliability of the barge mooring lines, draught, heel and trim shall be provided.

Under unfavourable weather conditions, the continuous barge monitoring shall be provided. An adequate number of spare mooring lines of required dimension and in proper condition shall be provided during the barge berthing.

If a sub-zero temperature is expected, measures shall be taken to avoid freezing of water in tanks and on deck. Similar precaution shall be taken in respect to liquids in machinery installation and systems.

3.7 Object offshore lifts

3.7.1 During the operation, craft shall be kept in specified position by means of mooring designed to be capable to withstand extreme values of wind, current and waves occurring once in every 10 years provided that one line breaks.

3.7.2 If buoys or anchors are required for mooring, they shall be installed and tested prior to the operation.

3.7.3 Restriction of the operational criterion shall be based on the results of crane ship motions evaluations, depending on sea state. To verify the design restrictions it is recommended to carry out model tests or an appropriate computer simulation.

3.7.4 For subsea structures or submerged part of the object subjected to wave loading, which is considerable for them, the maximum permissible wave conditions shall be established, primarily, as regards lengths and directions of waves including swell. Effect of wave impacts in the splash zone shall be also evaluated.

Consideration shall be given to hydrostatic and hydrodynamic loads on the object being submerged.

3.8 Load analysis during skidding/rolling

3.8.1 In calculating loads arising during skidding/rolling consideration shall be given to the following:

weight and rigidity of the object and its supporting structures;

friction forces;

resistance of non-propelled trailers;

winch pull;

race/rail track tolerances;

craft/stability block heel and trim;

soil subsidence (in case of the craft/stability block setting on the seabed during the operation).

3.8.2 At the stage of developing skidding/rolling operations, the following values of errors in determination of mass-dimensional characteristics shall be taken into account:

unaccounted weight: 10 %;

CoG shift: longitudinal ± 1,0 m, transverse ± 0,5 m.

3.8.3 Final load distribution in the object structures, support structures and hydraulic system of the trailers shall be confirmed after weighing of the object before the operation.

3.8.4 To avoid deformations of the object when loaded out while being supported at more than three points, provision shall be made for a load equalizing system.

3.8.5 When the object is transferred onto a craft by skidding or rolling method while resting on the seabed, the craft strength, primarily, the strength of longitudinal bulkheads shall be checked.

3.8.6 When calculating loads required to start moving the object, consideration shall be given to friction forces, inertia forces, as well as the horizontal component of gravity force during skidding or rolling on sloping surface.

3.8.7 The friction coefficient values shall be established on the basis of test results or previous experience. Data given in Table 3.8.7 may be also used.

Table 3.8.7

Recommended friction coefficients for level surfaces

	Static			Dynamic		
	Min.	Typ.	Max.	Min.	Typ.	Max.
Sliding						
Steel/Steel	0,15	0,20	0,35	0,10	0,15	0,25
Steel/Grease/Steel	0,10	0,15	0,30	0,08	0,12	0,20
Steel/Teflon	0,10	0,15	0,25	0,04	0,05	0,10
Stainless steel/Teflon	0,08	0,10	0,20	0,03	0,04	0,07
Teflon/Grease/ Dressed Wood	0,08	0,14	0,25	0,03	0,06	0,08
Teflon/Grease/Wood	0,10	0,18	0,30	0,05	0,10	0,15
Steel/Wood	0,20	0,40	0,60	0,15	0,30	0,40
Steel/Grease/Wood	0,15	0,30	0,40	0,10	0,15	0,20
Rubber tyres (fixed)	0,20	0,35	0,50	—	—	—
Rolling						
Steel wheels/Steel		0,01			0,01	
Rubber tyres/Steel	0,01		0,02	0,01		0,02
Rubber tyres/Gravel	0,02		0,06	0,02		0,04

3.8.8 When evaluating loads on winches, rigging, jacks and braking system, consideration shall be given to at least unfavourable longitudinal slope of the track being equal to 1:100.

3.9 Skidding/rolling operations

3.9.1 During loading with the use of trailers, loads acting thereon shall not exceed allowable limits established by the manufacturer, namely:

loads on the trailer hydraulic suspension;

loads on the axis;

shearing and bending stresses of the main longitudinal beam of the trailer.

When substantiating the possibility of using this method of loading operation, consideration shall be given to:

seabed level and ramp/sponson slope;

object sagging;

allowable barge heel and trim;

trailer hydraulic suspension stroke.

When designing the operation, it is recommended to provide a jam travel margin not less than 100 mm.

The object shall be secured in such a manner as to prevent its movement relative to the trailers.

3.9.2 Provision shall be made for a braking system capable to stop moving of the object transferred.

A reverse movement system shall be provided to return the object to its starting point in an unforeseen situation unless it is proven that the craft with the object on board can be at the same level with the quay/stability block during the skidding/rolling operation with due account of possible delays and effect of tide variations.

3.9.3 The design load on the traction system shall not exceed the certified safe working load (SWL) of the system. Two modes: start and steady movement shall be evaluated. When calculating the SWL of rope systems, proper assumption shall be made regarding bending of wire ropes and also friction losses in sheaves.

The traction systems shall enable the object to be transferred from support to support with no changes of rigging, and in case of failure of any component or secondary system the said systems shall continue to operate effectively.

3.9.4 Capacity of main electrical power source shall be sufficient to supply all the equipment which may be used during the operation to ensure continuous operation of the machinery at maximum capacity.

Provision shall be made for stand-by power supply sufficient for safe completion of the operation.

3.9.5 When rolling the object with the use of trailers, the design position of the object and the possibility of its adjusting with the use of shims shall be checked during lowering the object to its seat. Lowering shall not be completely finished until the satisfactory adjustment and positioning are carried out and accepted. If there are more than four points for the object support, preliminary alignment shall be carried out by ballasting.

4 TRANSPORTATION/TOWING OF THE OBJECT

4.1 Local and global strength of craft loaded during marine operation

4.1.1 The loading operation manual shall contain local and global strength calculations for the craft loaded during MO.

4.1.2 The local and global strength of the craft loaded during MO shall satisfy the requirements of Part II "Hull" of the Rules for the Classification.

4.1.3 In case where the local and/or global strength does not satisfy the requirements of the above-mentioned Part, it will be necessary to provide and calculate arrangements for re-distribution of forces, moments and loads or the craft hull strengthening in order to ensure compliance with the requirements of 4.1.2.

4.2 Calculation and means for securing the object on craft

4.2.1 Every object or parts thereof shall be individually secured on the craft by attachment to the craft hull.

4.2.2 Flexible, semi-rigid and rigid industrial products, as well as those manufactured in accordance with the MO design (stops, brackets, braces, wedges, etc.) shall be used as the means for securing the object.

4.2.3 When the object is secured by means of stops, braces, brackets and other fixed elements, they shall be fitted in the plane of the stiffeners being part of the craft hull framing.

4.2.4 Calculations of loads on the structural elements of the securing system shall be made with due account of the safety factor K_s being equal to 1,3.

4.2.5 Where lashings are used for securing the object their points of attachment to the object and craft, as well as their elements shall be of the same strength, or shall exceed the allowable loads (refer to Table 4.2.5).

Table 4.2.5

Strength standards of securing means

Type of securing means	Safe working load (SWL)	Test load (TL)	Breaking load (BL) or breaking strength (BS)	Safety factor
Rope, car lashings	0,33 × BL	1,25 × SWL	3,0 × SWL	3
Chain lashings	0,4 × BL	1,25 × SWL	2,5 × SWL	2,5
Bars, turnbuckles, straps, jacks	0,5 × BL	1,25 × SWL	2,0 × SWL	2
Other devices	0,5 × BL	1,25 × SWL	2,0 × SWL	2

4.2.6 During MO the object is subjected to weight forces, inertia forces in motion, friction forces, reaction forces of loadout supports and securing elements, while the objects on the open deck are subjected to wind pressure and wave loads. The craft with the object on board is subjected to surging oscillation, rolling, pitching, heaving and yawing, which produce certain accelerations and inertia forces. The calculations of sea fastening of the object and/or parts thereof on board the craft shall take account of particular, significantly important components of the said forces in coordinates related to the craft, with its origin at the intersection point of the base line, midship section and centreline (CL) of the craft. The X-axis is directed forward, the Y-axis to starboard, and the Z-axis upwards.

4.2.7 Where the object is transported on a craft with length exceeding 80 m, breadth exceeding 12 m, draught exceeding 3 m, length to breadth ratio 5 — 10, breadth to draught ratio 2 — 6, transverse metacentric height 0,3 — 3,5 m, transverse metacentric height to breadth ratio 0,02 — 0,12, Froude number for design speed 0 — 0,3, CoG position not higher than 6 m above the upper deck, the dimensionless projections of the total weight and inertia forces acting on the object shall be determined by the formula

$$\left.\begin{aligned}\bar{X} &= A\cdot(0{,}18+12/L)\\ \bar{Y} &= A\cdot(0{,}3+20/L)\cdot K\\ \bar{Z} &= 1{,}0+A\cdot(0{,}36+25/L)\end{aligned}\right\} \qquad (4.2.7)$$

where $A = 0{,}25 + 0{,}45h_{3\%} + 0{,}25\sin(0{,}28h_{3\%} - 1{,}573)$;
$\bar{X}, \bar{Y}, \bar{Z}$ = design dimensionless projections of weight and inertia forces, acting on the object in direction of coordinate axes;
L = ship's length between perpendiculars, in m;
K = coefficient is equal to 1 if bilge keels with the area over 1,5 % of the waterline area are provided, and equal to 1,4 where no bilge keels are provided. If the area of bilge keels is less than 1,5 %, the value of K shall be determined by linear interpolation.

4.2.8 If the length or breadth of the transported object exceeds the overall dimensions of the craft or the craft parameters are inconsistent with those specified in 4.2.7 and 4.2.9, or the craft is multi-hulled, the calculation of motions which takes account of the following shall be submitted to the Register for approval:

actual hull shape, the value of the craft's metacentric height and speed;
actual arrangement of the object;
dimensions of bilge keels;
angle between the craft direction and mean wave direction;
non-linearity of rolling associated with the relationship between non-wave damping and roll amplitude;
spectral density of the wave ordinates corresponding to set wave height and mean wave period (based on one of the approved spectra: JONSWAP or Pierson-Moskowitz, etc.), shall be submitted to the Register for approval.

The calculations shall be made both for dead swell and for the two- and three-dimensional irregular waves depending on their intensity. The amplitudes of motions and accelerations accounting for wave height with 3 % probability shall be taken as the design ones.

For weather-unrestricted operations, the accelerations at motions may be calculated using the procedure specified in 1.3.3, Part II "Hull" and Part III "Arrangements, Equipment and Outfit" of the Rules for the Classification.

4.2.9 Where the object is transported on a craft having the shape of a rectangular pontoon, with length 30 — 90 m, breadth to draught ratio 4 — 8, metacentric height to breadth ratio 0,02 — 0,12, length to breadth ratio 3 — 6, at wave height with 3 % probability, the design dimensionless projections of wave and inertia forces acting on the object or parts thereof shall be determined by the formula

$$\left.\begin{aligned}\bar{X} &= \frac{h_{3\%}}{5}\cdot(0{,}27-0{,}001\cdot L-0{,}01\cdot B/T)\\ \bar{Y} &= \frac{h_{3\%}}{5}\cdot(0{,}65-0{,}0034\cdot L)\cdot(0{,}086+0{,}35\cdot B/T)\times\\ &\times[1{,}0+(0{,}015\cdot L-0{,}45)\cdot(h/B-0{,}02)\cdot(8-B/T)]\\ \bar{Z} &= \frac{h_{3\%}}{5}\cdot(1{,}235-0{,}005\cdot L+0{,}005\cdot B/T)\end{aligned}\right\} \qquad (4.2.9)$$

where L = ship's length between perpendiculars, in m;
B = ship's breadth, in m;
T = ship's draught, in m;
h = metacentric height, in m.

4.2.10 Supporting surface of the object are subjected to frictional forces the design dimensionless projections of which along the X and Y axes shall be determined by the formula

$$\bar{X}_f = \bar{Y}_f = f_0\,[(2 - \bar{Z}) + \frac{\Sigma Z_{pret}}{P}] \qquad (4.2.10\text{-}1)$$

where f_0 = coefficient of static friction which standard values are given in Table 4.2.10;
Z_{pret} = vertical component of the pre-tension of the *i*-th cargo securing lashing;
P = cargo weight, in tf (numerically equal to cargo mass, in t).

Z_{pret} value is accounted for only when the tension of lashings is permanent and shall be determined by the formula

$$Z_{pret} = 0{,}0833 T_{br} \sin\alpha \qquad (4.2.10\text{-}2)$$

where T_{br} = breaking strength of the lashing, in tf;
α = angle of lashing inclination to supporting surface.

The vertical component of the inertia force is directed upwards in Formula (4.2.10-1), therefore the value of friction force determined from this formula is the minimum possible value (error is included into safety margin for securing elements)

Table 4.2.10

Friction pair	Coefficient of static friction, f
Cast iron on steel	0,32
Cast iron on wood	0,72
Steel on steel	0,21
Steel on wood	0,5
Reinforced-concrete on wood	0,55

4.2.11 The design dimensionless projections of wind pressure forces (acting only on the object or parts thereof located on the open deck) shall be determined by the formula

$$\left.\begin{aligned}\bar{X}_v &= 0{,}15 \cdot F_v'/P\\ \bar{Y}_v &= 0{,}15 \cdot F_v''/P\end{aligned}\right\} \qquad (4.2.11)$$

where F_v' and F_v'' = a portion of cargo projection above bulwark on the midship section and centreline, in m^2. The areas F_v' and F_v'' for non-continuous structures shall be taken with regard to their permeability, and in winter time with regard to icing, assuming that the ice thickness is equal to 0,05 m;
P = cargo weight, in tf (numerically equal to cargo mass, in t).

4.2.12 The wave force in transverse direction shall be considered only for the object or parts thereof located on the open deck at a distance not exceeding 3 m from the side. The value of the design dimensionless projection o transverse wave force shall be determined by the formula

$$\bar{Y}_w = 0{,}5 \cdot (h_w - h_b)^2 \cdot \frac{l}{P} \qquad (4.2.12)$$

where h_w = the greatest height of cargo above the waterline, in m ($h_w > h_{3\%}$, then $h_w = h_{3\%}$, if $h_w \le h_{3\%}$, it is assumed that $\bar{Y}_w = 0$);
h_b = height of the bulwark top above the effective waterline, in m;
I = cargo length along the side, in m;
P = cargo weight, in tf (numerically equal to cargo mass, in t).

The point of application of the wave force is situated at a height h = 0,667h_b + 0,333h_w, above the effective waterline.

4.2.13 The summarized axial projections from the force acting on the cargo shall be determined by adding together the projections of loads along relevant axes determined by Formulae (4.2.7) or (4.2.9), (4.2.10-1), (4.2.10-2), (4.2.11) and (4.2.12):

$$\left.\begin{aligned} X &= P(\bar{X} + \bar{X}_v - \bar{X}_f) \geq 0 \\ Y &= P(\bar{Y} + \bar{Y}_v + \bar{Y}_w - \bar{Y}_f) \geq 0 \\ Z &= P\bar{Z} + \Sigma Z_{pret} \end{aligned}\right\} \quad (4.2.13)$$

where P = cargo weight, in tf or kN;
X = component of the design shear force leading to the cargo shift in the direction of the X-axis, in tf or kN;
Y = ditto, in the direction of the Y-axis, in tf or kN;
Z = vertical component of the support response, in tf or kN;
$\bar{X}, \bar{Y}, \bar{Z}$ = dimensionless values determined by Formula (4.2.9);
$\bar{X}_v, \bar{Y}_v$ = dimensionless components of wind pressure forces determined by Formula (4.2.11);
$\bar{X}_f, \bar{Y}_f$ = dimensionless components of friction forces determined by Formula (4.2.10-1);
$\bar{Y}_w$ = dimensionless component of wave force determined by Formula (4.2.12);
ΣZ_{pret} = sum of the vertical components of lashing pre-tension is determined by Formula (4.2.10-1) in accordance with the requirements of 4.2.10, taking into account that the breaking strength of the lashing is taken in the same system of units in which the Z force is determined.

The calculated values of X and Y cannot be negative since the frictional forces cannot exceed the shear forces. If, however, the values of X and Y calculated by the formulae appear to be negative, it is necessary to assume that $X = 0$ and $Y = 0$, respectively. In this case, no securing means that stop shifting of the object and/or parts thereof shall be provided.

4.2.14 The design of sea fastening shall, wherever possible, provide for a minimum number of elements in order to minimize load irregularity between them.

4.2.15 The sea fastening elements are subdivided into those which prevent shift of the object and/or parts thereof and those which prevent its overturning. Where possible, it is necessary to separate the sea fastening element intended to prevent the object shift, and the elements which prevent its overturning. Statically determinate cargo securing devices shall be provided.

4.2.16 In order to reduce the size of sea fastening, it is recommended to take measures to increase forces of friction between the object and/or parts thereof and the supporting surface, and the elements preventing its overturning shall be located as far from the estimated overturning axes as practicable.

4.2.17 All sea fastening elements shall be reliably attached to the craft hull structures, which strength and rigidity shall be substantiated by a calculation. In calculating, it shall be taken into account that the estimated longitudinal and transverse overturning axes pass through the elements preventing shifting.

4.2.18 Moments of forces overturning the cargo about axes (M_x — about longitudinal axis, M_y — about transverse axis) shall be determined by the formula

$$\left.\begin{aligned} M_x &= P[(\bar{Y} l_{\bar{y}} + \bar{Y}_v l_{yv} + \bar{Y}_w l_{yw} - (1 - \bar{Z}) l_{yz'}] \\ M_y &= P[(\bar{X} l_{\bar{x}} + \bar{X}_v l_{xv} - (1 - \bar{Z}) l_{xz'}] \end{aligned}\right\} \quad (4.2.18)$$

where $l_{\bar{y}}$ и $l_{\bar{x}}$ = arms of $\bar{Y}$ and $\bar{X}$ forces applied to the cargo centre of gravity about the estimated overturning axes, in m;
l_{yv} and l_{xv} = arms of $\bar{Y}_v$ and $\bar{X}_v$ forces applied to the windage centers, in m;
l_{yw} = arm of $\bar{Y}_w$ force about estimated longitudinal overturning axis, in m;
l_{xz} and l_{yz} = arms of $(1 – \bar{Z})$ force applied to the cargo centre of gravity about the above-mentioned axes.
l_{yz}' = arm of the $(1 – \bar{Z})$ force applied to the cargo centre of gravity about the above the mentioned axes determined either graphically at heel angle θ or by formula

$$l_{yz}' = l_{yz} * \cos\theta - l_y * \sin\theta$$

where θ = total heel angle (deg) of the ship due to combined roll and wind action;
l_{xz}' = arm of the $(1-\bar{Z})$ force applied to the cargo centre of gravity about the above-mentioned axes determined either graphically at trim angle y or by formula

$$l_{xz}' = l_{xz} * \cos\psi - l_x * \sin\psi,$$

where ψ = total trim angle (deg) of the ship due to combined pitch and wind action.

The above-mentioned roll angle θ and pitch angle ψ may be determined for the design wave height through the model test in a model basin or through simulation of roll motion in CAD systems approved by RS. If there are no technical means, roll amplitude θ may be determined according to Part IV "Stability" of the Rules for the Classification, while the pitch amplitude ψ may be determined in accordance with Table 4.2.18.

Table 4.2.18

Wave height $h_{3\%}$, m	Transportation barge length, m	Pitch amplitude ψ, deg
> 5,2	> 70	15
	≤ 70	30
≤ 5,2	> 70	10
	≤ 70	15

Diagram of forces acting in the transverse plane and possible arrangement of sea fastening elements are shown in Fig. 4.2.18.

For large-sized cargoes, in calculating the overturning moment due to action of the resultant components of inertia forces reduced to the cargo centre of gravity, the main moment of inertia forces resulted from non-uniform distribution of inertia forces over the large-sized cargo elements and depending on the cargo intrinsic moment of inertia of the shall be considered.

4.2.19 The formulae given in 4.2.18 correspond to properly designed stops which prevent shifting when the reaction force of these stops is applied near supporting surface. Otherwise, consideration shall also be given to the moment of friction forces.

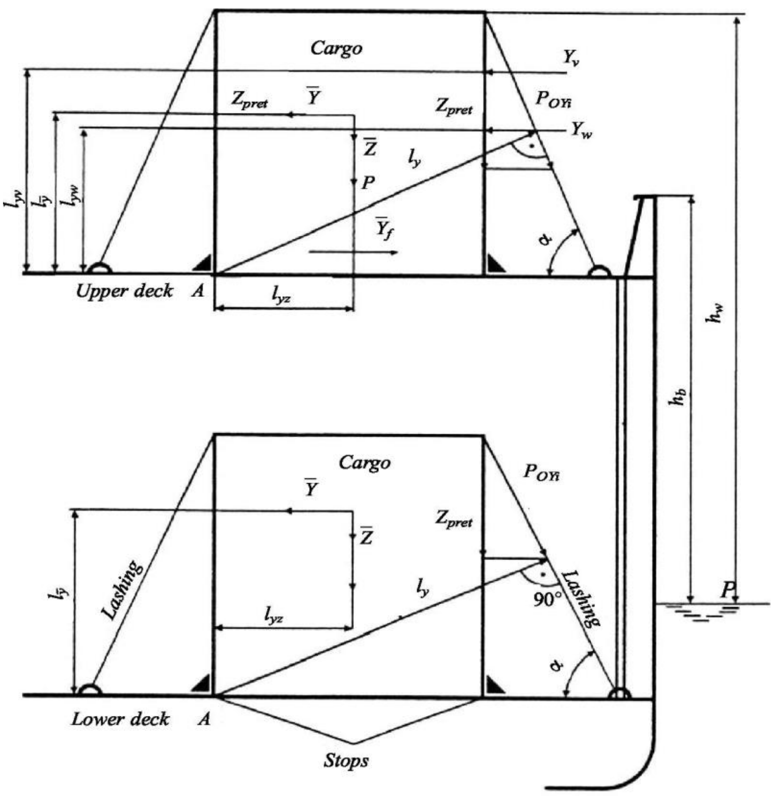

Fig. 4.2.18

4.2.20 If the values of moments M_x and M_y obtained by calculations are positive, this indicates that the object requires securing to prevent its overturning.

4.2.21 For the securing structure in question, the horizontal forces acting on identical elements preventing transverse and longitudinal shifting shall be determined by the formula

$$\left.\begin{aligned} P_{1x} &= X/n \\ P_{1y} &= Y/m \end{aligned}\right\} \qquad (4.2.21\text{-}1)$$

where X and Y = design forces determined by Formula (4.2.13), in tf;
n and m = number of stops preventing cargo shifting.

Forces P_{ox} and P_{oy} tensioning longitudinal and transvers lashings, respectively, shall be determined by the formula

$$\left.\begin{aligned} P_{ox} &= \frac{M_y}{n_o l_x \cos\beta_x} \\ P_{oy} &= \frac{M_x}{m_o l_y \cos\beta_y} \end{aligned}\right\} \qquad (4.2.21\text{-}2)$$

where M_x and M_y = moments determined by Formulas (4.2.18), in tf;
n_o and m_0 = number of longitudinal and transverse lashings;
l_x and l_y = arms about longitudinal and transverse axes, in m;
β_x and β_y = angles of inclination of lashing projections on supporting surface to axes X and Y, respectively.

4.2.22 In case where the transported object and/or parts thereof are welded to deck, it may be assumed that the same welds perform conditionally separate functions, that is, Formulas (4.2.9) and (4.2.10-1) may be used, assuming that $n = n_o$ and $m = m_o$ are the number of similar welds (parts of intermittent weld) and that l_x and l_y are the distance between the transverse (approximately, cargo length) and longitudinal (approximately, cargo width) welds, respectively. Forces applied to welds shall be determined by the formula

$$\left.\begin{aligned} P_x &= \sqrt{P_{1x}^2 + P_{ox}^2} \\ P_y &= \sqrt{P_{1y}^2 + P_{oy}^2} \end{aligned}\right\} . \qquad (4.2.22)$$

4.2.23 In case where it is impracticable to design the structure for securing the object taking into account the requirements of 4.2.15 and 4.2.17 for separation of functions, Formulas (4.2.18) have no application and the forces in the sea fastening elements shall be determined on the basis of the general equations of statics, and for the statically indeterminate structures — on the basis of equations considering also structural deformations.

4.2.24 When designing sea fastening, consideration shall also be given to the strength of the object itself. Prior to securing of an object, which is inadequately rigid, the mathematic simulation in compliance with 3.2.4 shall be performed. In case where the object is not capable to withstand forces applied to it by the sea fastening elements, the additional restrictions on wave conditions shall be imposed, or strengthening of the object structures shall be provided, or another craft shall be selected, etc.

4.2.25 The nominal acting stresses obtained by standard structural mechanics and exposed to the above mentioned loads P_{1x}, P_{1y}, P_{ox} and P_{oy} shall be multiplied by K_s specified in 4.2.4, and the product obtained shall be compared with the ultimate loads for the materials of sea fastening specified in the normative-technical documentation or certificates.

4.2.26 The ultimate loads on the materials of sea fastening shall be as follows:

for rigid members — specified yield stress of steel elements and welds;

for wood — design strength;

for flexible members — 0,5 × MBL (minimum breaking load of the constituent elements of lashing: chain, rope etc.).

4.3 Calculation of total towing resistance of the towed object

4.3.1 In general, total towing resistance of the towed object R_0, in kN, consists of hydrodynamic component (resistance in calm water R_{CW}, in kN, and added resistance in waves R_{AW}, in kN) and aerodynamic resistance due to wind R_{Air}, in kN:

$$R_0 = R_{CW} + R_{AW} + R_{Air}. \qquad (4.3.1)$$

In some cases, the additional components of resistance (added resistance of the towed object due to movement in floating ice, towline resistance, resistance due to inoperable propellers, resistance due to appendages, etc.), as well as hydrodynamic resistance in confined water (where there is a restriction in water depth or in waterway width or in both factors simultaneously) shall be considered. In case of short-line towing, the effect due to interference of jet from the tug propellers shall be also considered.

All towed objects may be roughly divided into three types:

type 1 — objects of rectangular or close to rectangular shape (pontoon, floating dock, barge sections, particular types of MODU, etc.);

type 2 — boat shaped object;

type 3 — objects of irregular shape.

It is recommended to make calculations of towing resistance for various towing speed (with a step of 1 knot) at various sea force and relative wind force. Based on these data, it is recommended to plot a towing resistance curve depending on towing speed and weather conditions.

4.3.2 Calculation of resistance in calm water.

4.3.2.1 The most accurate method for calculating R_{CW}, in kN, is the model basin test which allows to consider hull shape peculiarities of the object.

Recalculation of model test results for full-scale objects of type 1 and 3 being towed through calm water shall be made by multiplying the value obtained from the model test by the cubed value of the model scale according to the formula

$$R_{CW_s} = R_{CW_M} M^3 \qquad (4.3.2.1\text{-}1)$$

where index s refers to the full-scale object, and index M refers to the model;
M = scaling factor.

Correlation of the towing speed of the model with the full-scale object shall be provided by the Froude number equality

$$Fr_s = Fr_M \qquad (4.3.2.1\text{-}2)$$

where for indices s and M, refer to Formula (4.3.2.1-1);
Fr = Froude number determined by the formula

$$Fr = V/\sqrt{gL} \qquad (4.3.2.1\text{-}3)$$

where V = towing speed, in m/s;
g = 9,81 — acceleration due to gravity, in m/s^2;
L = length of the towed object, in m.

Recalculation of the model test results for the full-scale objects of type 2 being towed through calm water shall be made using standard Froude method by dividing the towing resistance coefficient C_T into following components: the friction coefficient of the equivalent flat plate C_{F0} and residual resistance coefficient C_R.

The value of R_0 for the object being towed in confined waters shall be obtained from the model tests considering ratios of the depth to the draught H/T and the channel width to the object breadth B_{CH}/B.

4.3.2.2 Where the model tests are not available, R_{CW} may be determined by the recalculation to the prototype.

In case of recalculation to the prototype, R_{CW} may be determined by the formula

$$R_{CW} = F \cdot Fr^2 \cdot \nabla \cdot 10^{-2} \qquad (4.3.2.2)$$

where F = coefficient determined on the basis of the data for the prototype;
for Fr, refer to Formula (4.3.2.1-3);
∇ = volume displacement of the object, in m^3.

Dimensionless coefficient F for some simple shapes of towed objects:
square being towed side forward: 550;
equilateral triangle being towed by its angle: 545;
equilateral triangle being towed by its side: 723;
cylinder 360.

For objects of type 2, the recalculation to the prototype shall be made using the results of R_{CW} calculations for ships which are similar by dimensions and shape to the towed object.

4.3.2.3 To determine the approximate value of R_0 is permitted to use standard formulae, empirical relationships, statistical methods, etc. with mandatory substantiation of the possibility to use the chosen method of R_0 calculation for the object in question.

4.3.3 Calculation of added resistance in waves.

4.3.3.1 The value of R_{AW} shall be preferably obtained from model tests. Where the relevant model tests are not available the standard formulae may be used.

4.3.3.2 The value of R_{AW}, in kN, for objects of type 1 may be determined by the following formulae:

object with vertical front wall:

$$R_{AW} = \frac{Bh_p}{4}\left[\sqrt{\frac{2\pi g}{\lambda}} \cdot \frac{h_p}{2} + V\right]^2; \qquad (4.3.3.2\text{-}1)$$

object with a hull undercut in the fore end for the case when the wave amplitude remains within the undercut:

$$R_{AW} = \frac{Bh_p}{4}\left[\sqrt{\frac{2\pi g}{\lambda}} \cdot \frac{h_p}{2} + V\right]^2 \cdot \sin^2\psi; \qquad (4.3.3.2\text{-}2)$$

object with a hull undercut in the fore end for the case when the wave amplitude exceeds the undercut height:

$$R_{AW} = \frac{Bh_p}{4}\left[\sqrt{\frac{2\pi g}{\lambda}} \cdot \frac{h_p}{2} + V\right]^2 \cdot \left[1 - \left(\frac{h_p/2 + c}{h_p}\right)^2 \cdot (1 - \sin^2\psi)\right] \qquad (4.3.3.2\text{-}3)$$

where B = breadth of the towed object, in m;
$h_p = h_{3\%}/k_1$ is a design wave height, in m;
$h_{3\%}$ = wave height with 3 % probability, in m;
k_1 = reduction factor depending on V and obtained from Table 4.3.3.2;
for V, refer to Formula (4.3.2.1-3);

$$\lambda = 1{,}56T_z^2 \qquad (4.3.3.2\text{-}4)$$

where λ = wave length, in m;
T_z = average wave period, in s;
c = distance between undercut in the fore end and waterline of floatation (when $c < h_p/2$), in m;
ψ = angle of the front wall inclination to the base line of the object.

When the data on T_z are unavailable, it is recommended to assume $\lambda = L$ where L is the object length, in m.

Table 4.3.3.2

Towing speed V, in knots	k_1
2	1,20
4	1,30
6	1,45

4.3.3.3 For objects of type 2, it is recommended to obtain added resistance in irregular waves for different values of the Froude number from the relationships shown in Fig. 4.3.3.3.

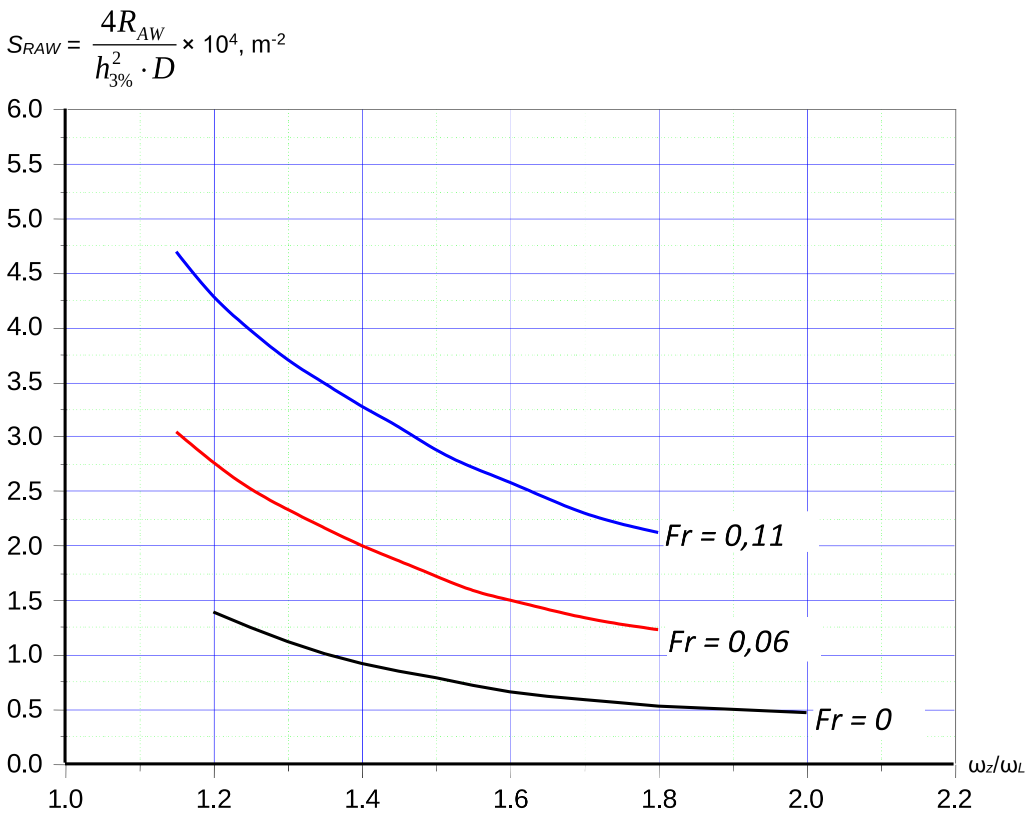

Fig.4.3.3.3
Relationship between the relative added resistance for object of type 2 being towed through waves and the dimensionless average wave frequency

$$S_{RAW} = \frac{4R_{AW}}{h_{3\%}^2 \cdot D} \qquad (4.3.3.3\text{-}1)$$

where S_{RAW} = relative added resistance in waves, in 1/m^2;
R_{AW} = added resistance in waves, in kN (refer to 4.3.3.2);
D = weight displacement of the object, in kN;
ω_z/ω_L = dimensionless wave frequency;

$$\omega_z = 2\pi/T_z \qquad (4.3.3.3\text{-}2)$$

where ω_z = average wave frequency, in 1/s;
for T_z, refer to Formula (4.3.3.2-4);

$$\omega_L = \sqrt{\frac{2\pi g}{L}} \qquad (4.3.3.3\text{-}3)$$

where ω_L = wave frequency with the length of the wave equal to the length of the object, in 1/s;
for L and Fr, refer to Formula (4.3.2.1-3).

4.3.3.4 The value of R_{AW} for objects of type 3 shall only be obtained from model tests results.

4.3.4 Calculation of aerodynamic resistance due to wind.

4.3.4.1 When large-size objects are towed, R_{Air} may substantially contribute to R_0, therefore R_{Air} cannot be neglected. This is especially the case for objects with the superstructure having large windage area.

4.3.4.2 The most accurate value of R_{Air} may be obtained from the wind tunnel model tests.

4.3.4.3 Where the wind tunnel model tests are not available, the value of R_{Air} may be determined as a sum of aerodynamic components for separate structures presented as simple geometric elements. In this case, the total windage area shall be considered.

4.3.4.4 To determine the approximate value of R_{Air}, in kN, it is recommended to use the formula

$$R_{Air} = C\frac{\rho}{2}(V + V_w)^2 S \cdot 10^{-3} \qquad (4.3.4.4)$$

where C = 0,82 in a head wind parallel to centreline (CL);
C = 1,0 for wind at an angle of 30° to CL;
S = above-water projected area to midship section plane, in m²;
ρ = 1,225 = air density, in kg/m³;
for V, refer to Formula (4.3.2.1-3);
V_w = wind speed, in m/s.

4.3.5 Calculation of added ice resistance of the towed object due to movement in floating ice.

To determine the approximate value of added ice resistance of the towed object due to movement in floating ice R_I, in kN, the following formula may be used:

$$R_I = g\left[\rho_I \sqrt{rh_I}\left(\frac{B}{2}\right)^2 k_1\left(1 + 2 f_{ID}\alpha_B \frac{L}{B}\right) + k_2\rho_I rh_I B\left(f_{ID} + \alpha_B\ tg\alpha_0\right)Fr + k_3\rho_I rh_I L\ tg^2\alpha_0 Fr^2\right]10^{-3} \qquad (4.3.5\text{-}1)$$

where for g , refer to Formula (4.3.2.1-3);
ρ_I = ice density, in kg/m³, in calculations it is recommended to assume the value of ρ_I equal to 850 kg/m³;
rh_I = typical parameter of floating ice, in m²;
h_I = floating ice thickness, in m;
for B, refer to 4.3.3.2;
k_1, k_2, k_3 = dimensionless empirical coefficients, which are chosen depending on the ice concentration (refer to Table 4.3.5);
f_{ID} = coefficient of friction between ice and shell plating. In calculations it is recommended to assume the value of f_{ID} equal to 0,1 for freshly painted hull, and f_{ID} equal to 0,15 for the hull coating being in service;
for L, refer to Formula (4.3.2.1-2);
α_B = coefficient of fineness of waterline fore end of the towed object;
α_0 = waterline fore end angle to CL, in deg.;
for Fr, refer to Formula (4.3.2.1-3).

Table 4.3.5

Dimensionless empirical coefficients

Ice concentration s, in 10 number scale	2	4	6	8	10
k_1 10^2	0	0	0	3	8
k_2	0	1	2,8	5,1	8,5
k_3	4,2	4,2	4,2	4,2	4,2

The following approximation formulae are convenient for obtaining dimensionless empirical coefficients:

$$k_1 = (3 - 2s + 0{,}25s^2)10^{-2}; 6 \leq s \leq 10;$$
$$k_1 = 0; s < 6;$$
$$k_2 = 0{,}46 - 0{,}305s + 0{,}1125s^2$$

where for s, refer to Table 4.3.5.

Average statistical value of rh_I for natural ice is relatively stable. On average, it is assumed equal to approximately 4 m^2 for non-restricted channel width. When moving in channels following an icebreaker in compact ice, the value of rh_I may be determined by the formula

$$rh_I = 0{,}0114 + 0{,}4543h_I + 0{,}5429h_I^2.$$

Formula (4.3.5-1) is applied to the boat shaped objects being towed, i.e. objects of type 2.

When a bluff object of type 1 or 3 is towed in ice, an ice area is formed before its bow, which is towed together with the object. Extent of the area of ice being towed L', in m, for objects of type 1 shall be determined by the formula

$$L' = \frac{B\prime}{2\text{tg}\delta} \quad (4.3.5\text{-}2)$$

where B' = typical transverse dimensions of the towed object, in m;
δ = internal friction angle of floating ice as loose medium. As a first approximation, this angle may be assumed equal to 45°.

For objects of type 3, which angle of waterline inclination to CL varies from 90° to 0° (circle, ellipse, oval, etc.), the extent of the area of ice being towed $L"$, in m, shall be determined by the formula

$$L" = \frac{B"}{2\text{tg}\delta} \quad (4.3.5\text{-}3)$$

where $B"$ = typical transverse dimensions of the towed object, in m, determined in the point where the angle of waterline inclination to CL is assumed equal to 45°;
e.g. for a circle, $B" = \sqrt{2}R$ and $L" = \frac{\sqrt{2}R}{2\text{tg}\delta}$ where R is the radius of the circle.

Now, if the area of ice being towed is considered as part of the towed object, Formula (4.3.5-1) may be applied modified as follows:

instead of L the following values shall be used for objects of type 1

$$L^* = L + L'; \quad (4.3.5\text{-}4)$$

for objects of type 3

$$L^{**} = (L - l) + L"$$ (4.3.5-5)

where l = length of the fore end of the object at which the angle of waterline inclination to CL exceeds 45°; instead of angle α_0 the angle δ shall be used in Formula (4.3.5-1);

for objects of type 1, α_B shall be determined by the formula

$$\alpha_B = 1 - \frac{L'}{L+L'};$$ (4.3.5-6)

for objects of type 3, α_B shall be obtained from the lines plan;
$\alpha_B \approx 0{,}59$ for waterline fore end in the form of semi-circle.

Froude number for objects of type 1 shall be determined by the formula

$$Fr = \frac{v}{\sqrt{gL^*}};$$ (4.3.5-7)

Froude number for objects of type 3 shall be determined by the formula

$$Fr = \frac{v}{\sqrt{gL^{**}}}.$$ (4.3.5-8)

4.3.6 Calculation of towline resistance.

The towline resistance R_t, in kN, may be determined by the formula

$$R_t = \Delta C \cdot K_t \cdot c \cdot l_t \cdot D_t \cdot \frac{\rho}{2} \cdot V^2 \cdot 10^{-2}$$ (4.3.6-1)

where ΔC = coefficient taking into account alteration in towline resistance depending on the angle of towline inclination to the horizon α, in deg. (refer to Table 4.3.6);

Table 4.3.6

α, in deg.	ΔC
10	0,030
20	0,076
30	0,173
40	0,309
50	0,492
60	0,686
70	0,854
80	0,963
90	1,000

Note. Angle α of the steel towline ends of more than 400 m in length inclination to the horizon may be calculated by the formula

$$\text{tg}\alpha = \frac{P}{R_0}$$

where P = towline weight, in kN;
R_0 = total towing resistance of the towed object, in kN (refer to Formula (4.3.1)).

K_t = 1,2 for wire rope roughness coefficient;
c = resistance coefficient for a cylinder of infinite length located normally to flow. The coefficient c may be assumed equal to 1,2 for Reynolds numbers from 10^4 to $2\text{-}10^5$. Reynolds number shall be determined by the formula

$$R_e = \frac{VD_t}{\gamma}$$ (4.3.6-2)

where γ = kinematic viscosity factor of water,
l_t = towline length, in m;
D_t = towline diameter, in m;
p = sea water density, in kg/m^3;
V = towing speed, in m/s.

4.3.7 Calculation of inoperable propellers resistance.

Resistance of fixed propeller R_{pf}, in kN, may be determined by the formula

$$R_{pf} = 5\rho \frac{A_E}{A_0} V^2 D^2 \cdot 10^{-2} \quad (4.3.7\text{-}1)$$

where for p, refer to Formula (4.3.6-1);
$\frac{A_E}{A_0}$ = plate area ratio;
A_E = total expanded blade area, in m^2;
A_0 = disc area, in m^2;
V = water speed in the propeller disc, in m/s;
D = propeller diameter, in m.

It is preferable to determine the resistance of free-running propeller R_{pr}, in kN, based on its hydrodynamic characteristics (propeller performance curves), however, to get a rough estimate the approximation formulae may be used. In particular, the value of R_{pr} may be determined by the formula

$$R_{pr} = 0{,}35\, R_{pf} \quad (4.3.7\text{-}2)$$

where for R_{pf}, refer to Formula (4.3.7-1).

4.3.8 Resistance due to appendages shall be calculated based on their shape using methods adopted for calculation of resistance of bluff structure.

4.4 Towline pull required

4.4.1 The minimum towline pull required F_{PR}, in kN, sufficient for station-keeping of the towed object relative to the seabed in open seas shall be calculated for the following metocean parameters:

wind speed 20 m/s;
wave height of 3 % probability of exceeding level, $h_{3\%}$= 6,7 m;
significant wave height, h_s = 5,0 m;
current speed 0,5 m/s,
acting simultaneously and in the same direction.

Where the towing in open seas is unexpectedly exposed to more severe conditions, the drift of the order may be permitted for short duration towing.

4.4.2 For inshore towing and short duration towing, the lesser metocean parameters for calculation of F_{PR} may be considered:

wind speed 15 m/s;
wave height of 3 % probability of exceeding level, $h_{3\%}$= 4,0 m;
significant wave height, h_s = 3,0 m;
current speed 0,5 m/s; or
the maximum predicted surface current if greater.

4.4.3 For towing in areas with favourable weather, the following metocean parameters for calculation of F_{PR} may be considered:

wind speed 15 m/s;
wave height of 3 % probability of exceeding level, $h_{3\%}$= 2,7 m;
current speed 0,5 m/s.

4.4.4 For towing in areas partly sheltered from wave action, but exposed to strong winds, the metocean parameters shall be agreed with the Register and insurance company.

If reliable information on the MO metocean conditions is available, the design criteria for determination of F_{PR} shall be corrected in compliance with the data provided.

4.4.5 The tug involved shall ensure a reasonable speed to be achieved by the order in moderate weather throughout the towing. It is recommended for the tug(s) to maintain a minimum speed of 5 knots in MC determined by the following metocean parameters:

wind speed 10 m/s;

significant wave height, h_s = 2,0 m;

wave height of 3 % probability of exceeding level, $h_{3\%}$ = 2,7 m.

4.4.6 If the towing route passes through an area of restricted navigation, of continuous adverse current or weather, a greater F_{PR} may be required in comparison with the design one. Such cases shall be considered separately for each particular operation design provided they ensure the required safety level.

4.4.7 For safe execution of MO, sufficient F_{PR} shall be provided in relation to total towing resistance of the towed object. For this purpose, it is recommended to increase F_{PR} in relation to the design towing resistance by 20 % in open seas and by 15 % in enclosed seas.

4.5 Calculation of the towline pull required

4.5.1 The towing shall be provided with tugs of sufficient power and arranged in such a manner as to give adequate towing speed, control and holding power.

Calculations shall prove that the actual bollard pull of the tug is sufficient for each stage of the towing operation. For towing involving several tugs, the relevant reductions shall be applied for determination of total F_{PR} (aggregate of all tugs assumed to contribute).

4.5.2 The relationship between F_{PR}, equal to total towing resistance of the towed object, and the continuous static bollard pull of the tug(s) F_{BP} shall be determined by the formula

$$F_{PR} \leq \Sigma F_{eff} \cdot 1/k \qquad (4.5.2)$$

where F_{eff} = ($F_{BP} \cdot T_{eff}$ /100) – tug efficiency of each tug, in kN;
T_{eff} = coefficient of tug efficiency, in %;
F_{BP} = continuous static bollard pull of each tug, in kN;
k = irregularity coefficient equal to:
1,00 for one tug;
1,15 for two tugs;
1,30 for three or more tugs.

4.5.3 The value of T_{eff}, depends on the size and configuration of the tug, the sea state considered and the calculated towing speed. In the absence of alternative information, T_{eff} may be calculated according to Table 4.5.3.

Table 4.5.3

F_{BP}, in t	T_{eff}, in %, for various sea conditions (wave height)			
	Calm sea	h_s = 2 m ($h_{3\%}$= 2,7 m)	h_s =3 m ($h_{3\%}$= 4 m)	h_s = 5 m ($h_{3\%}$= 6,7 m)
F_{BP} ≤ 30	80	50 + F_{BP}	30 + F_{BP}	F_{BP}
30 < F_{BP} < 90	80	80	52,5 + F_{BP}	7,5 + 0,75 × F_{BP}
F_{BP} ≥ 90	80	80	75	75
Note. To convert into kN, the ton values shall be multiplied by conversion factor 9,8.				

4.5.4 The tug efficiency F_{eff} in the different sea states (wave height) is shown in Fig. 4.5.4.

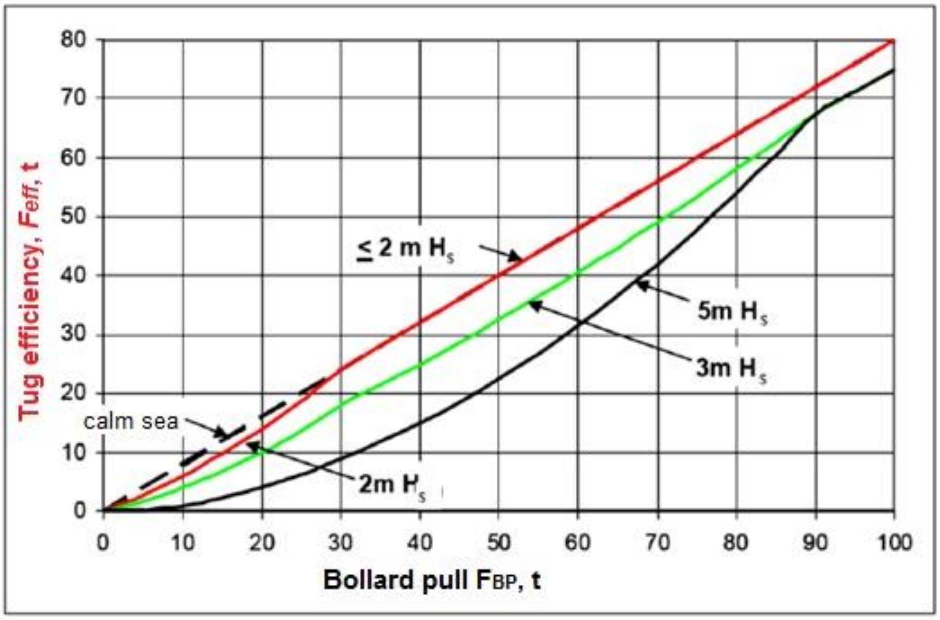

Fig. 4.5.4
Tug efficiency F_{eff} in the different sea states (wave height)
Note. To convert into kN, the ton values shall be multiplied by 9,8.

4.5.5 Unless more accurate calculations of T_{eff} are made, it is permitted to multiply F_{BP} given in the Bollard Pull Certificate (Form 6.3.45) by the following efficiency factors:

0,85 in enclosed seas;

0,75 in open seas.

4.5.6 Only those tugs connected so they are capable of pulling effectively in the forward direction shall be assumed to contribute to effective F_{BP}. Stern tugs shall not be considered when calculating effective F_{BP}.

4.5.7 For certain towing operations, for example for towing involving several tugs or for single tug towing where the towed object is sensitive to wind actions or is difficult to maneuver, an escort tug shall be provided for critical phases of the operation. The escort tug shall be of sufficient F_{BP} and shall be available for immediate use in case any of the towing tugs requires assistance.

4.5.8 For towing large structures (objects) and towing in the vicinity of shipping waterways (to avoid interference with the towing operation from shipping traffic), the practicability of involving an escorting ship to prevent potential hazards to the order arising from other ships and floating objects shall be considered.

4.5.9 For towing the platforms and other significant structures (objects) in areas with high shipping intensity, an escort tug shall be available for immediate assistance in case of the leading tug failure. In this situation, the riding crew may need on board and remain on the towed object for lifting the towline out of the water or dropping the anchor in case of the towline damage.

4.6 Towing arrangement

4.6.1 Towing arrangement fitted on the towed object (structure) shall be designed to ensure its reliable connection to the tug and provide manoeuvrability during the operation.

The towline arrangement shall ensure:

taking-up F_{PR} to provide station-keeping of the towed object in severe weather conditions specified in the design of the towing operation;

damping of dynamic loads arising during the towing;

avoidance of the ropes (towlines) chafing against the hull structures and guard rails;

towline quick release, if necessary;

recovery of the bridle legs or towing pendant aboard the towed object.

4.6.2 The components of the towing arrangement shall be surveyed (refer to 4.10.10.) and valid certificates shall be available confirming their compliance with the requirements for F_{BP}.

4.6.3 All wire rope (towline) terminations shall be hard eyes, i.e. reinforced thimbles or sockets (wire rope clamps). To prevent chafing, the towline shall be terminated with hard eyes.

4.6.4 For the towline strength assessment, the following components shall be considered:

towline (rope);

towing bridle or towing pendant;

tri-plate;

chafing chain;

connecting shackles, eye rings;

towline connections to the towed object;

hawse pipe;

synthetic spring (if used).

4.6.5 Towing shall be from the forward part of the towed object. However, there may be a case for towing some structures by the stern to obtain better directional stability. These could include:

part-built or damaged ships, or any structure when the bow sections could be vulnerable to wave damage;

converted ships or FPSOs without a rudder of skeg, or with a turret or spider fitted forward;

any structure with overhanging or vulnerable equipment near the forward part, which could interfere with the main and emergency towing connections.

A decision whether to tow by the stern shall be subject to special consideration by the Register based on the preliminary submitted documentation.

4.6.6 Where the tugs with F_{BP} greater than the required (design) value are used, for this object it is recommended to apply the "weak link" in the towline, which shall be indicated in the towline arrangement, and which prevents damage to the main components of the structure (arrangement) under occasional overloads exceeding the design ones.

4.6.7 Towline connections to the towed object shall be as follows:

locking device;

bitts;

towing bollards;

towing eye-plates.

Towline connections shall be capable of quick release, if necessary, as well as shall be secured against premature release.

Towline connections shall be located at the crossing points of longitudinal and transverse bulkheads.

Towline connections shall be designed to resist F_{PR} from any likely direction, with due regard to the use of guides.

For towing operations, a typical Smit bracket is the most preferable towline connection applied in practice.

4.6.8 Limiting devices in the form of hawse pipes or fairleaders shall be installed to prevent vertical and horizontal movement of the towline relative to the hull of the towed object to ensure linear transfer of load to its towline connections, as well as to prevent chafing of the wire rope or chain against the hull.

Hawse pipes shall be of sufficient size to allow smooth passage of the largest links of the chafing chain or wire rope with shackles.

Hawse pipe shall be sited in line with the towline (chain) connection and located along the deck edge to prevent towline chafing.

Hawse pipes shall be located as close as possible to the deck so that the chafing chain (or rope) position is approximately parallel to the deck when its part between the towline connections and the hawse pipes is tensioned.

Hawse pipes shall be shaped so as to prevent excessive bending stress in the chain (or rope) links.

Where a hawse pipe is fitted, the radius of the upper rail shall not be less than 7 times the diameter of the associated rope.

4.6.9 Chafing chains may be used in way of hull structures to prevent towline's rope chafing.

The chafing chain shall consist of stud-link anchor chain and enlarged end links to ensure connection with the towline components.

The length of the chafing chain shall be sufficient for the towing rope end to be extended beyond the hawse pipe throughout the towing operation; for this purpose the outer part of the chafing chain shall not be less than 3,0 m.

Minimum breaking load *(MBL)* of the chafing chain shall not be less than 1,1 times the towline *MBL.*

4.6.10 T o w i n g p e n d a n t is a section of steel wire rope used when the object is towed in one line or when it is forming part of the bridle (bridle legs).

Towing pendant shall be terminated with hard eyes or sockets. During hard eye manufacture, the press-type joint shall be used, spliced connections shall be avoided.

The towing pendant *MBL* shall not be less than 1,1 times the design *MBL* of the towline.

4.6.11 I n t e r m e d i a t e p e n d a n t is a section of wire rope, normally, having the length of 10 to 15 m and terminated with hard eyes or sockets. Intermediate pendant shall be fitted between the towing pendant and the tug's main towline, or between the towing pendant and the synthetic spring. It is mainly used for easy connection of the tug's main towline with the towing arrangement components.

4.6.12 All pendants shall be of the same lay (i.e. right or left hand) as the main towline.

4.6.13 A synthetic spring, if used, shall not normally replace the intermediate wire rope pendant.

4.6.14 To improve the towed object manoeuvrability a use of bridle is recommended.

The bridle legs may be both integral (chain or wire rope) and compound consisting of chafing chain and wire pennant.

The angle between the bridle legs shall normally be between 45° and 60°. If the angle exceeds the above values then the bridle components *MBL* shall be increased.

A tri-plate with the openings for connecting shackles shall be used as a connection joint. An enlarged bow shackle (omega-shaped) may be used instead of tri-plate.

4.6.15 To absorb the towline jerks during the towing on a short towline, the towline shall include a synthetic spring. In this case the towline length may be reduced up to 350 m.

A synthetic spring shall be made up as a continuous loop with hard eyes each end.

4.6.16 The towline components shall be connected by the connecting shackles. Standard D-shackles and omega shackles (enlarged bow shackles) shall be used.

Apart from the locking nut, the shackle pins shall have locking unclamping split pins. Single screw pin shackles shall not be used in the towline.

Shackles shall be adequately protected against corrosion.

4.6.17 The towing wire rope (towline) belongs to the tug and is fixed to a winch drum. All wire rope (towline) terminations shall be hard eyes, i.e. reinforced thimbles or sockets.

The towing wire rope (towline) length may be determined by the following formula:

$$L_t = 1800F_{BP}/MBL \quad (4.6.17\text{-}1)$$

where L_t = minimum length of the towline, in m;
F_{BP} = continuous static bollard pull of each tug, in kN;
MBL = minimum breaking load, in kN.

For areas with favourable weather, the minimum length may be determined by the following formula:

$$L_t = 1200F_{BP}/MBL. \quad (4.6.17\text{-}2)$$

4.7 Strength calculations of the towline and towline connections

4.7.1 The required parameters of the towline shall be related to F_{BP} of the tug sufficient for towing the object with a given speed under design conditions.

MBL of the main and emergency towlines including each bridle leg shall comply with the effective F_{BP} of the tug with regard to coefficients given in Table 4.7.1. *SWL* of shackles included in towlines shall be at least equal to F_{BP}.

Table 4.7.1

F_{BP}, in t	Areas with favourable weather	Other areas
$F_{BP} \le 40$	2,0 × F_{BP}	3,0 × F_{BP}
$40 < F_{BP} \le 90$	2,0 × F_{BP}	(3,8–F_{BP}/50) × F_{BP}
$F_{BP} > 90$	2,0 × F_{BP}	2,0 × F_{BP}
Note. To convert into kN the ton values shall be multiplied by conversion factor 9,8.		

4.7.2 *MBL* for the towline connections for securing the towline to the towed object shall not be less than 1,3 times the *MBL* of the towline.

4.7.3 *MBL* of the towline connections (rope pendants, connecting shackles, tri-plates, chafing chains, bridle legs, etc.) shall not be less than 1,1 times of *MBL* of the total towline.

If *MBL* of a shackle cannot be identified then its SWL may be determined depending on the tug F_{BP} in compliance with Table 4.7.3.

Table 4.7.3

F_{BP}, in t	*SWL*, in t
$F_{BP} < 40$	1,0 × F_{BP}
$F_{BP} \ge 40$	(0,5 × F_{BP}) + 20
Note. To convert into kN, the ton values shall be multiplied by conversion factor 9,8.	

4.7.4 *MBL* of any synthetic spring shall not be less than:

2 times the towline *MBL,* for tugs with F_{BP} less than 40 t;

1,5 times the towline *MBL,* for tugs with F_{BP} greater than 90 t; and

linearly interpolated between 1,5 and 2 times the towline *MBL* for tugs with F_{BP} between 40 to 90 t.

Note. To convert into kN, the ton values shall be multiplied by conversion factor 9,8.

4.8 Emergency towing arrangement

4.8.1 To minimize any risk associated with the loss of the towed object in case of accident situations due to the towing arrangement failure, an emergency towing arrangement shall be provided. Its main function is to enable the towing operation to be continued.

4.8.2 Emergency towing arrangement design is determined by structural particulars of the towed object and conditions of the towing and shall comply with the requirements of MSC/Circ.884 "Guidelines for Safe Ocean Towing".

4.8.3 The emergency towing arrangement shall consist of the following:

emergency steel wire rope;
towline connections to the towed object;
chafing chain;
fall line;
pick-up gear;
mark buoy;
connecting shackles;
securing arrangements of emergency towline.

4.8.4 *MBL* of emergency towline and strength of its attachment to the hull of the towed object shall not be less than those of the main towline.

4.8.5 Depending on the towed object design and conditions of its towing, the emergency towline may be attached both at the fore and aft ends of the object. Precautions shall be taken to prevent the emergency towline chafing against the hull structures of the towed object.

If the emergency towline is attached forward, it shall be led over the main towline. It shall be secured to the outer edge (side) of the towed object with soft lashings or metal clips opening outwards, approximately every 3 m.

4.8.6 The fall line shall be made of buoyant material of at least 75 m in length and shall have *MBL* not less than 30 t.

N o t e . To convert into kN, the ton values shall be multiplied by conversion factor 9,8.

4.8.7 Distance form the aft end of the towed object to the buoy shall enable recovery of the buoy and emergency towline in severe weather conditions and accident situations. The distance from the buoy to the nearest hull structure of the towed object shall not be less than 50 m.

Where necessary, the pick-up gear made of synthetic material and having length of up to 100 m may be introduced between the fall line and the buoy.

The buoy shall be clearly seen in the stormy weather and shall be of rich colouring.

It is reasonable to install swivels between the fall line and the towline, and between the pick-up gear and the buoy.

4.8.8 For towing of very long objects alternative emergency arrangements may be approved, but any arrangements shall be agreed with the tug master to ensure that reconnection is possible in accident situation.

4.9 Equipment for the towline retract

4.9.1 The towed objects shall be equipped with the arrangements for hoisting the towlines which are used for lifting and lowering the bridle or towing pendant during the preparation and completion of the towing operation, as well as for renewal of the towline in case of break.

4.9.2 The hoisting arrangement consists of the following:

winch with a fall line;
block and tackle system to be installed on the deck or on the special hull structures;
connecting shackles and locking devices.

4.9.3 Hoisting of the towing arrangement components shall be made by the winch rope secured by the shackle to the tri-plate of the bridle or the shackle at the towing pendant end, when the towing is made in one row.

MBL of the towline shall not be less than 6 times of the weight of the bridle with the tri-plate, or the weight of the towing pendant, connecting shackles and the intermediate pendant. The winch shall be located at the easily accessible place.

4.10 Requirements for tugs

4.10.1 The main criteria of selecting the tug for particular operation are the following:

F_{BP} of the tug;

availability of the towing winch and relevant equipment;

towing area;

the route and its length;

fuel reserve on board the tug.

4.10.2 F_{BP} of the tug shall be specified in the Bollard Pull Certificate (form 6.3.45), each tug engaged in the operation shall have valid Bollard Pull Certificate (form 6.3.45).

4.10.3 The tug shall be fitted with at least one towing winch. The winch shall be remotely controlled from the wheelhouse and shall be equipped with instrumentation for monitoring the loads on the towline. Towing shall not be used only for auxiliary purposes and in enclosed seas.

4.10.4 The tug shall be fitted with a spare towline, which characteristics shall fully comply with the main towline. Spare towline shall be kept at the special reel upside down or shall be preferably laid on the second drum of the towing winch.

4.10.5 The tug shall be able to refit all towline in case of its break, i.e. it shall have adequate supply of towing pendants, shackles, eye rings and other connecting equipment.

4.10.6 Speed of the tug with the towed object shall be assigned with regard to:

limitations for conducting the operations due to weather conditions;

plan of transit and instructions for ensuring safety of the particular towing;

actual metocean situation during the transit.

4.10.7 The tug shall have sufficient reserve of fuel, food and other consumables for the estimated transit. It is recommended to foreseen 25 % margin for the maximum duration of passage or 5-day reserve, whichever is greater. During the towing in ice, the above reserves shall be summarized.

When refuelling is planned, it shall be foreseen in the towing order schedule.

4.10.8 The tug shall be fitted with at least one self-propelled workboat for examination and communication with the object during the towing. The tug shall be equipped with relevant means for launching of the workboat in open seas at Beafourt 4 and 5.

Inflatable boat with outboard motor may be acceptable when the deck plating allows for transportation of the emergency equipment to the towed object.

4.10.9 Auxiliary equipment shall be available on board the tug:

searchlight(s) for illumination of the towed object during the night operations;

portable receivers/transmitters for communication with damage control party, fitted with extra battery or recharging arrangements;

fire fighting and draining equipment;

gas cutting equipment;

welding equipment;

steel plate material;

sealing material, etc.

4.10.10 The towing ship is subject to survey by the Register or another classification society (ACS), it is classed with, prior to mobilization measures on the MO preparation and performance in compliance with the RS (or ACS) rules and international conventions, having regard to necessary transit (passage)/towing to the MO area as well as its position in this area for the duration of the operation.

4.10.11 When forming the towing order it is permitted to consider the possibility of using two or several towing ships when one ship of the required output is not available due to any reason. In this case each tug shall have approximately similar dimensions and output. The total F_{PR} shall be determined by Formula (4.5.2). Each tug shall ensure F_{BP} of 15 — 30 % in excess of F_{BP} divided by the number of tugs.

4.10.12 For towing large size objects or towing in areas with restricted manoeuvring space, the escort tug shall be additionally provided to perform the following:

operate as a lead tug in case of the lead tug's propulsion plant failure;

remove the failed tug from the towing order in case of towline breakage;

provide any other assistance in the accident situation.

4.10.13 All ships of the towing order including escort tugs, auxiliary ships (anchor handling tugs, supply vessels, special purpose ships, etc.) shall comply with the approved towing operation design, and the ships themselves shall comply with the requirements of 4.10.10.

5 LAUNCHING

5.1 General

5.1.1 A launching operation represents a sequence of stages from initiation of the launch to the stage where the barge and object float separately.

5.1.2 Launching is made possible by the following methods:

by ballasting of the transport pontoon and, where necessary, buoyancy pontoons and by moving the object aside;

by ballasting of the transport dock and by moving the object out through the stern gate of the dock;

longitudinal launching from a launch barge with the use of symmetrical aft rocker arm, e.g. for the truss-type substructure.

The requirements of this Section apply in full measure to the longitudinal launching. For launching by means of ballasting, use shall be made of the applicable provisions of this Section.

5.1.3 Launching from multi barge system with unsymmetrical launch frames, sideways sliding of piles and separate object elements is subject to special consideration by the Register.

5.1.4 The following parameters shall be considered in relation to operational feasibility and structural limitations for the launched object and of the barge:

size and buoyancy and stability characteristics of the object;
barge size;
position of the object on the barge;
barge draught;
barge heel and trim;
barge bending moment;
barge submersion;
position of ballast water in the barge;
limiting environmental conditions;
rocker arm arrangement and rotational limitations;
allowable rocker arm reactions;
friction coefficient during launching;
water depth on the launching site;
auxiliary buoyancy.

5.1.5 Prior to start preparations for launching, it is necessary that the weather forecast shall be for the steady weather progress with the weather being invariable throughout the planned operation duration. The decision to initiate launching shall be based on the forecast window suitable for completion of all the object positioning operations, including acceptable margins for unforeseen cases. The object may be considered safe when it is capable to withstand an extreme storm which occurs once every ten years. Therefore, both the Manual and the schedule shall confirm that the extreme conditions can be withstood throughout the operation, after the decision on launching was taken.

5.1.6 The launching operation shall be performed in specified area which is subject to hydrographic survey confirming that the area concerned is free of any obstructions. It is not recommended to perform launching over subsea pipelines, underwater facilities or other underwater obstructions.

5.1.7 The calculations made shall show that the launched object will behave in a stable manner during the launching operation. Model tests shall be used for verification of the object's behavior and evaluation of forces acting during launching, especially when launching is performed in shallow waters and at low reserve buoyancy.

5.1.8 The trajectory of the launched object shall normally be computed by a dynamic analysis. The analysis shall include assessment of the barge motions.

All significant forces influencing the behavior of the barge and launched object shall be considered. Particular attention shall be given to the behavior of the barge and the effect of resulting uplift forces from the rocker arm onto the launched object.

5.1.9 The basic load case shall be analyzed distributing the self weight, buoyancy forces, barge foundation/support forces to the structural elements of the launched object and barge.

5.1.10 Loading effects from wind, motions due to waves and movements/ displacements of the object and barge during the launching operation shall be considered. The resulting increase in hydrodynamic forces may be accounted for by use of a dynamic amplification factor on the static forces.

5.1.11 When analyzing launching, consideration shall be given to damage of any one compartment of the object with the design hull weight and CoG position.

5.2 Requirements for the launched object

5.2.1 The design weight and buoyancy of the object shall be determined using drawings along with physical weighing of components. Potential inaccuracies in the determination of the buoyancy shall be included into the allowance used for the design weight in the object analysis.

The allowance in the analysis, used for the object weight, shall be at least ± 3 % (including inaccuracies in determining buoyancy).

The allowance in the analysis, used for the CoG position of the object (including inaccuracies in the CoG position), shall be at least:

X ± 0,3 m;
Y ± 0,3 m;
Z ± 1,0 m

where X and Y are horizontal axes and Z is a vertical axis for the final orientation of the object.

The above allowance shall be used in final analysis, when the whole material for the structures is put in production. Smaller allowances may be used if they are established on the basis of accurate weighing. It is recommended to take account of the greater unaccounted weight at the early design stages considering uncertainties which decrease progressively.

The analysis of the launching acceptability, to be made, shall consider at a time change of only one of the above allowances:

change of the weight and CoG position shall not be considered;
the CoG position shall change only in one direction (X, Y, Z).

5.2.2 The object shall be equipped with sliding cradle.

5.2.3 When launching, consideration shall be given to the following sequence of loads acting on the object:

self weight;
buoyancy;
braking (friction);
barge/rocker arm reactions;
inertia forces.

5.2.4 The resultant loads in each element of the object shall be calculated in discrete time during launching. So, e.g. the enveloping load shall outline each element and compare the maximum load with the allowable value.

The effective values of the self weight, CoG position and friction coefficient may be known only within certain allowances. The load elements shall be determined with consideration for the maximum possible allowances and thereafter correlated with the allowable values.

Some structural components may be subjected to impact loads during launching operation, which shall be taken into account in compliance with 5.1.7 and 5.1.8. Stresses due to hydrostatic loads when the object is submerged during launching shall not exceed the allowable stresses. The pressure of a water head for calculation of the maximum allowed depth for each element during launching shall be taken with a margin.

5.2.5 The launched object shall have sufficient strength to withstand the loads acting on the object during launching, especially at the time of turning on the rocker arm and at the initial moment of entry into water. Special attention shall be paid to local support loads and loads acting on the launch frame including consideration of the properties and fabrication tolerances of the launch timber. The buoyancy and stability of the object shall comply with 1.2.2.3.

5.2.6 Preferably all watertight structures having positive buoyancy, e.g. supports with positive buoyancy or buoyancy pontoons, shall have a small internal overpressure at departure from shore. Provision shall be made for monitoring pressure inside such structures from a readily accessible position.

5.3 Requirements for the barge

5.3.1 The barge shall have sufficient positive intact stability and the necessary reserve buoyancy at all stages of launching operation in compliance with the requirements of 1.2.2 considering the behavior of the object during the operation. The transverse metacentric height shall exceed 1 m throughout the period from the initiation of the launch to the end of the rocker arm rotation. The depth of the barge stern submersion shall be within the range of permissible limitations at all times.

5.3.2 The loads on the barge shall be verified to be within the operational limitations assessed by the classification society the barge classified with. This verification normally includes evaluation of:

bending and torsion of the barge hull;
rocker arm reactions;
barge submersion;
barge hydrostatic stability;
compliance with the special requirements of the classification society.

Strengthening shall be subject to acceptance by the classification society the barge classified with.

5.3.3 Any structural components on the barge not assessed by the classification society the barge classified with shall be verified to have sufficient global and local structural strength to withstand all loads during launching operation. Such structural components may include launching ways, positioning brackets for attachment of positioning lines, attachments for winches, hydraulic jacks, sheaves, etc.

Rigging equipment shall be connected to attachment points (lugs, trunnions, bollards, etc.) especially designed for the corresponding loads. Other attachment points shall not be used.

5.3.4 The barge ballasting system shall have sufficient capacity to achieve the predetermined barge launch parameters within a time period not exceeding 25 % of the favourable weather forecasting period.

5.3.5 The ballast tank volume shall have sufficient spare capacity such that the required trim, heel and draught can be maintained in the event of accidental flooding of any one compartment.

The barges shall be equipped with means to monitor the barge trim and water level in the ballast tanks.

Hatch covers over barge tanks shall not be open prior to or during launching, and when using submersible pumps.

5.3.6 The power supply on the barge shall have sufficient capacity for lighting during night work, welding and flame cutting operations.

5.3.7 The flame cutting facilities shall have sufficient capacity for cutting of the sea-fastening elements within a time period not exceeding 25 % of the favourable weather forecasting period. Sufficient number of workers and equipment items shall be provided to perform such operation.

5.3.8 The object to be launched shall be secured to the barge with anti-self-launch devices to prevent a spontaneous premature launch after cutting of the sea fastening elements.

5.3.9 Anti self-launch devices shall have sufficient structural strength to withstand the horizontal gravity component due to barge trim. Friction may be considered provided the lowest expected dynamic coefficient of friction is used together with conservative values for both static and dynamic barge trim (refer to Table 3.8.7).

5.3.10 The launch initiating push/pull system shall have sufficient capacity to overcome the static friction forces, and shall be capable of applying this force over a sufficient distance to ensure initiation of the launch.

5.3.11 The sliding surfaces shall have a finish that assures a relatively low coefficient of friction.

5.3.12 The launching appliance (power units, winches, slings, shackles) shall have sufficient working load, be fit for its intended purpose and arranged so as to:

ensure short start-up time;

avoid damage to the object during launch;

allow for possible object yaw during launching by the guiderails on the rocker arms.

5.3.13 The barge including all permanent equipment and systems and auxiliary equipment and systems to be used during the launch operation shall be inspected and/or tested prior to departure from shore. The tests/inspections shall verify that the equipment and systems are in good working order, comply with the requirements of the classification society the barge classified with and fit for the intended use.

5.3.14 A survey of the launching ways and rocker arms shall be performed to verify that the alignment and level is within the criteria considered in the structural verification of the barge and the launched object.

5.4 Operational aspects

5.4.1 A launching operation control station shall be provided. The control station shall be equipped to obtain the whole information on the operation procedure.

5.4.2 The barge shall be positioned by lines attached to the tugs and relative to a set of predetermined coordinates to ensure that the launched object will not hit the seabed or structures positioned on the seabed.

The barge heading for launch shall, where possible, be into the prevailing wind and wave direction.

5.4.3 The following conditions shall be complied with before starting the cutting of sea-fastening and/or ballasting of the barge:

the environmental parameters correspond to the design ones;

the launch position and orientation has been found acceptable;

all structures and equipment necessary for the launch operation are correctly rigged, ready to be used, and have been inspected and tested;

means which ensure the structure resistance to extreme seasonal weather conditions after installation are ready to be used;

obstacles which may unduly delay the operation have been removed.

5.4.4 Sea-fastening elements shall be cut in accordance with a predetermined procedure containing a number of steps. The cut lines shall be painted. Continuous watch on the weather conditions, including the weather forecast shall be performed. The point of no return shall be identified in the procedure.

Sea-fastening elements that have been cut shall be secured to the barge to avoid interference with the object during launch. After cutting of the sea-fastening element and prior to ballasting of the barge, it is recommended to initiate the object movement by the use of the push/pull system or launch initiation system.

5.4.5 When removal of the sea-fastening elements is finished, the barge shall be so ballasted as to achieve the trim necessary before the launch. By the time of completing of the barge trimming, the crew on board shall be reduced to the minimum required number that will allow to exercise control over the launching operation.

During launching the object shall be free from any obstructions. If any lines comprise the object's rigging before the launch, it shall be proved than they will not get foul of the obstacles during the launching operation.

5.4.6 The launch shall be initiated in a controlled manner by removing the anti self-launch devices and/or by pushing/pulling the launched object to overcome the static friction forces.

Tugs shall not be used to initiate the launch.

5.4.7 The lugs and similar structures shall have sufficient structural strength to overcome the maximum static friction forces and ensure self-release of the pulling lines.

5.4.8 The launched object shall be connected to positioning and hold-back ships, by lines with sufficient slack to allow free movement during the launch.

5.4.9 The number of tugs shall be sufficient to hold the object after launching, and, as a minimum, one tug shall be permanently connected to the barge (in the forward part).

5.4.10 The following parameters shall be monitored and recorded during preparations for launch:

barge trim and draught;
barge position and orientation;
barge motions;
barge ballast and stability parameters;
draught, heel and trim of the object after launch.

5.5 Upending

5.5.1 Upending of the object may be required when the object is towed in horizontal position or when it is transported on the barge and launched in the same position.

5.5.2 Upending operations shall be carried out by controlled ballasting and deballasting of buoyant compartments.

Upending operations assisted by crane lifting, and the necessary reserve buoyancy in this case are subject to special consideration by the Register.

5.5.3 An upending operation represents a sequence of different load cases from the initial self-floating condition to the final self-floating condition (installation).

The basic load cases shall be analyzed by static analysis considering the buoyancy, self weight and any loads applied during upending.

5.5.4 Loads on buoyant compartments shall be calculated for the largest submergence draught considering accidental flooding of any one watertight compartment

5.5.5 Upon completion of the upending operation the object shall remain afloat in stable equilibrium and with sufficient freeboard to allow commencement of positioning and setting operation.

5.5.6 Structures shall have sufficient strength to withstand the loads described in 5.5.3 and 5.5.4.

5.5.7 The ballast system including the buoyancy tanks connected to the ballast system shall be designed such that the upending operation may be suspended and reversed at any stage. It shall be taken into account that there is normally a moment in the process when the operation comes out of control. Such situation takes place when the waterline area is drastically reduced during rotation (at the large tilt angles) and the object continues its rotation without additional ballasting. The same situation takes place in the reverse operation.

The upending sequence shall clearly identify such points of upending operation no return.

The ballast system shall be designed so that the object remains afloat in stable equilibrium except for the situation described above.

5.5.8 The ballast tanks shall, where possible, be designed such that they are flooded uninterruptedly by 100 %.

5.5.9 When carrying out ballasting operations, the following parameters shall be monitored manually or by remote monitoring system:

draught, trim and heel;
seabed clearance;
environmental conditions;
amount of water in the ballasting compartments;
open/close mode for valves;
air pressure in tanks;
ballasting rate;
crane hook load.

5.5.10 Two separate methods shall be available for the starting or stopping of flooding of anyone independent compartment. Where requirements in 5.5.8 are satisfied a back-up method of halting flooding may be omitted.

5.5.11 The minimum seabed clearance of an intact structure shall be 5 m in deep water and 10 % of water depth (from the lowest level) in shallow water considering displacements due to motions, heel due to current and towing forces, general inaccuracy, possible overloading of hull and sea level variations due to barometric pressure variations.

The seabed clearance shall be positive when any one compartment is damaged. To fulfill the said requirement a clearance of minimum 2 m shall be available. In special cases, e.g. in shallow waters, the clearance may be reduced.

5.5.12 The hook load of a crane shall be determined on the basis of ballasting calculation. The accidental flooding during the crane operation shall not cause an uncontrolled overturning of the object or interfere with the sling release.

It may be assumed that an occasional flooding during upending of the object by hook shall be sufficiently slow and provide the crane operator with a better possibility of avoiding overloading of the crane by means of slacking of the line. In this case, the hook load may be increased. The resultant loads and stresses due to hook loads shall be evaluated and added to the loads due to self weight and buoyancy.

The effect of the crane ship on the object displacement characteristics shall be considered when analyzing displacement.

The design shall contain calculation of the additional resultant loads of the crane depending on the upending procedure.

A horizontal clearance of minimum 3 m shall be available at all times between any part of the crane ship and the object A horizontal clearance of minimum 3 m shall be normally available between the crane ship and the cargo barge, but it may be reduced provided that the adequate tendering protection is used.

6 INSTALLATION OF THE OBJECT ON SITE

6.1 General

6.1.1 For the purpose of these Rules, the term "installation of the object in a design position" (hereinafter referred to as "object installation") is considered to mean a sequence of activities, procedures, control checks and corrective actions that ensure safe transfer of the object from transportation position to one as designed which is resistible to external effects during the entire time the object being in the above position.

Installation of the object includes:

working site preparation;

positioning of the object over the installation site and orientation thereof in space;

submersion of the object;

securing of the object to the seabed (by piling or by gravity, installation of position mooring system);

mating of the object parts (if applicable).

6.1.2 Position of the installation site shall be given by the customer and established in the MO design (or work performance design).

When developing the installation design, consideration shall be given to the following:

compliance with the prescribed allowable deviations;

prevailing wave, wind, current directions;

capability of using available technical means as applied to the structural particulars of the object and ambient conditions;

capability of using technical monitoring means providing the required accuracy of the object position;

scope and productivity of ballasting operations;

need for monitoring the object position by means of divers and/or remotely operated vehicle (ROV), and the time period when such monitoring shall be performed, as well as the duration thereof.

6.1.3 The MO operator shall monitor the execution of the operation and shall be sure that the tolerances for installation of the object are maintained throughout each installation phase.

6.1.4 When preparing the installation site, provision shall be made for sufficient tolerances which account for the inaccuracies of:

positioning;

instrumentation used during installation;

other errors.

6.1.5 The accuracy of the object installation shall be substantiated in its design and specified in the MO plan/design.

6.1.5.1 Unless expressly provided otherwise, the objects shall be installed under sea conditions with the following accuracy:

center of the object within a circle with a radius of 7,5 m with its center at the design position point;

CL within ± 1° of the design direction;

base line within ±30 cm from the theoretical elevation;

heel and trim: corner elevations above the centre of the object shall be within ± 7,5 cm and the slope shall be max. 1:100.

6.1.5.2 Unless expressly provided otherwise, the objects attached to the existing structures shall be installed within the following tolerances:

foundation center shall be within a circle with a radius of 1 m with its center in the theoretical coordinates given in the drawings:

orientation ± 1°;

lift at center ± 30 cm;

heel and trim: corner elevations above the centre of the object shall be within ± 7,5 cm and the slope shall be max. 1:100.

6.1.5.3 Particular attention shall be paid to the FOP topside/modules lifting. The following requirements shall be established for these operations:

angle between the main-deck beam being installed and the top surface of the substructure is less than 0,5°;

rise of the deck plating at the center within ± 3 cm above the design level;

deck angles shall be corrected within ± 12 mm of the actual deck plating rise at the substructure center.

6.1.6 Boat landing area for disembarkation from the craft shall be checked during falling tide. The position shall be within ± 30 cm of the design one.

6.1.7 During the object installation, it is necessary to use calibrated equipment and instrumentation, which proved a reliable and regular monitoring of the object positioning.

The accuracy of measuring instruments shall be consistent with the installation tolerances.

6.1.8 The composition of the equipment and instruments required to control the installation of the object is determined in the MO plan/project.

6.1.9 Provision shall be made for a system capable of providing continuous monitoring of the position and orientation of the object in relation to the desired position (beacon), as well as a second (independent of the first system) system intended to duplicate and monitor the primary system.

It is recommended to monitor and record the object installation process by means of ROV or pre-installed TV cameras.

6.1.10 Prior to submersion, the object shall be oriented to the design position by means of ships or pre-installed mooring buoys.

6.2 Working site preparation

6.2.1 Preparation of the working site shall be provided prior to the object installation and shall be carried out in compliance with the requirements as for the designed object. At determining the dimensions of the working site, the necessary allowances shall be provided to consider the inaccuracy of:

positioning;

instrumentation used during the installation;

other mistakes.

Preparation of the working site shall include but not be limited to the following operations:

seabed survey and removal of obstacles both on and in soil strata, presence of which is not allowed;

levelling;

removal, where necessary, foul holding ground, silt, etc.;

layout of good holding ground (if necessary).

Immediately prior to installation, the control examination of the working site shall be made in order to confirm the possibility of the object installation.

6.2.2 The MO design on the object installation shall specify the issues concerning:

navigational equipment and recommendations for underwater survey of the installation location;

site preparation procedure;

composition of technical facilities and equipment for site preparation;

composition of technical facilities, equipment and instruments for underwater engineering works and diving operations;

object installation accuracy;

tolerances for geometrical parameters of the site;

safety measures to be taken during site preparation;

safety measures to be taken during diving operations.

6.2.3 Scope and level of detail of documentation used for the development of the MO design on the object installation at the working site shall be determined based on the specific character and scope of works to be performed.

6.2.4 Site survey shall be carried out in compliance with 3.10 and 3.11, Part II "General Requirements" of these Rules and the requirements of normative documents of the Russian Federation.

6.3 Positioning

6.3.1 The object shall be installed in a design position and kept in this position by own anchors, auxiliary ships, mooring buoys (pre-installed) or combination thereof.

6.3.2 The technical facilities shall ensure position keeping of the floating object within the limits specified in the design under rated MC specified by the design, but not less than the following:

design wave height with 3 % probability of exceeding level — not less than 2 m;

design wind velocity — not less than 10 m/s.

6.3.3 For better object orientation in relation to subsea structures available at the working site, these structures are recommended to be marked with clearly visible buoys.

6.3.4 To monitor object position in relation to the end section of subsea pipeline, these structures are recommended to be clearly marked.

6.4 Submersion and setting down

6.4.1 The method of object submersion (on an even keel, with a heel/trim or with the initial heel/trim and further levelling of the object at the even keel) shall be determined in the object plan approval documentation and specified in the technical documentation of MO.

6.4.2 The following parameters shall be considered in evaluation of the operational feasibility:

limiting environmental conditions;

time limitations determined by the weather window;

structural limitations for the object;

ballasting system capacity;

object buoyancy and stability;

soil characteristics and on-bottom stability.

6.4.3 The ballasting system shall ensure:

design time of the object setting down on the seabed;

submersion rate, primarily, when the substructure approaches the seabed, that prevents impacts upon the seabed which may cause damages to the substructure, especially, to the skirt, if any;

generation of required clamping force to ensure on-bottom stability when the object is exposed to external loads during installation until it is finally fastened;

capability of the object alignment in a horizontal plane by asymmetric ballasting considering soil parameters and seabed topography.

The procedure for flooding the ballast tanks and/or ballast transfer during the levelling shall be determined by the plan approval documentation of the object.

6.4.4 When submerging the object on an even keel, the procedure for filling ballast tanks shall be provided that ensures safe submersion of the object without any excessive heels/trims. For this purpose, provision shall be made for simultaneous filling of tanks located symmetrically relative to the substructure center. Estimated correction for the metacentric height due to free surface effects in the simultaneously filled ballast tanks shall be provided.

6.4.5 The number of simultaneously filled tanks and the procedure of their filling shall be determined by the ballast plan with regard to the object stability.

6.4.6 The ballasting plan shall contain a graphical chart showing the metacentric height variation during the object submersion and possible heels/ trims (under the design wind and wave conditions), and a suitable equipment shall be provided for monitoring thereof. Particular emphasis shall be placed on the moment of abrupt change of the waterline area which may cause a drastic increase in heel/trim.

6.4.7 Where skirts are available, to avoid effect on the soil surface and formation of obstructions on the outside of the skirts, the side drift of the object shall be prevented. These obstructions may block the skirt penetration into the seabed. This operation shall be monitored to avoid pore water overpressure (pressure excessive in relation to hydrostatic pressure arising in the seabed soil saturated by sea water due to soil stabilization) inside the skirt elements which may result in local seabed erosion.

6.4.8 Lines used in the object installation shall, where possible, be attached to the object structures located above the final waterline and easily released (step-by-step).

6.4.9 Provision shall be made for a deballasting plan in the event of not precise object setting on the seabed, upfloat and re-ballasting.

6.4.10 If the ballast tanks are filled not by own pumps, but by delivery of water from the supply vessels, the arrangements shall be provided on the object deck enabling to connect the hoses from the supply vessels to the object ballast system

6.4.11 The calculations shall be made to prove the object stability after touching the seabed in weather conditions accepted for the operation till completion of ballast intake and/or pile driving.

The same calculations shall be made for weather conditions that may arise in case of delays, which prevent timely ballast intake. The said calculations shall be made by the object designer and their results shall be indicated in the MO design.

6.4.12 A person who is a member of the key personnel, familiar with the peculiarities of the submergence operations, has experience in similar operations (e.g., dockmaster of floating dock) shall be responsible for the performance of submergence operation. All these operations shall be executed only after the approval has been granted by the above person or at his command.

6.4.13 Object position monitoring during submersion may be performed using GNSS or by checking points.

6.4.14 The operation design shall specify the requirements for:

disposition and positioning of ships and sequence of the operation;

equipment of mooring and anchoring arrangements with line tension monitoring systems (if applicable);

composition of positioning systems;

facilities to monitor the object displacements, draught, heel and trim;

means of communication between the control centre, control stations and ships;

activities of persons involved in the operation under changing MC, in case where the parameters of environmental effects exceed the design ones, and in accident situations.

6.4.15 After the object have been set down on the seabed/cushion, the underwater survey of its actual position shall be carried out, which shall include (if applicable) measurements of the relative position of the object and end portion of the subsea pipeline or other pre-installed objects. Based on the results of underwater survey, an appropriate report shall be drawn up, and the operation shall be considered as completed if the actual measurements are within the design tolerances.

6.4.16 Protection of soil from erosion for gravity-type objects.

6.4.16.1 Depending on the shape of the base, type of soil, local currents, the object may require protection against erosion, such as bunding with gravel, stone, special protective materials.

6.4.16.2 During construction of soil protection, a considerable number of ships are involved in the vicinity of the platform (object), so it is reasonable to provide a section containing requirements for the object installation in the object installation design.

6.4.16.3 The section may contain the following process steps:

passage of flood protection vessel (FPV) to the object with specified amount of supplies on board, and commencement of protection construction works;

protective materials supply to the operation area as per their expenditure (performed by a transport ship — TS);

TS temporary anchorage and FPV approach thereto;

transshipment of materials from TS to FPV;

monitoring of protection parameters compliance in height and size with the design ones (can be performed by ROV, which is provided on FPV).

6.4.16.4 Construction of protection is performed according to the FPV owner's procedures and its general provisions shall be specified in the documentation of protection construction design.

The acceptable metocean conditions (AMC) for construction of protection shall also be determined in this documentation. If AMC are exceeded, the construction of protection shall be interrupted and FPV shall be laid up at the temporary anchorage for anticipation of better weather conditions.

The protection construction design shall determine the allowable AMC for transshipment operations.

6.4.16.5 At least two temporary safety zones shall be determined — the most hazardous zone where FPV performs construction, and more extensive zone, which includes anchorage/transshipment areas and maneuvering areas for entering/departing.

6.4.16.6 An initial bathymetric survey along the profiles of future protection shall be performed before the construction of the protection. The survey results shall be used as the basis for the approval of protection construction results. Monitoring of the protection height shall be carried out by the repeated bathymetric survey along the same profiles as the initial ones. The actual protection height (thickness) shall be determined by the profiles height differences and shall be compared with the designed one.

6.4.16.7 It shall be provided, that the minimum distance between FPV and the object defined considering the location and length of the material windrowing pipe will be sufficient to avoid collisions between the object and FPV.

To avoid possible collisions, when FPV moves along the object, particularly if the length of the object is significant, it shall be provided, that the ship's speed does not cause the suction phenomenon of FPV to the object's board.

To monitor the distance between FPV and the object's board the appropriate equipment and alarm system that alerts to dangerous approach of FPV towards the object shall be provided.

6.5 Fixing of the object at the installation site

6.5.1 Piling.

6.5.1.1 Selection of the pile driving equipment shall be based on a calculation.

6.5.1.2 The following parameters shall be established by the calculation:

pile driving resistance of soil;

check for proper selection of the hammer for pile driving down to the required mark or the pile bearing capacity;

maximum dynamic compressing and tensile stresses in cross-sections along the pile length due to hammer blow;

determination of the failures during driving;

determination of the pile capacity based on the results of measurements of and elastic displacement of pile head due to hammer blow during driving.

6.5.1.3 The pile driving calculation shall be based on the wave theory of impact. The computer calculation programs recommended by the Rosstroy (RAM-2, DIZO-2) or similar foreign programs may be used for calculation.

6.5.1.4 The soil resistance may be determined by means of the design tabulated soil resistances in accordance with SP 24.13330.2021 "SNiP 2.02.03-85 Pile Foundations" or from the physical and mechanical properties of the soil (internal resistance factor, adhesion, density, etc.) in accordance with the algorithm for sandy and clay soils.

6.5.1.5 The maximum dynamic stresses during driving of piles shall not exceed 0,9 of the pile material yield strength.

6.5.1.6 The failure parameters during driving of piles (minimum pile penetration at a certain number of drive blows) shall be specified by the designer, but under no circumstances they shall be less than those indicated in the hammer specification.

6.5.1.7 Arrangements shall be made to cover initial failure when penetration is less than the design one (soil erosion, drilling over). Penetration of the pile which is less than the design one may be permitted only upon agreement with the designer of piling.

6.5.1.8 The object on-bottom stability shall be ensured during driving of piles when the object is subjected to the design external loads. If necessary, temporary ballasting of the object shall be provided.

6.5.1.9 As a minimum, the following information shall be documented for each pile to be installed:

pile number and support position;

date and time of driving;

penetration due to self-weight of the pile and weight with the pile-driving hammer stabbed on top of the pile (and with spacer pile, if applicable);

pile penetration depth;

drive blow counts (number of blows for each 250 mm of pile penetration).

6.5.1.10 Upon completion of pile driving, object position and verticality shall be verified.

6.5.1.11 Piles shall be secured in the pile sleeves by the method specified in the design – by grouting, expansion of piles in the guide grooves (method HYDRA-LOCK), swaging of piles, welding. The securing procedure shall be submitted to the Register for consideration.

6.5.1.12 Requirements for the procedure of the pile head grouting in the substructure pile slots:

.1 fast-hardening portland cement shall be used for making up the grout mix;

.2 the grout supply system shall be capable of filling the clearance between the pile and pile slot without any free space;

.3 it is recommended to carry out grout supply pipe assembly during the object manufacture;

.4 closed grouting system with installation of seals to isolate the water annular is preferable;

.5 during grouting the amount of grout mix shall be monitored by means of regular measurement of the grout mix density in the grout mixing plant prior to injection and in the clearance;

.6 during grouting reference specimens shall be made to determine concrete strength in accordance with GOST 10180-90 (4 specimens per pile). Reference specimens during hardening shall be kept under the same conditions wherein the grout in the annular clearance of the pile connection gains strength;

.7 arrangements shall be made for unforeseen situations:

cementation when the clearance is filled incompletely, e.g. in the event of the concrete pump failure;

clearance seal failure in the upper and lower parts with the grout leaking;

chocking of the grout supply pipes;

.8 arrangements shall be made to prevent marine pollution.

6.5.2 Gravity penetration.

6.5.2.1 Gravity penetration into the seabed is achieved by adding weight to the object by water and solid ballast intake.

6.5.2.2 The pore pressure indicators shall be provided. The required amount of the water and solid ballast shall be determined to ensure clamping force.

6.5.2.3 Where solid ballast is loaded, a special group of tanks intended only for clamping force generation, and the sequence of filling thereof which makes it possible to simplify control of the amount of water taken shall be determined.

6.5.2.4 Where solid ballast in the form of a flow concrete mix that fills the object compartment is loaded, the work performance design shall take account of:

arrangement of equipment for making up concrete mix;

procedure of delivery, storage and inspection of direct materials prior to use;

moist curing of concrete, which define production of a durable structure.

6.5.2.5 The requirements for solid ballast placement are given in Appendix 3.

6.5.3 Installation of position mooring system for floating objects.

6.5.3.1 The position mooring system shall be installed in the following sequence:

anchor positions shall be determined;

anchors with attached bridles and buoys marking anchor positions shall be installed;

bridles shall be laid from each anchor to floating object and attached thereto;

anchor with high holding capacity shall be tightened up and thereafter position of anchors and bridles shall be verified.

6.5.3.2 In case where position mooring system is installed in the area with water depth exceeding 60 m and with pre-installed offshore structures, it is recommended that the design clearances determined with consideration for environmental impact on the object and breakage of one anchor line are not less than the distances from those structures to the position mooring system elements given in Table 6.5.3.2.

When synthetic fiber ropes are used, clearances shall be particularly determined for each case. They depend on the system geometry under environmental load variation and on the effects of contact between the anchor line and offshore structures.

The lines of synthetic fiber ropes shall touch the seabed neither during installation nor in operation.

The minimum clearances from structures on the seabed given in Table 6.5.3.2 are valid for drag anchors. For other types of anchors (without substantial dragging) lesser clearances may be accepted.

The customer may establish more stringent requirements for the clearances.

For sea depths less than 60 m, after detailed review of the position mooring system characteristics and effects of failures or wrong actions, less stringent requirements than those proposed in Table 6.5.3.2 may be accepted.

Table 6.5.3.2

Minimum distances from the position mooring system elements to the structures upon completion of installation

Structures	Direction of anchor lines	Distances to structures	
		Vertical	Horizontal
On the surface			
Floating and fixed objects or two floating objects	—	—	10 m[1]
Submerged			
Anchor lines of objects in operation	Any direction	*a*) 10 m[2] *b*) Without contact[1]	*a*) 10 m[2] *b*) Without contact[1]
Anchor lines of objects taken out of operation	Any direction	*a*) 5 m[2] *b*) Contact is acceptable[1]	*a*) 5 m[2] *b*) Contact is acceptable[1]

Structures	Direction of anchor lines	Distances to structures	
		Vertical	Horizontal
Anchor line and unprotected pipeline/ flexible drill stem	Pipeline crossing	*a*) 10 m[2)] *b*) Without contact[1)]	—
Anchor line and protected pipeline/ flexible drill stem	Pipeline crossing	*a*) Without contact[2)] *b*) Contact is acceptable[1)]	—
Anchor line and subsea structure	Crossing of subsea structure	—	Crossing is generally unacceptable
Anchor line and subsea structure or unprotected pipeline/flexible drill stem	Without crossing (parallel)	—	150 m
Anchor line and protected pipeline/ flexible drill stem	Without crossing (parallel)	—	50 m
Anchor and subsea structure or fixed object	Any direction	—	300 m or 50 m[3), 4)]

[1)] In case of one anchor line breakage and object shifting.
[2)] In case of intact position mooring system with consideration for the object shifting due to design environmental loads.
[3)] Provided that the anchor is installed by means of ROV.
[4)] If the anchor dragging sector is located out of the structure.

6.5.3.3 Other types of anchors shall be installed within the tolerances specified in the operation design.

In case where piles are used as anchors, bridles may be attached to them with the help of divers and laid with the help of supply vessel.

6.5.3.4 Additional requirements for installation with reinforced-concrete mooring anchors:

.1 such installation shall be carried out in accordance with specially developed procedure approved by the Register;

.2 positions of the mooring anchors shall be checked by divers or ROV;

.3 central ring of the mooring anchors shall not be in "underneath" or "sidewise" position at which the anchor practically loses its holding capacity. The ring shall lie in the bridle plane to avoid occurrence of excessive bending stresses in operation.

.4 in order to give to the anchor correct position it shall be lifted by the bridle above the seabed and embedded into the soil smoothly;

.5 since the bridle length always exceeds its portion laying on the seabed while in working position, of about a value equal to the sea depth, so when laying bridle, a bend (a half-loop) shall be made at the end of laying in order the bitter end of the bridle does not get entangled with the bridles of adjacent anchor lines;

.6 prior to completion of bridle laying (moment of half-loop formation) the anchor holding capacity shall be checked through testing it by tension with the use of a tug. It will be practicable for bridle laying to use a tug on the deck of which the completely retrieved bridle may be stowed.

Anchor holding capacity may be by slinging the bridle on the ship and by engine operation to produce pull corresponding to design load on the anchor. In case where during 15 min the anchor does not creep, the laying of the bridle shall continue until its full length is slipped. The case of considerable design load and insufficient tug power is subject to special consideration by the Register;

.7 bridle end shall be marked by a buoy with a hauling line so that with its help the bridle can be subsequently lifted for connection to the object.

6.6 Mating of objects or parts thereof afloat

6.6.1 Mating of the objects or parts thereof afloat (hereinafter referred to as "mating") on high seas is concerned with the operations of joining the topside or topside modules and the substructure together.

In so doing, the following shall be performed:

designing, manufacture and installation of special mating arrangements prior to the mating operation;

ballasting of the objects and transport facilities;

positioning;

alignment of the structures to be mated;

setting of the topside on the substructure or floating-up of the substructure.

6.6.2 The following parameters shall be considered when designing the mating operation:

limiting environmental conditions;

time limitations determined by the weather window;

structural limitations for object and barges;

ballasting system capacity;

buoyancy and stability;

horizontal and vertical mating tolerances;

skew loads and whether the skew loading effects remain as permanent after completion of the mating or not.

6.6.3 Adequate protection of the object against impact loads shall be ensured.

To avoid damages, the Register-approved guides, shock absorbers and compensators based on steel springs, hydraulic/pneumatic damping systems, block pulley, etc. shall be adopted.

The compensator shall be of safe design and certified materials

6.6.4 Sufficient freeboard to any open compartment shall be ensured during all stages of joining objects considering the consequences of its accidental flooding.

For mating operation where the reserve buoyancy is small, any open separate compartment is recommended to temporarily closed.

6.6.5 The basic load cases for the topside and the substructure shall be determined by evaluating the following activities:

ballasting of the substructure to mating draught (or setting of the substructure on the seabed in accordance with the requirements of 6.4 and 6.5);

positioning of the barge with the topside thereon above the substructure;

submersion of the barge or floating-up of the substructure until the topside comes into contact with the substructure;

structural deformation of substructure at initial stage of the topside weight transfer from the barge to the substructure in case of mismatch (detachment) of the topside surfaces and the substructure surfaces to be mated horizontally;

topside weight transfer from the barge to the substructure by continuing to perform ballasting/deballasting operations;

ballasting of the substructure to design draught (if applicable).

6.6.6 The basic load cases may be analyzed as static ones and determined by loads from:

.1 for the substructure:

external/internal hydrostatic pressure;

ballasting of the substructure;

topside (topside module) weight;

structural deformation of substructure at initial stage of the topside weight transfer from the barge to the substructure;

.2 for the topside (topside module) on the barge:
transfer of the topside self weight from the barge to the substructure;
ballasting of the barge;
contact interaction with the substructure under structural deformation at initial stage of mating.

Additionally, positioning and mooring loads acting on the substructure or the deck on barges shall be considered.

All realistic accidental load conditions shall be identified. Identified accidental loads that cannot be neglected due to low probability of the event shall be included in the design calculations.

6.6.7 In the period from topside weight transfer to the substructure until the permanent connection between topside and substructure has been established, the topside shall be horizontally restrained.

The capacity of the horizontal restraint capability shall be sufficient to hold the topside or the deck in the worst possible damage case including wind heel and possible effects of current and waves. The effects of friction shall be taken into account.

Connections between the topside and the substructure after mating shall have sufficient strength to withstand at any draught the loads arising at the lesser of the following inclination angles in combination with the inclination due to wind:
angle at which flooding takes place;
angle at which the allowable stresses are exceeded in the structure or in its parts;
angle of 15°.

6.6.8 The barge supports and connections restricting horizontal displacement of the topside, as well as strength and stability of the topside and substructure components shall have sufficient strength to withstand all vertical and horizontal loads caused by the topside and the barge inclinations during the weight transfer.

The substructure shall be protected against possible accidental loads such as mooring line failure (not relevant if the mooring lines are slack during topside mating), flooding of buoyancy pontoons, dropped objects, collision loads.

6.6.9 The ballast/deballast system shall:
have sufficient capacity to complete the mating operation within the time limitations determined by the weather window. Normally, the operation shall be designed to be performed within a period of 48 h;
be capable of leveling the structure by eccentric ballasting/deballasting to compensate for any shift of the centre of gravity during the mating operation;
prevent accidental cross flooding and uncontrolled ingress of water;
ensure reversibility of the operation, that is, restoration of the safe draught.

6.6.10 Valves used for ballasting/deballasting shall be doubled when installed on the objects not complying with the one compartment damage stability requirement.

6.6.11 The design shall provide for the following tank water level control systems:
remote reading sounding system;
a back-up system, e.g. ullaging by hand.

6.6.12 Ballast compartments, which are intended to remain dry, shall have adequate drainage capability to eliminate uncontrolled ingress of water.

6.6.13 Provision shall be made for monitoring and control of the ballasting/ deballasting to prevent excess structural loading during ballasting and deballasting of the compartments.

6.6.14 Umbilicals of the hydraulic systems shall be adequately protected and be backed up to cover breakdowns or rupture.

6.6.15 Systems and arrangements shall have redundancy to cover failures during the object transfer within the specified time.

6.6.16 The design shall provide for a primary and secondary positioning systems.

The primary positioning system incorporates mooring and towing arrangements for the substructure and barge, which shall be capable of securing the structure in predetermined position in the event that the mating operation is interrupted. The primary positioning system shall ensure safe positioning of the barge close to the substructure.

The secondary positioning system shall ensure accurate and well controlled positioning of the barge with the topside located thereon above the substructure. The positioning shall take place without causing local impact loads exceeding the energy absorption capability of the positioning shock absorbers. Winches, wires, jacks of this system shall have sufficient capacity to resist wind forces, wave forces, current forces.

6.6.17 If ships specially intended for performing mating operations by float on method, e.g. flo-flo type ships, they shall be positioned using their own anchors in the water area previously surveyed by divers.

Where a barge without regular anchor arrangement intended for its securing is used, the equipment including anchors, bridles and mooring buoys to which the barge is moored shall be installed prior to commencement of mating operation by float on method.

6.6.18 Prior to mating operation, the following shall be tested:

compliance of the freeboard with that determined in the design;

availability of structures specified by the design and which shall be tested according to their specifications;

possibility of remote control of the ballast valves and the by-pass valves fitted in the watertight bulkheads;

adequate protection of all inlets to prevent damage by entering debris and cables;

condition of the temporary closures;

absence of debris in the internal compartments to be closed.

Trials shall be carried out to test the operation of the equipment and systems and watertightness of the object.

6.6.19 During mating, the relative movements of the objects due to environmental loads shall be carefully considered. All back-up systems shall be ready for immediate activation during the critical stages of the mating operation.

6.6.20 All connections between the barge and the object structures except those with securing devices restricting horizontal displacement shall be removed prior to commencement of weight transfer.

6.6.21 Assuming maximum excursions caused by environmental loads, the following minimum bottom clearances apply:

sideways clearance during positioning shall be of 0,5 m;

vertical clearance of 0,25 m shall be maintained between the underside of the object and the top of the substructure;

for safe removal of the transport and installation barge, the minimum clearance between the barge keel and any part of the underwater structure shall be assumed equal to 0,5 m considering maximum movement at the maximum draught.

6.6.22 The following parameters shall be monitored manually or by monitoring systems during mating operations:

environmental conditions (monitoring shall begin well in advance of the operation);

relative position, orientation, and clearances of substructure and topside prior to and during positioning;

clearances between barge deck supports and topside;

trim, heel and draught of barge and substructure;

submersion/emersion rate of the barge and substructure;

barge and substructure motions parameters;

water level and air pressure (if applicable) in barge and substructure compartments;

open/closed status for ballast valves.

6.6.23 To float the topside over the substructure use shall be made of tugs, winches or combination of these. Structures shall be joined by reference points or by optical/laser systems.

6.6.24 During the mating operation, support reaction measurements and comparison of the results with the design ones. The actual deviation in total load and moments shall be noted for each measurement and compared with agreed tolerances.

6.7 Connection with other objects

6.7.1 Connection with the previously installed objects shall be carried out in accordance with the design requirements and applicable provisions of the MODU Rules and the FOP Rules.

6.7.2 Where connection is made to subsea pipeline, the strength test of the spool pieces between the pipeline end manifold (PLEM) and the installed object shall be carried out during manufacture in compliance with the requirements of the Rules for the Classification and Construction of Subsea Pipelines[1]. After connection to the object and subsea pipeline, the leak test of spool pieces shall be carried out in compliance with the requirements of the SP Rules. If connection to the subsea pipeline is carried out by welding, the strength and leak tests of spool pieces and field joints shall be carried out in compliance with the requirements of the SP Rules.

[1] Hereinafter referred to as "the SP Rules".

7 DECOMMISSIONING AND REMOVAL

7.1 In order to ensure safety of navigation and fishing and also to prevent the pollution of the marine environment, the abandoned and unused structures and installations shall be removed (dismantled) by their owners within the time periods stipulated in their construction permit.

7.2 Information on complete or partial removal (dismantling) of the structures and installations with indication of water depth, geographical coordinates and sizes of those structures and installations which have not been completely removed shall be delivered to the Head Department of Navigation and Oceanography of the Ministry of Defense of the Russian Federation and to the Federal Agency for Sea and Inland Water Transport for publication in the Notices to Mariners, sailing directions and other nautical publications.

7.3 Prior to removal (dismantling), the production process on the object shall be completely stopped, the equipment shall be completely released from products, all the pipelines and apparatus shall be flushed out, steamed and, if necessary, shall be purged by inert gas. Measures shall be taken to prevent freezing of the liquid residues in the pipelines and apparatus. Explosive, radioactive and toxic substances shall be removed from the object, meeting all the requirements of the existing normative documents. Wells shall be abandoned or suspended in accordance with the established procedure.

7.4 Systems essential for the safe functioning of the object shall operate under normal operational conditions until equipment dismantling.

7.5 After removal the site shall be safely cleared of debris. The procedure of handling harmful and dangerous substances shall be defined.

7.6 If the object or parts thereof will be reused, all the disassembly operations shall be performed in compliance with the requirements of these Rules. Calculations shall take account of changes made in operation and of the actual object condition.

APPENDIX 1

RECOMMENDATIONS FOR LIFTING EQUIPMENT[1]

1 Padear

1.1 In strength calculation, consideration shall be given to additional horizontal load equal to about 5 % of the sling load applied at the level of the hole for shackle pin. Inclination of the sling from the padear plane shall not exceed ± 5°.

1.2 The main welds shall be calculated for shear. Elements subjected to forces perpendicular to the rolled product thickness shall be manufactured of zet-steel.

1.3 Radius of the main padear plate shall not be less than the maximum of two values:

1,25 x D;
$D/2$ + 75 mm

where D = the diameter of a hole for the shackle pin, mm.

1.4 The diameter of a pinhole shall be, as maximum, 5 mm greater than the pin diameter of the rigging shackles with *SWL* ≥ 200 t, and 3 mm greater at *SWL* < 200 t.

1.5 Pinholes shall be machined and shall follow welding of the doubling plates to base plates. All acute angles that can damage sling during loading and transportation shall be rounded off.

1.6 Doubling plates.

1.6.1 If doubling plates are used, they shall be fitted on both sides of the base plate. The thickness of a doubling plate shall be less than or equal to the thickness of the base plate. Radius of the doubling plate shall be equal to the radius of the base plate minus the thickness of the doubling plate.

1.6.2 The doubling plate shall be welded from the outer side all around to the base plate by fillet welds, as well as inside the pinhole, if the hole diameter exceeds 100 mm.

2 Trunnions

2.1 The trunnion diameter shall be, as a minimum, 4 times greater than the sling diameter. The trunnion length shall be, as a minimum, 1,25 times greater than the sling diameter plus 25 mm.

2.2 The trunnion shall be provided with a device to prevent the sling from slipping.

3 Platform for rigging

3.1 Auxiliary platform for rigging shall be provided with guard rails around the platform and withstand rigging weight (slings, shackles, spreader bards, etc.) plus uniformly distributed load of 5 kN/m^2.

4 Bumpers and guides

4.1 The bumpers and guides shall:

facilitate positioning of the object after lifting within the required tolerances;

protect the object being lifted, adjacent structures and equipment against damage during installation.

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[1] Where no other methodologies are available, the calculations according to this Appendix may be adopted. Upon agreement with the Register the calculations according to GOST R 58772-2019 (ISO 19901-6:2009) may be used.

4.2 The requirements for the bumpers and guides shall be specified as early as at the design stage considering lifting scheme and damage risk assessment.

4.3 Design tolerances for guide arrangement shall be closely checked. Prior to lifting, the actual dimensions of the guides shall be checked to verify maintenance of design tolerances.

4.4 The design loads on the bumpers and guides shall not be less than those given in Table 1. The requirements for the design dynamic loads on the guides are given in Table 2.

4.5 Different "guides — bumpers" configurations are shown in Figs. 1 — 4.

Table 1

Design loads acting on the structures of bumpers and guides

Types of design loads	Bumpers	Guides	Rising pier/guide
Vertically directed friction forces	1 % MDW	1 % MDW	1 % MDW
Vertically directed stabbing forces (F_v) (type of rising pier)	10 % MDW	10 % MDW [1] 20 % MDW [2]	10 % MDW
Horizontally directed friction forces	1 % MDW	1 % MDW	1 % MDW
Horizontal forces directed normally in the plane of bumper (F_h)	10 % MDW	5 % MDW	5 % MDW
Horizontally directed forces in any direction (F_1)	5 % MDW	5 % MDW	5 % MDW
[1] For secondary structures. [2] For primary structures. MDW — maximum design weight of the object (refer to 3.3, Part III "Special Requirements").			

Table 2

Design dynamic loads acting on the structures of guides

Loads	Primary structure	Secondary structure
Vertically directed stabbing forces	10 % SHL	5 % SHL
Horizontally directed stabbing forces in longitudinal direction	10 % SHL	5 % SHL
Horizontally directed stabbing forces in transverse direction	10 % SHL	5 % SHL
SHL — static hook load, including cargo weight and rigging weight (refer to 3.3, Part III "Special Requirements").		

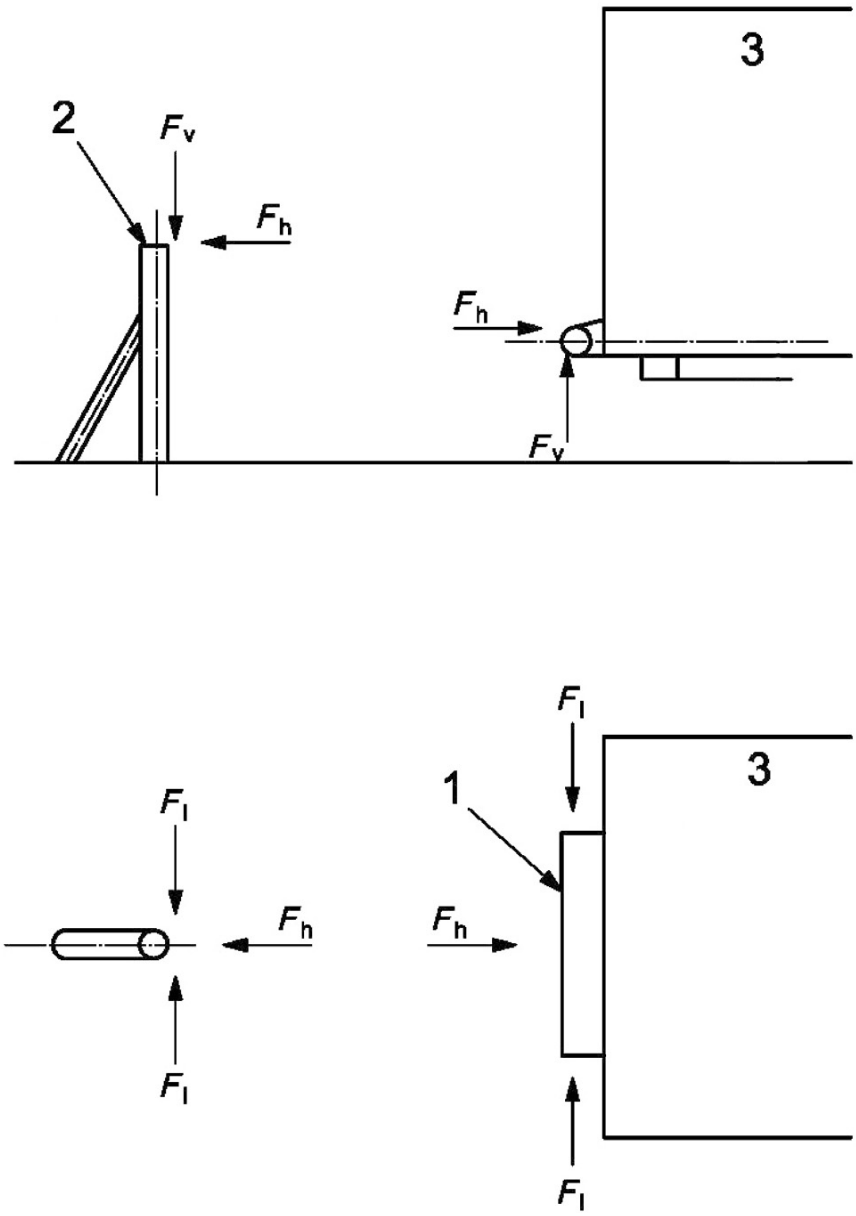

Fig. 1
Guides — bumper:
1 — horizontal primary bumper; *2* — guides; *3* — incoming module

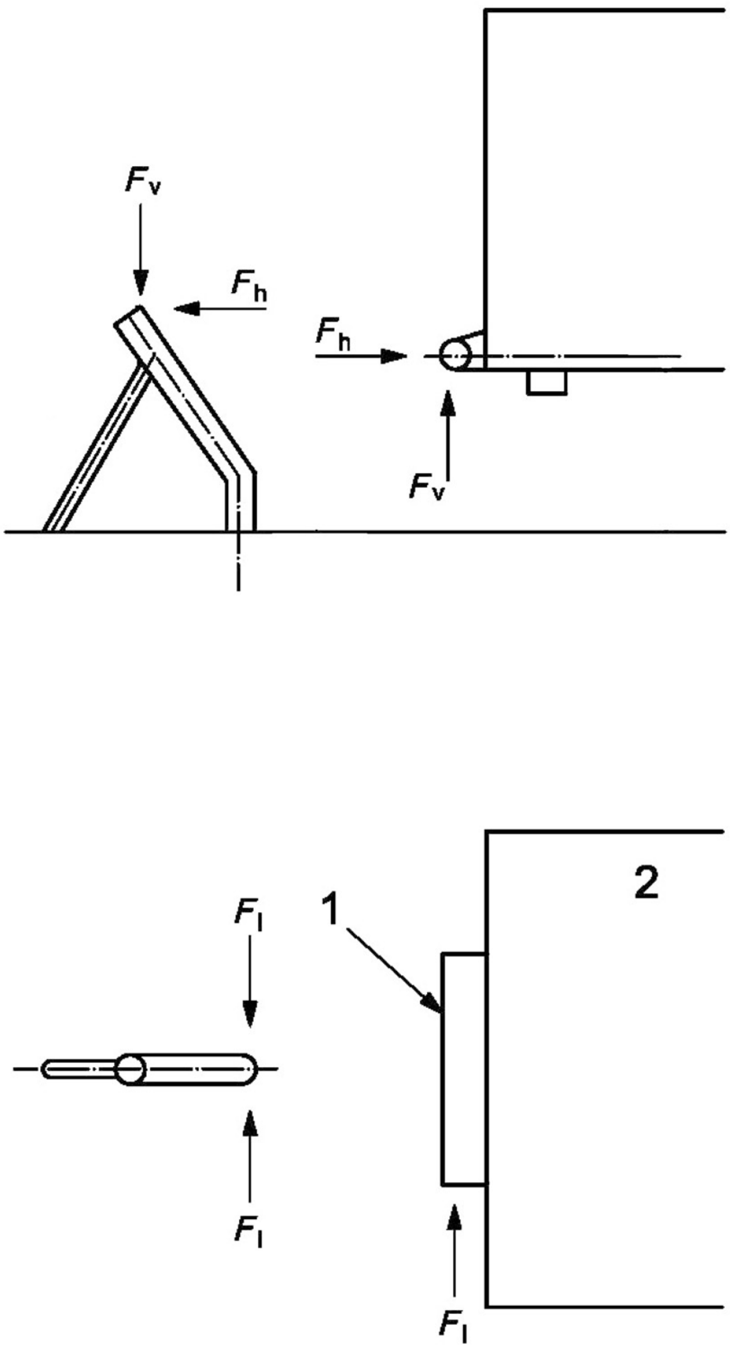

Fig. 2
Vertical sliding bumper:
1 — horizontal primary bumper; *2* — incoming module

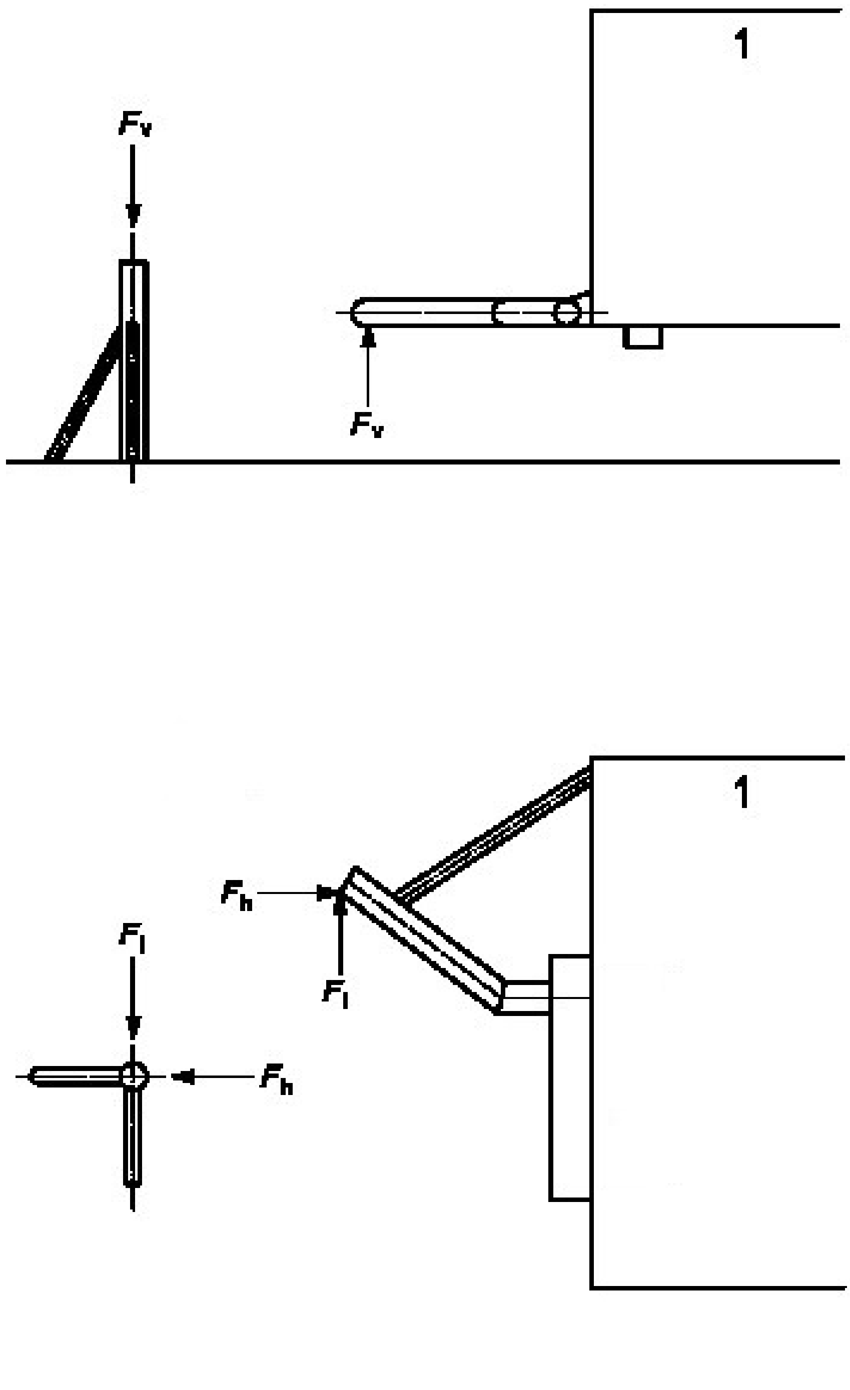

Fig. 3
Horizontal sliding bumper:
1 — incoming module

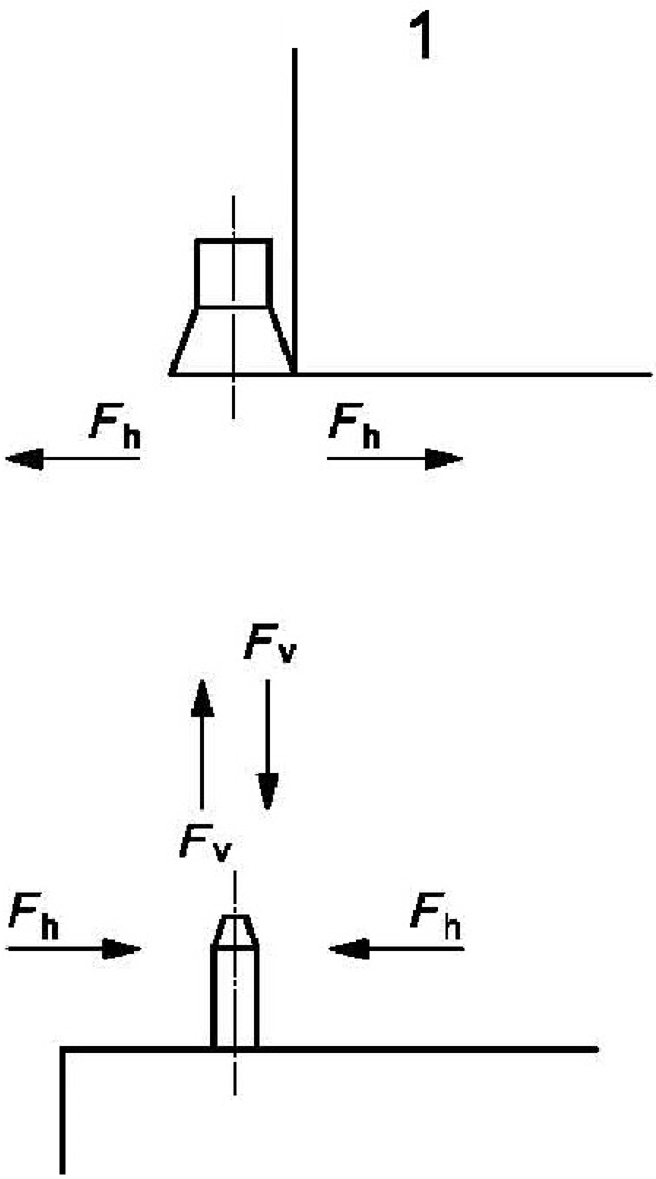

Fig. 4
Rising pier/guide:
1 — sliding structure

5 Guiding system

5.1 When designing the guiding system (bumpers, guides, lugs, etc.), the following requirements shall be taken into account:

position of each element of the guiding system shall be assigned depending on the acceptable support points on the object;

residual deformations of any part of the object shall be prevented;

connections of bumpers and guides, and the members supporting bumper or guide locations, shall be at least as strong as the bumpers and guides;

stiffness of bumper and guide members shall be as low as possible, in order to avoid deformation of the object structure;

easy sliding motion of the bumper when in connection with the guide shall be ensured;

sloping member of guides shall be at an acute angle to the direction of movement;

ledges and sharp corners shall be avoided in areas of possible contact;

weld beads shall be ground flush.

5.2 For bumpers and guides designed as secondary structures, the forces F_v, F_h and F_1 may be taken to 50% of the values given in Table 1.

5.3 The bumpers with vertical guide shall be designed for the following loads:

horizontally directed force in any direction F_h: 0,10 x MDW

where MDW is equal to the sum of the gross weight and the rigging weight, in t;

vertically directed (friction) force F_v: 0,01 x MDW.

5.4 The vertical guide with horizontal bumper:

horizontally directed force in any other direction F_h: 0,05 x MDW;

vertically directed (stabbing) force on inclined face of guide F_v: 0,10 x MDW.

5.5 The load from all vertical and horizontal forces acting on the object in any other direction shall be determined as resultant load for all cases including the most onerous ones.

6 Slings

6.1 For doubled slings due attention shall be paid to friction losses in way of the cargo handling gear or crane hook, the total sling force shall be divided between two sling parts in the ratio 45/55.

6.2 Where possible, slings shall be pre-installed on the object to simplify lifting and access to the eyes and lifting points, as well as to remove safety the slings and shackles.

6.3 Minimum distance from the sling to any obstacles shall be 3 m.

6.4 Minimum tilt angle of the sling shall be 60° ± 5°.

6.5 Breaking strength of the sling bent around a trunnion shall be multiplied by the bending coefficient C_b equal to:

$$C_b = 1 - 0{,}5 \times (d_2/d_1)^{1/2}$$

where d_1 = trunnion diameter;
d_2 = sling diameter.

6.6 The length of slings or eyes shall be within ± 0,25% of their nominal length. During measuring, the slings shall be fully tensioned under the action of a load which shall be in the range of 2,5 — 5,0 % of MBL.

6.7 Used slings shall be inspected before each lift. If a sling is not a part of shipboard rigging covered by annual inspection by the Register, the detailed background records of the sling and records of lifts for which the slings have been used shall be available for inspection.

7 Hydraulic clamps

7.1 Hydraulic clamps are recommended to be used for lifting and upending of piles.

7.2 Clamps shall be so designed that failure to hydraulic systems during lifting does not result in cargo falling.

APPENDIX 2

RECOMMENDATIONS FOR CALCULATIONS AND MODEL TESTS OF THE OBJECT LAUNCHING ON WATER, TILTING, FLOATATION AND INSTALLATION ON THE SEABED

1 Launching of the object from barge

1.1 General.

1.1.1 The objective of launching investigation is to analyze behavior of the object and barge at various launching stages. This investigation shall consider, inter alia, an accident case including filling of one ballast compartment/tank.

1.1.2 Below are given the minimum requirements for investigation of object launching on water. Depending on the size and weight of the object to be launched, more detailed investigations may be required.

1.1.3 Launching investigations at the stages from commencement of movement till stable position on water includes the following calculations:

hydrodynamic calculation which shall determine displacement and resultant load acting on the object and barge;

structural calculation which shall determine stresses arising in the object and barge structure.

1.1.4 Launching investigation shall identify requirements for auxiliary buoyancy devices.

1.2 Hydrodynamic analysis of object launching on water.

1.2.1 The analysis shall be made using a recognized computer program which shall describe in detail the following:

systems of coordinates;

initial data;

output data.

1.2.2 Models used for the barge, object, launching races, as well as the launching procedure shall be described in detail in technical background which shall at least include the following:

geometry of objects;

mass and moments on inertia;

hydrodynamic factors;

description and characteristics of ballast tanks and other displacing volumes including arrangement of buoyance pontoons;

boundary conditions (including sliding cradle friction coefficient);

initial conditions for launching (angle of trim, barge draught, position of the object on the barge, etc.);

water depth;

step of computer modelling (not more than 2 s) and number of calculation steps;

modelling of accident situation (flooding of one ballast compartment that provides the worst result).

Relevant drawings shall be included into technical background.

1.2.3 The following results shall be documented in detail in technical background for each calculation step in the form of object-barge function;

object position relative to the barge (CoG position of the object about the ship's systems of coordinates axis);

object position relative to the water surface and the seabed;

vertical and horizontal constituents of the CoG of the object and barge;

forces and moments of forces for object support;
sum of the acting forces and moments;
stability criteria (CoB position, metacentric height in two directions and righting moment);
waterline parameters (moments of inertia, angle between the main axis and the system of coordinates, CoG position).

1.2.4 The following modeling characteristics shall be documented and accompanied by figures (one per calculation step):
barge trim (forward and aft draughts);
CoG position of the object;
depth of the highest point of the object in water;
depth of the lowest point of the object in water;
horizontal and vertical constituents of velocity of the object center of gravity;
horizontal constituent of velocity of the barge center of gravity;
equilibrium (setting) position of the object;
time from the moment of operation commencement.

1.2.5 The following acceptance criteria shall be provided:
position of the lowest protruding member of the object relative to the seabed shall not be less than 10 m in intact condition and 5 m when one ballast compartment is flooded;
speed of object lowering/skidding relative to the barge shall not exceed 1 m/s.

1.3 Structural analysis of launching.

1.3.1 The behavior of the object structures during launching shall be verified by a static analysis based on the loads obtained according to 1.2.

1.3.2 Each position of the object shall be analyzed in passing calculation steps considering additional transverse loads equal to 0,05 MDW. The stresses involved shall be compared with the allowable stresses.

1.3.3 Launching tools/appliances (pushing or pulling lugs, sideways guides, etc.) shall be calculated taking into account uneven load distribution in the ratio of 25/75.

The pushing or pulling lugs shall be designed for the action of maximum power produced by the pushing/pulling equipment when the coefficient of static friction is increased by 1,5 times.

1.3.4 The structural integrity of ballast compartments, waterproof membranes, etc. under the action of hydrostatic pressure, impact loads, etc. shall be confirmed.

2 Buoyancy of an object

2.1 Investigations of the object launched on water behavior shall be carried out regardless of the installation method.

2.2 The following results shall be included in the calculation for an intact object and for the case with a ballast compartment flooded:
position of the center of buoyancy;
righting moments for various inclinations up to 6°;
heeling moment necessary to change the object draught by 0,5 m;
metacentric height in two directions;
waterline parameters.

2.3 The compliance with the following requirements shall be confirmed:
in shallow waters and in critical situations, the reserve buoyancy shall be 20% in intact condition and 12% when one tank is flooded. For other cases these values may be reduced to 15% and 8%, respectively;
righting moment shall be positive for an inclination up to ± 6°;
heeling moment necessary to change the object draught by 0,5 m shall be less than the relevant righting moment;
metacentric height shall be positive at all times and more than 1 m.

3 Upending of the object by means of a crane

3.1 The objective of the investigations is to analyze the object behavior, determine the hook loads and develop the ballasting plan during the upending of horizontally floating object to the vertical position. This objective shall be achieved through performance of a three-dimensional hydrodynamic analysis which considers at least 10 intermediate steps.

3.2 The hydrodynamic analysis shall be made using a program meeting the requirements of 1.2.1.

3.3 The following results in the form of tables and curves of relative object position for each intermediate calculation step, which define the equilibrium position shall be presented:

ballasting scheme;
change in ballasting scheme as compared to preceding step;
hook and sling load;
angles of roll and pitch;
bottom clearance;
metacentric height in two directions;
positions of centers of gravity and buoyancy;
position of the object relative to water.

3.4 The following acceptance criteria shall be met:

metacentric height shall be positive and more than 1 m;
bottom clearance shall not be less than 5 m;
allowable hook loads;

if the object weight (in air) is less than or equal to the crane capacity, the allowable hook load shall be taken equal to the crane capacity;

if the object weight (in air) is by 1 — 1,5 times greater than the crane capacity, the allowable hook load shall be taken equal to 2/3 of the crane capacity;

if the object weight (in air) is more than by 1,5 times greater than the crane capacity, the allowable hook load shall be taken equal to 1/3 of the crane capacity.

3.5 Structural inspection.

3.5.1 The object structure shall be checked for strength considering the hook loads obtained as a result of the hydrodynamic analysis.

3.5.2 The object parts and buoyancy pontoons shall be checked for strength under the action of hydrostatic pressure.

3.5.3 In the lift points, consideration shall be given to the change of sling angle during tilting due to application of an additional transverse force comprising 10 % of the load on the slings.

4 Upending of the object by means of ballasting

4.1 The objective of the investigation is to analyze the object behavior and develop the ballasting plan during upending of horizontally floating object to the vertical position. This objective shall be achieved through performance of a three-dimensional hydrodynamic analysis, which considers, at least, one step for each inclination to 10°.

4.2 The stability and position of the object shall be verified according to the requirements of Section 3.

4.3 The metacentric height shall be greater than any of the following values:

0,2 m;
0,002 x height of the object in inclined position;
0,01 x height of the object in vertical position.

4.4 The bottom clearance shall be more than 5 m.

4.5 The object parts and buoyancy pontoons shall be checked for strength under the action of hydrostatic pressure.

5 Setting down the object on the seabed

5.1 The objective of the investigation is to analyze the object behavior during setting down on the seabed and the step-by-step inspection (step down — 1 m).

5.2 Calculation shall be made according to the requirements of Section 3.

APPENDIX 3

RECOMMENDATIONS FOR SOLID BALLAST PLACEMENT

1 General

1.1 Solid ballast in the form of high flowability concrete to be loaded on the object may be of two types:

mass type with bulk density of 2200 — 2500 kg/m^3, may be lightened with the crushed stone being replaced by sand and with bulk density of 1850 kg/m^3 (type I);

structural type, that is bearing external load, e.g. ice load with bulk density of 2250 — 2400 kg/m^3 (type II).

1.2 Depending on the peculiarities of design, construction, transportation, operation and dismantling/removal, concrete may be placed at various places of object position:

at the yard water area;

at relatively sheltered water area (in bay, gulf, etc.);

on-site (in a floating/fixed condition).

In the two last cases, the concrete may be placed from a suspended platform, moored pontoon, supply vessel or from the deck of the object with the topside installed.

1.3 Regardless of the point of placement, the concrete shall withstand alternate freezing and thawing, as well as temperature gradient which cause thermal crack formation in the concrete.

In cold season, the concrete can be cooled to –55 °C on the shell plating in the above-water part and simultaneously, when in contact with oil, heated up to +60 °C on the inner skin.

It may be practicable to use various concrete types depending on the operational conditions and arrangement of filled spaces.

1.4 The major factors which determine concrete quality are as follows:

use of base materials which are the most durable under operational conditions;

design and selection of the concrete optimum composition at low-water discharge;

application of concrete making and consolidation technique contributing to the production of the most homogeneous structure of the cement stone and concrete texture;

creation of the appropriate thermal and moisture conditions of the concrete curing which determine production of a durable structure of the cement stone and reduce thermal stresses in the concrete.

1.5 The recommended technical characteristics of aggregates, concrete mix and concrete are given in Table 1.

1.6 To improve the basic properties of the concrete, reduce water consumption, provide easy concrete placement and reduction of cement consumption, it is recommended to add air-entraining admixtures and plasticizers to concrete mix in compliance with the normative and technical documentation.

Application of power station fly ash as an active mineral admixture is permitted.

2 Process requirements

2.1 List of applicable standards and specifications is given in Ta ble 2.

2.2 The performer shall carry out cement coarse aggregate and sand quality control.

2.3 The concrete mix shall be made by a forced-type concrete mixing plant for the type II concrete a gravity-type mixer may be used.

2.4 When organizing work and selecting technology, the ambient temperature shall be taken into consideration.

2.5 The concrete mix delivery pipeline shall be made of steel seamless pipes connected together by level locks and flexible inserts. It is reasonable to mount the concrete mix delivery pipelines, two working and one stand-by main, during construction of the object.

Table 1

Technical characteristic of the concrete

Characteristic	Concrete type	
	I	II
Requirements for the concrete mix components		
Cement		
Concrete grade	400	400
Consumption per 1 m^3 of concrete, in kg	440 — 460	460 — 480
Coarse aggregate		
Fractional composition, in mm (%)	10 — 20 (35 — 60) 20 — 40 (65 — 40)	5 — 10 (25 — 40) 10 — 20 (75 — 60)
Strength, in kg/cm^2	800	1000
Consumption per 1 m^3 of concrete, in kg	1100 — 1200	1050 — 1150
Sand, consumption per 1 m^3 of concrete, in kg	680 — 730	700 — 750
Water, consumption per 1 m^3 of concrete, in l	150 — 160	160 — 170
Requirements for the concrete mix		
Slump (fluidity), in cm	12 — 16	12 — 16
Maximum water – cement ratio	—	0,4
Entrained air content, in %	2 — 3	2 — 3
Water separation, in %	—	< 2
Requirements for the concrete		
Minimum compressive strength of a standard specimen (15 x 15 x 15 cm), in MPa	30	42
Maximum compressive strength of a standard specimen (15 x 15 x 15 cm), in MPa	—	54
Maximum period of concrete specimen curing by the time of compressive strength test, in days	90	28
Density: minimum, in kg/m^3 maximum, in kg/m^3	 2400 2500	 2250 2450
Maximum temperature difference between the interior of the concrete block and the surface hereof, in °C	25	—

2.6 To ensure loading of the upper part of the compartments, it is recommended to provide special access holes with dimensions of 400 x 300 mm in each compartment cell.

2.7 To place the concrete mix directly into the compartment cells it is recommended to use steel pipes (sleeves), two pipes per cell. To reduce pressure in the sleeve during delivery of the concrete mix special holes shall be provided at the end portion. Upon completion of delivery of the concrete into the cell, the sleeve shall remain inside.

Table 2

List of standards and specifications applicable to solid ballast placement

Designation	Code name
Cements. Test methods. General	GOST 310.1-76[1)]
Cements. Methods of grinding fineness determination	GOST 310.2-76[1)]
Cements. Methods of tests of consistency, times of setting and soundness	GOST 310.3-76[1)]
Cements. Methods of tests of bending and compression strengths	GOST 310.4-81[1)]
Crushed stone and gravel of solid rocks for construction work. Specifications, amend. No. 3, 1995	GOST 8267-93[1)]
Mountainous rock road-metal and gravel, industrial waste products for construction work. Methods of physical and mechanical tests	GOST 8269.0-97[1)]
Mountainous rock road-metal and gravel, industrial waste products for construction work. Methods of chemical analysis	GOST 8269.1-97
Sand for construction work. Testing methods	GOST 8735-88[1)]
Sand for construction works. Specifications	GOST 8736-2014
Concretes. Methods for strength determination using reference specimens	GOST 10180-2012
Concrete mixtures. Methods of testing	GOST 10181-2014
Water for concretes and mortars. Specifications	GOST 23732-2011
Concretes. Rules for mix proportioning	GOST 27006-2019
Concretes. Methods for strength determination on cores selected from structures	GOST 28570-2019
[1)] Valid GOST as amended.	

PART IV. SAFETY ASSESSMENT

1 GENERAL

1.1 Application

1.1.1 This Part is intended to establish the methodologies to be used when revealing and accessing the hazards related to MO.

This Part covers recommendations on measures to be taken to prevent potential emergency situations (ES) as well as to control and mitigate their effects according to the MO type and their conditions.

1.2 Terms and explanations

1.2.1 For the purpose of this Part, the following terms and definitions have been adopted.

Emergency is a situation in the course of MO, during which an accident may occur.

Accident is a hazardous technogenic event that poses a risk to life and health of the crew on an object engaged in MO and that results in destruction of the equipment, loss of the object, and/or harm to the environment.

Risk analysis is a process of identification of hazards and assessment of risk to the crew, property and environment during MO.

Fault tree (fault tree analysis, FTA) is a graphical way to track all logical interrelations between malfunctions, ambient conditions and human errors leading to the event concerned.

Event tree (event tree analysis, ETA) is a graphical way to qualitatively describe potential E, and their quantitative assessment for each branch.

Hazard identification is a process used to reveal a hazard and define its characteristics during MO.

Individual risk is a frequency of individual injury of a crew member of the MO object caused by action of the ES hazard factors concerned.

Incident is a failure of, or a damage to, the technical devices used during MO, a deviation from the process mode, violation of regulatory acts and documents establishing regulations for MO.

Potential loss of life (PLL) is an expected number of crew members of the MO object injured as a result of possible ES during MO.

Risk matrix is a method to classify and represent the risk by ranking its consequences and probability.

Hazard is a potential source of harm to a crew member of the MO object, property, environment cause by ES during MO.

Failure is a malfunction in serviceability of the object of MO.

Risk assessment is a process to identify the probability, frequency and extent of adverse effects caused to health of MO object crew, property and/ or environmental by ES.

Acceptable risk is a risk whose level is recognized as tolerable and substantiated based on technical, economical and social considerations.

Negligible risk is a level of risk above which measures are to be considered and taken for elimination thereof.

Risk is a combination of ES probability and its consequences during MO.

Risk register is a recording format containing data on an identified risk.

Societal risk (F/N curve or F/G curve) is a probability/ frequency of ES for a group consisting of MO object crew members which is defined as a function of consequences/harm during MO graphically depicted as a F/N curve or F/G curve.

Technical risk is a probability of ES during operation of objects involved in MO.

R i s k c o n t r o l is a combination of activities aimed to reduce the risk level and mitigate potential losses during MO.

R i s k l e v e l is a value to characterize the probability of ES.

E c o n o m i c r i s k is a probability of losses expressed in monetary terms which result in ES during MO.

1.3 Abbreviations

ES — Emergency situation.
MC — Metocean conditions.
MO — Marine operation.
FOP — Fixed offshore platform.
MODU — Mobile offshore drilling unit.
FPU — Floating offshore oil-and-gas production unit.
SSC — Safety sufficiency criterion.
PP — Power plant.
AIR — Annual individual risk.
ALARA/ALARP — As low as reasonably applicable/practicable.
CEA — Cost effectiveness analysis.
ETA — Event tree analysis.
FAR — Fatal accident rate.
FEED — Front-end engineering and design.
FSA — Formal safety assessment.
FTA — Fault tree analysis.
HAZID — Hazard identification.
HAZOP — Hazard and operability study.
HRA — Human reliability analysis.
HSE — Health and safety executive (UK).
ICAF — Implied cost of averting a fatality.
PEM — Physical effect modeling.
PHA — Preliminary hazard analysis.
PFD — Probability of failure on demand.
PLL — potential loss of life.
POB — personnel on board.
QRA — quantitative risk analysis.

2 MARINE OPERATIONS RISK ANALYSIS

2.1 Safety concept of marine operations

The MO design shall ensure an acceptable safety and exclude/minimize:
fatalities or loss of health of people involved in MO;
pollution or other kinds of damage to the environment;
losses/failures of object and technical facilities involved in the MO performance.

2.2 Identification of typical hazards and ES during marine operations

2.2.1 During MO at least the following hazards (refer to Part II "General Requirements"), ES (refer to Table 2.2.1-1) and key hazards which increase the risk of ES (refer to Table 2.2.1-2) shall be taken into account.

Table 2.2.1-1

Typical hazards and ES during marine operations

No.	Description	Typical hazards and/or ES
1.	Load in/out operations	Excessive cargo weight Defective machinery, cargo-gripping devices, ropes/slings Incorrect slinging and handling of cargo Hazardous swinging of cargo during lifting Instable cargo position Cargo falling or sliding along the deck Oblique tension of the lifting rope during cargo lifting/handling Excess of permissible reach of crane
2.	Lifting objects at sea (launching in the yard water area, installation of the object on site)	Deterioration of weather conditions: increase in wind speed; heavy seas; visibility deterioration (mist, precipitation); adverse ice conditions. Impact with dock Failure of ballast system Excessive impact upon the seabed soil Rope jerks/breakage during lifting/launching
3.	Towing operations (approach, throwing, towing through ice and through open water)	Deterioration of the weather conditions beyond the limits Stranding of the towed object Breakage of the towline, failure in the towing winch Failure in the tug main engines Collision of the tug or other ship with the towed object Damage to the hull and watertight integrity of the object/tug Flooding of compartment/compartments Failure in communication between support vessels and/or the object
4.	Positioning of anchor/mooring lines	Incorrect anchor position on soil during dropping/digging or anchor out-of-ground due to loose soil. Breakage of the anchor-mooring line/towline during anchor embedding or anchor line tightening up (proper tensioning of the anchor line for holding the object at a given position) Breakage of the anchor chain/rope Breakage of the chaser line Breakage of the mark buoy or buoy with explosively-released rope

No.	Description	Typical hazards and/or ES
5.	Pile driving/installation (sequence of operations to ensure sufficient stability of the object during all the installation phases) and securing	Failure in pile driving equipment Collisions/impacts (of support vessels with the object being installed) The pile cannot be driven down to the design depth Piles are not hydraulically swaged/locked. The cementing mortar flows to environment during pile cement grouting
6.	Mooring operations (ship's approach to or departure from another ship, quay, or buoys)	Breakage of the mooring line Defective mooring arrangement
7.	Object passing through restricted waters (straits, fairways, channels, bridges)	Failure in tug's PP Impact with channel bank, stranding/grounding Impact with fairway marking (buoys, beacons, etc.) Collision with other ships/objects in the fairway Breakage of the towline Excess of permissible speed Violation of recommended navigation lanes in restricted waters
8.	Launching of objects (launching in a dry dock, by pontoons, launching from the construction site, etc.)	Impact with bridge supports Impact with dock Damage to the hull and watertight integrity of the object Flooding of compartment/compartments Failure in hydraulic (ship carrying) bogie/bogies (jacks, rollers)
9.	Installation of objects on site (installation of floating objects, fixed objects)	Uncontrolled inclination of the object hull during submersion Seabed scouring under the object due to bottom currents Shift of the structure Object overturning Loss of stability on the seabed Failure of one or several anchor chains or mooring lines Collision with ships or a floating object Collision with an iceberg/floating ice hummock during arctic operations Falling/destruction of a structure inside the object Falling of a helicopter or a flying object onto the structure Excess of permissible MC during operation Emergency flooding of compartment/compartments
10.	Decommissioning operations (dismantling of the object position mooring system, seabed scouring near substructure, pile cutting off, removal of a part of solid ballast, dismantling (if necessary) of the topside (entirely or by modules)	Uncontrolled emersion of a gravity structure Damage to the hull and watertight integrity of the object Flooding of compartment/compartments

No.	Description	Typical hazards and/or ES
11.	Mating of the objects or parts thereof afloat	Mooring line failure due to excessive wind, wave loads Flooding of buoyancy pontoons due to integrity failure (leakage, ingress of water into compartments) Dropped object load Collision of the topside with the substructure Seizure of the mated structures in guides Locking of the topside/mated structure during lifting and launching Damage to structural members of pontoons, guide columns, braces, etc. Uncontrolled inclinations of the substructure or topside

Table 2.2.1-2

Key hazards increasing the risk of ES

No.	Description	Typical hazards and/or ES
1.	Weather conditions (destructive wind/wave loads)	Various structural damages in operating position due to abnormal course of events. Shift, overturning or subsidence of the object (foundation of the platform, module, block, etc.) on the soil in case of adverse combination of external conditions and changing soil conditions. Transportation of the object under conditions inconsistent with permissible ones based on structure strength and reliability criteria. Significant fatigue cracks due to intense wave, wind, ice, seismic actions. Brittle failures under low temperatures and impulse loads
2.	Navigational risks	Multiple mooring operations Staying in the restricted area with heavy ship traffic Failure in navigation equipment Securing with a large number of working anchors at the operation area Low freeboard Low turning ability and steering performance Increase windage of superstructures Low canal edge depths Insufficient navigation and mapping support arrangements including unmapped sunk objects Close coast line Excessive natural effects (winds and waves) Technogenic emergency effects (fire on the object, failures of equipment, power plant, etc.) Errors of pilot or vessel traffic management system (VTMS) Personnel errors
3.	Stranding of the object	Human-related effects. Force-majeure circumstances (weather conditions) Contact with unknown obstructions Lack of navigation support aids Failure in the main engine/steering gear

2.3 Statistics on accidents during marine operations.

The MO safety assessment shall take into account the worldwide accident statistical data, information from accident databases (DB) (refer to Table 2.3).

Table 2.3

Statistical databases on accidents during marine operations

No.	DB application	DB description
1	Marine accidents	WOAD, Worldwide Offshore Accident Data Accident statistics for fixed offshore units on the UK Continental Shelf Accident Statistics for Floating Offshore Units on the UK Continental Shelf Accident/incident data International Association of Oil & Gas Producers (OGP)
1.1	Collisions/impacts	SAFETEC. Computer assisted shipping traffic (COAST) Ship/platform collision incident database
2.	Cargo handling operations. Lifting/falling of objects	CODAM. Dropped objects
3	Injuries. Accidents during MO	Facts and statistics from the Petroleum Safety Authority Norway Statistics from the Reporting of Injuries, Diseases and Dangerous

2.4 Modeling during marine operation risk assessment

During the MO risk assessment, it is reasonable to use physical, analytical and statistical modeling methods (refer to Table 2.4, Appendices 1 and 2).

Table 2.4

Recommended modeling methods for MO risk assessment[1]

No.	Method
	Analytical modeling
1	Checklists
2	Structured What If Technique (SWIFT)
3	Expert judgment method
4	Risk matrix
5.	Hazard identification
6	Failure mode and effect analysis (FMEA)/failure mode, effect and criticality analysis (FMECA)
7	Hazard and operability study
8	Preliminary hazard analysis
9	Human reliability analysis
10	Physical effect modeling
11	Quantitative risk analysis
	Physical modeling
12	Fault tree analysis (FTA)
13	Event tree analysis (ETA)
	Statistical modeling
14	Monte Carlo simulation
15	Bayesian analysis
[1]	The methods are described in Appendix 1.

2.5 Methods to assess risk during marine operations.

2.5.1 Qualitative analysis methods.

The MO qualitative risk analysis methods shall be used in case of absence and/or lack of data on objects, equipment/devices and MO conditions.

These methods are the simplest ones since they require no detailed review of MO stages.

When qualitative analysis methods are used, the need for experts is minimum, while the characteristic of frequency/probability and effects/loss of ES may be expressed analytically.

The MO qualitative risk analysis shall be performed by the designer at the MO FEED stage.

2.5.2 Quantitative analysis methods.

2.5.2.1 The MO quantitative risk analysis methods are recommended in case of detailed data available for the objects, equipment/devices and the MO conditions.

These methods give the full insights of the MO risk level and require detailed review of all the MO stages.

2.5.2.2 When the MO quantitative risk analysis methods are used, the characteristic of the ES frequency/probability and effects/loss is expressed numerically (for example, one event per year, accident probability is 25 %, loss amounts to 100 million rubles, probability of a person being injured is 50 %, etc.).

2.5.2.3 Pursuant to 2.7.2, Part X "Safety assessment" of the Rules for the Oil-and-Gas Equipment of MODU, FOP and Floating Offshore Oil-and-Gas Production Units, a risk may be also defined as a frequency or probability of event B when an event A occurs, i.e. as a dimensionless quantity within 0 to 1.

2.5.2.4 The MO quantitative risk analysis shall be performed by the designer at the basic design stage.

2.5.3 Expert and statistical analysis methods.

2.5.3.1 The MO expert and statistical risk analysis methods shall be used in case of insufficient data on objects, equipment/devices and MO conditions.

2.5.3.2 When MO expert and statistical risk analysis methods are used, the characteristic of the ES frequency/probability and effects/loss is expressed in a combination of analytical and numerical formats.

2.5.4 Requirements for application of marine operation risk analysis methods.

2.5.4.1 The MO risk analysis methods shall be selected based on the following:

the most detailed characteristic of the risk level at the design stage concerned;

methodological approaches accepted in the international practice and Russian regulatory base;

time intervals comparable to the MO period or normalized to the time intervals concerned;

the extent to which this MO risk analysis method is known and clear to the group of experts engaged in risk assessment;

presentation of clear risk analysis results subject to further verification by other groups of experts.

2.5.4.2 The designer shall select the risk analysis methods in accordance with GOST R ISO/IEC 31010-2010 or other equivalent documents.

To get the full insights on MO risk level, it is recommended to combine several risk analysis methods to allow the results to be compared, deficiencies and omissions to be revealed. In case of quantitative comparison, the quantitative indicators shall prevail over the qualitative ones.

2.6 Safety sufficiency criteria during marine operations

2.6.1 Safety sufficiency criteria (SSC) are to be assessed during MO to conclude on the possibility of occurring various ES during MO on the interacting objects, equipment/device, and to establish the acceptable and tolerable safety/risk parameters.

2.6.2 With taking SSC into consideration, comparison safety/risk assessment may be performed provided that several options of MO performance are available.

2.6.3 SSC are classified as follows:

SSC related directly to the MO objects (module, block, sea-going vessel, craft, equipment/device);

SSC relative to the operation of safety system of the MO objects.

2.6.4 In terms of safety, SSC are classified as follows:
SSC related to the object personnel/crew safety;
SSC related to safety of the equipment/device used during MO;
SSC related to ecological and environmental safety of the MO adjacent water area
2.6.5 Based on the MO worldwide experience analysis, the following shall be taken as basic SSC:
as low as reasonably practicable (ALARP);
fatal accident rate (FAR);
potential loss of life (PLL).
2.6.6 For the general algorithm of safety/risk assessment during MO with the use of SSC, refer to Fig. 2.6.6. The basic risk regions accepted in the worldwide practice during MO are considered in Table 2.6.6.

Table 2.6.6

Basic risk regions during MO

Name	Description	Values	
As Low As Reasonably Practicable (ALARP)	The ALARP principle is that the as low as reasonably practicable effects on the personnel/crew and environment are provided with regard to economical and social factors. The risk is reduced as far as possible thanks to actually existing inventories and financial resources. MSC-MEPC.2/Circ.12 (8 July 2013)	Tolerable risk	$<10^{-3}$
		Acceptable risk	$<10^{-6}$
Fatal Accident Rate (FAR/AIR)	Fatal accident rate (FAR) is the alternative to the individual risk expression and allows for complementation of PLL value. It is defined as the number of people killed per 100 million exposure hours. ISO/DTS 16901	Tolerable risk	$<10^{-3}$
		Acceptable risk	$<10^{-6}$
Potential Loss of Life (PLL)	PLL is defined as the expected value of the number of fatalities per year (or for a period of ship operation). PLL is a type of risk integral and is expressed by the product of frequency and consequence (number of fatalities). PLL allows for summation of various risk types over all potential undesired events that can occur. MSC-MEPC.2/Circ.12 (8 July 2013)	Crew member	$<10^{-3}$
		Passenger	$<10^{-4}$
		Third parties	$<10^{-4}$
		Acceptable risk/ Target values for new ships	$<10^{-6}$

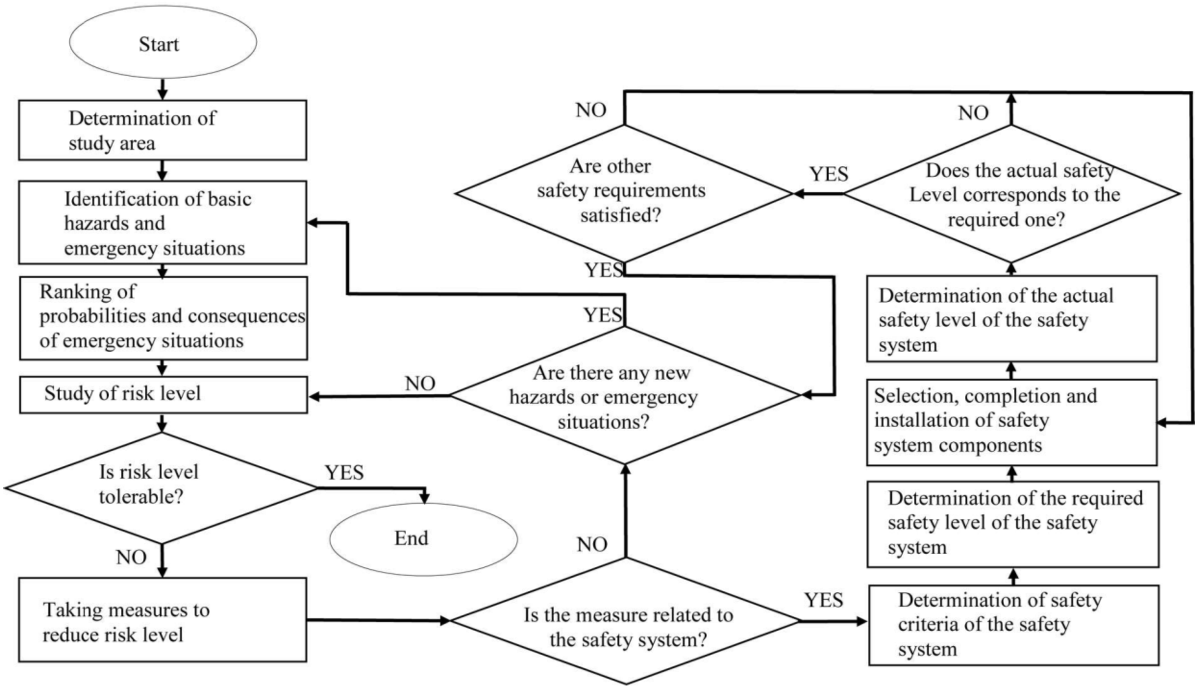

Fig. 2.6.6
Algorithm of safety/risk assessment during MO with the use of SSC

2.7 Risk analysis during marine operations

2.7.1 General.

2.7.1.1 The risks to personnel and crew of the ships engaged in MO are expressed as an individual and societal risks to be assessed according to criteria given below.

2.7.1.2 The individual risk (IR) is defined as the probability of individual crew/personnel member being killed during MO within a specific period. Twelve months are usually taken as a time period and IR is indicated as an annual individual risk (AIR).

The following is taken to be criteria for measuring societal (group risk):

potential loss of life (PLL);

fatal accident rate (FAR);

F/*N* or *F*/*G* curve — societal risk;

risk matrix (refer to 2.8).

2.7.1.3 P L L value is defined as the statistically expected value of the number of fatalities during ES within a specific period associated with the MO without regard to the external effects. PLL criterion is based on the retrospective statistics. For Arctic seas it may involve a certain difficulty due to lack of complete informative databases except for databases of Health and Safety Executive (HSE) for the UK sector of the North Sea.

2.7.1.4 Fatal accident rate (FAR) is estimated as the expected number of fatalities during accidents occurred for the period of MO (10^8 hours is a risk exposure time). FAR value depends on unequal risks for groups of personnel and crew members with various time of the ES exposure, MO routes and differences between specific MO objects (modules, platforms, blocks, ships, etc.).

2.7.1.5 FAR values are usually within 1 to 35 (Offshore Risk Assessment (Norway), 2014; Comparative Assessment Report. Cordah Limited, 2015; SAFETEC, 2005, etc.), therefore this criterion is easy to compare. Unlike PLL, FAR allows for comparison of different options and technical solutions during MO since it takes into account external effects at specific MO. FAR criterion is conceptionally related to PLL and AIR criteria, but FAR does not take into account the scale of fatalities during MO and allows for assessment of the average individual risk like the majority of statistical measurement approaches.

2.7.2 Analysis of individual and societal risk.

2.7.2.1 Individual risk:

.1 when analyzing ES, individual risks, which characterize the frequency of specific effects during MO (risk of death, injury and ill health as experienced by crew/personnel during MO), are determined.

Annual individual risk (AIR) is determined by the total probability formula

$$AIR_k = \sum_{(i=1)}^{(i=n)} Q_i \cdot Q_{ik} \cdot Q_{ik}^p \qquad (2.7.2.1.1)$$

where Q_i = repeatability of *i*-th typical hazard and/or ES concerned;
Q_{ik} = probability of an accident during the typical hazard and/or ES concerned (risk of accident);
Q_{ik}^p = conditional probability of an individual crew/personnel member being affected when the typical hazard and/or ES concerned occurs;
n = number of typical hazards and/or ES concerned;
k = corresponds to the given typical hazard and/or ES;

.2 total annual individual risk (AIR) at different ES during MO (for example, collision/impact, stranding, fire, explosion, cargo falling, etc.) is defined as a sum of AIRs for individual effects, i.e.

$$AIR_{\Sigma} = \sum_{(k=1)}^{(k=m)} AIR_k \qquad (2.7.2.1.2)$$

where m = the considered number of possible ES consequences;

.3 for quantitative assessment of annual individual risk (AIR) during MO according to 2.7.2, AIR may be also determined based on integral risk factors (FAR and PLL) by the following formulas:

$$AIR = FAR \cdot 10^{-8} \cdot H, \qquad (2.7.2.1.3\text{-}1)$$

$$FAR = PLL \cdot 10^{8} / T_{td}, \qquad (2.7.2.1.3\text{-}2)$$

$$PLL = FAR \cdot 10^{-8} \cdot T_{td} \qquad (2.7.2.1.3\text{-}3)$$

where FAR = frequency of fatalities during MO (per 100 million man-hours);
PLL = the number of potential fatalities for a period of MO;
POB = the number of persons involved in MO (crew, personnel);
$T_{td} = POB \cdot H$ — total duration of MO (in man-hours);
H = determines the working period (watch keeping period) and rest period (watch off period) for crew members, personnel for a period of MO (h).

Table 2.7.2.1.3-1 shows the recommended format of risk assessment results. Table 2.7.2.1.3-2 shows FAR values corresponding to various MO.

Table 2.7.2.1.3-1

Format of risk assessment results

No.	Ship/object involved in MO	MO stage/ phase	Number of persons on board (crew, personnel) POB	Watchkeeping/ rest time per crew/personnel members (hours) H_{watch} or H_{rest}		Duration (hours) POB H_{watch} or POB·H_{rest}	FAR[1]	PLL
				H_{watch}				
				H_{rest}				

[1] FAR is based on statistical data of SAFETEC (2005), etc. per 10^8 man-hours.

Table 2.7.2.1.3-2

FAR values for various MO

No.	Marine operation	FAR[1]
1	Load in/out operations (own cranes)	26,8
2	Load in/out operations (external cranes)	$1{,}1 \cdot 10^{-5}$ per operation
3	Launching of objects (launching in a dry dock, by pontoons, broadside launching, etc.)	26,8
4	Decommissioning/dismantling marine operations	1,9
5	Object dismantling operations	4,1
6	Positioning of anchor/mooring lines	37,4
7	Towing operations	13,2
8	Installation of objects on site	5,5
9	Supporting underwater engineering work	7,5
10	Management and administrative personnel activities	0,4
11	Rest time, watch off time	0,2

[1] FAR is based on statistical data of SAFETEC (2005), etc. per 10^8 man-hours.

2.7.2.2 Societal risk.

The societal risk relates frequency of accidents (F) to the number of fatalities (N in persons) and evaluates the scale of potential catastrophes and critical accidents. The societal risk is an integral characteristic for evaluation of group risk (PLL) and defines the probability of the ES consequences occurred during MO. Depending on types of MO, N may mean total number of injured persons, total number of fatalities or other parameter characterizing the severity of consequences (G is loss suffered from the emergency situation during MO, in thousand rubles).

The societal risk may be graphically expressed as a *F/N* curve *(F/G* curve when assessing loss) (refer to Fig. 2.7.2.2, Table 2.6.6).

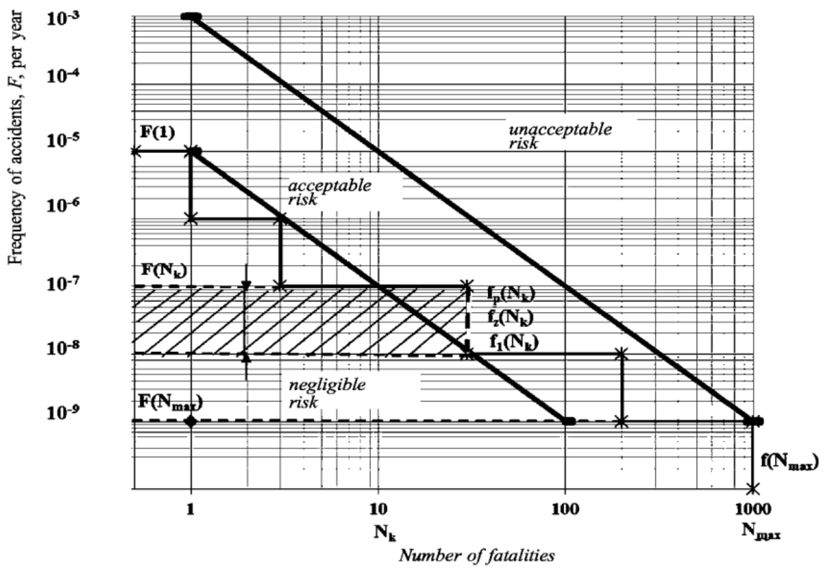

Fig. 2.7.2.2
F/N curve example

$f(N_k) = \sum_{j=1}^{p} f_j(N_k)$ — attack rack N_k man;
$f(N_k)$ = frequency of p scenarios in which N_k men are effected;
$F(N_k) = \sum_{v=1}^{h} f_v(N_r)$ — frequency of occurrence of haphazards *(h)* with number of victims $N_r \geq N_k$;
$f(N_{\max}) = F(N_{\max})$ — frequency of the most catastrophic scenario

2.7.3 Analysis of fire and explosion risks.

2.7.3.1 For quantitative assessment of fire and explosion risks during MO, use the Procedure for Determination of Fire Risk Design Values at Production Facilities developed by the Federal State Budgetary Establishment All-Russian Research Institute for Fire Protection, Ministry of Russian Federation for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters (FGU VNIIPO of EMERCOM) of Russia, Order of EMERCOM of Russia No. 404 dated 10.07.2009.

2.7.3.2 The possibility/frequency of fire/explosion shall be determined using both calculation and statistical approaches. To determine the fire/ explosion effects on personnel/crew, it is reasonable to use a probit-function.

2.7.4 Analysis of collision, impact, stranding, cargo falling, object sinking risks.

Table 2.7.4 shows formulas of the ES risk/frequency.

Table 2.7.4

Formulas of ES risk/frequency

Emergency situation	Formula of ES risk/frequency	Acceptable risks criteria
Collisions	$f_{collisions} = f_{basic} \times k_{traffic} \times k_{measures} \times k_{nav}$ where f_{basic} = basic frequency of collisions; $k_{traffic}$ = factor characterizing traffic density in way of MO (taken to be equal to 0,20 to 0,60 or navigation within channels, restricted areas, fairways; 0,20 for navigation within straits, bays, lagoons; 0,01 for navigation in the open sea); $k_{measures}$ = factor characterizing measures taken to prevent collision (taken to be equal to 1.0 for navigation in an unknown water area without a pilot onboard; 0.9 for navigation with a pilot onboard or within the known water area); k_{nav} = factor characterizing navigation conditions (taken to be equal to 1.5 for navigation conditions with seasonal variations in visibility range, and high seas and winds; 1.2 for navigation conditions with seasonal variations in visibility range; 0.9 to 1.0 for normal navigation conditions).	10^{-6} to 10^{-3}
Impacts	$f_{bav} = f_{basic} \times p_{heading} \times p_{(hazard\ alarm)} \times p_{(stand\ by)}$ where f_{basic} = basic frequency of ship impacts with offshore objects; $p_{heading}$ = probability of a ship staying within the operational area of the offshore object/platform and heading towards this object (defined as a probability of ships' transition through the operational area boundary based on operational area dimensions, ship navigation routes and traffic density in the region); $p_{(hazard\ alarm)}$ = relative probability that an approaching ship order or individual ship will be detected by the offshore object and no impact hazard alarm will be given (defined as a probability of failure in radar system of the offshore object/ platform and of failure in communication means provided the radar failure by the conditional probability formula); P_{action} = probability that no actions will be taken to prevent the impact (defined by the expert judgment and/or in accordance with statistical data); $p_{(stand\ by)}$ = probability that no actions will be taken by the support vessels to prevent the impact (taken to be equal to 1,0 in the absence of support vessels; 0,1 in case of support vessels).	10^{-6} to 10^{-3}

Emergency situation	Formula of ES risk/frequency	Acceptable risks criteria
Stranding (when propulsion plant is operative)	$f_{stranding} = f_{basic} \times k_{traffic} \times k_{measures} \times k_{nav}$ where f_{basic} = basic frequency of stranding; k_{nav} = factor characterizing the complexity of MO route (taken to be equal to 2,1 for navigation with course change within channels/restricted areas; 1,8 for navigation with the constant course within channels/restricted areas; 1,5 for navigation with course change in inland waters; 1,0 for navigation with the constant course in inland waters; 0,6 for navigation in the open sea with local grounds; 0,05 for navigation in the open sea without local grounds); $k_{measures}$ = factor characterizing measures taken to prevent stranding (refer to Table 2.7.4 above); k_{nav} = factor characterizing navigation conditions in the MO area (taken to be equal to 1,5 for navigation conditions with seasonal variations in waves and winds; 1,2 for navigation conditions with seasonal variations in visibility range; 0,9 — 1,0 for normal navigation conditions).	10^{-6} — 10^{-3}
Stranding (under free drift conditions)	$f_{strandig} = f_{basic} \times k_{distance} \times k_{mooring}$ where f_{basic} = basic frequency of stranding; $k_{distance}$ = factor characterizing distance from the shore (taken to be equal to 1.3 for navigation within channels, restricted areas, fairways; 1,0 — 1,1 for navigation in inland waters; 0,5 for navigation in the open sea); $k_{mooring}$ = factor characterizing the possibility for emergency mooring (taken to be equal to 1,2 where emergency mooring is not possible; 1,0 where emergency mooring is possible with probability of at least 0,5).	10^{-6} — 10^{-3}
Cargo falling	$f_{falling} = f_{basic} \sum_{op=1}^{p} p_{faihire}^{p} \sum_{i=1}^{L} p_{cargo}^{p,l}$ where f_{basic} – basic frequency of object falling; $p_{failure}^{p}$ – probability of failure in hoisting equipment during lifting/crane operation (to be determined by expert judgment or in accordance with statistical data); $p_{cargo}^{(p,l)}$ – probability of falling of an 1 type object during lifting/crane operation (to be determined by expert judgment or in accordance with statistical data); *P* – total number of consecutive lifting/crane operations; *L* – number of various objects subject to lifting/crane operations	10^{-6} — 10^{-3}
Object sinking	$f_{sinking} = f_{basic} \times k_{weather}$ where f_{basic} = basic frequency of object sinking; $k_{weather}$ = weather influence factor (taken to be equal to 1,5 for navigation in heavy seas and winds; 1,2 to 1,0 for navigation in moderate seas and winds; 0,1 for navigation in calm seas).	10^{-6} — 10^{-3}

2.8 Recommendations for reporting risk assessment of marine operations

2.8.1 Tables 2.8.1-1 and 2.8.1-2 are recommended to be used for determination or ranking of MO risk level.

Table 2.8.1-1

Assessment of ES consequences

Potential consequences					
Category	Consequence assessment	Impact on personnel safety	Environmental impact	Material and financial loss[1]	Reputation impact
1	Negligible (Very low)	No injuries	No environmental pollution	< USD 10 thousand Minor damage to equipment, no operation interrupted	No impact
2	Minor (Low)	Injuries not leading to disability are possible	Minor pollution of environment Period for environmental recovery < 1 month (costs: < USD 1 thousand)	USD 10 to 100 thousand Short-term inactivity due to ES (not resulting in the object damage)	Minor impact
3	Significant (Moderate)	Severe injuries are possible Multiple minor damages Long-term disability	Significant pollution of environment Period for environmental recovery > 1 month (costs > USD 1 thousand)	USD 100 to 1000 thousand Dwell of the object (up to several days) due to accident; repair work not related to hull structures	Significant impact
4	Major (High)	Possible fatality/ multiple severe injuries Singe casualty	Significant environmental impact Period for environmental recovery > 1 year (costs > USD 1 million)	USD 1 to 10 million Dwell time of the object (exceeding several days) due to accident; significant repair of hull structures	Major consequences for further activity
5	Disastrous (Very high)	Multiple casualties	Catastrophic environmental impact Global or national disaster Period for environmental recovery > 10 years	> USD 10 million Disaster, i.e. wreckage, sinking or complete destruction of the object	Disastrous consequences for activity
[1] The material and financial losses are assessed using cost estimates aimed at reducing risk level considered in 3.2.					

Table 2.8.1-2

Possibility of the event

Value	Extent of possibility of the event	Description
1	Extremely unlikely	Possible event that never occurred during MO
2	Unlikely	The event that is unlikely to occur during MO
3	Likely	The infrequent event that is likely to occur during MO
4	Probable	The event that may occur one or several times during MO
5	Frequent	Normal event that may occur one or more times during MO

2.8.2 Risk matrices.

A risk matrix being a tool to combine qualitative or mixed (qualitative + quantitative) assessments of consequences and probabilities shall be used for determination or ranking of risk level during MO. Tables 2.8.2-1 and 2.8.2-2 show the MO risk level matrix and risk acceptability table.

Table 2.8.2-1

MO risk level matrix

Consequence, severity rating	Possibility of the event, *P*, rating				
	1	2	3	4	5
	Extremely unlikely	Unlikely	Likely	Probable	Frequent
1 Negligible	1	2	3	4	5
2 Minor	2	4	6	8	10
3 Significant	3	6	9	12	15
4 Major	4	8	12	16	20
5 Disastrous	5	10	15	20	25

Table 2.8.2-2

Risk acceptability table

Risk level	Rating	Description
Low	1 — 6	Operations may be performed without taking special safety measures
Medium	7 — 12	It may be necessary to further consider and/or take measures to mitigate the risk and/or to implement a plan to mitigate the risk to the acceptable level
High	13 — 25	Operations may not be performed. Alternative risk mitigation ways or measures are to be worked out

2.8.3 Risk register

2.8.3.1 In case of insufficient information content of the MO risk assessment results recorded in the risk level matrix, these results shall be reported in a form of a risk register. The risk register shall contain data on identification, description of hazardous events, their risk assessment, loss, probability and level of risk/risks, data on potential effects of these events on MO. The risk register shall include risk control measures, their status, and residual risk assessment after taking these measures as well as full name and position of persons in charge of risk mitigation, control and management measures.

2.8.3.2 The risk register format used for the MO risk assessment is given in Table 2.8.3.2. Pursuant to GOST R 51901.22-2012, the risk register format shall be approved by the manager of organization engaged in MO and agreed by the designer with the owners of the MO objects and ships.

2.8.3.3 According to specific features of MO and/or inputs available, the risk register format for MO risk assessment may be used in a complete form and in a short form (without some columns).

Table 2.8.3.2

Marine operation risk assessment register format

Risk/hazard identification							Risk analysis				
							Initial assessment				
Risk/ hazard identificator	Risk/ hazard description[1]	Risk/ hazard name	Risk/ hazard description	Causes	Consequences	Risk category[2]	Probability of risk/hazard *P*	Consequence/ loss assessment at risk occurrence *I*	Risk assessment *P*×*I*	Overall risk[3]	Hazard rating in the risk increasing order[4]
MO stage											

	Risk control and management										Note
				Residual risk assessment					Measure timeframes		
Status of risk control measures[5]	Risk control measures	Risk owner (full name, position)[6]	Person in charge of risk handling (full name, position)[7]	Probability of risk/ hazard *P*	Consequence/ loss assessment at risk occurrence, *I*	Risk assessment *P* × *I*	Risk impact on MO cost (million rubles)	Risk impact on MO timeframes (days)	Commencement	Completion	
MO stage											

[1] technological, personnel qualification, climatic conditions, organizational, financial, reputational.
[2] very low, low, moderate, high, very high.
[3] negligible, acceptable, maximum tolerable, intolerable.
[4] from 2 to 10.
[5] effects reduction, mitigation, transfer/insurance, acceptance, exclusion.
[6] a person in charge of control of a specific risk/risks.
[7] identification, analysis, assessment, control and monitoring.

3 MARINE OPERATION RISK CONTROL AND MANAGEMENT

3.1 Risk control and management options during MO

3.1.1 Effective risk control and management provide the following:
control of all identified hazards;
review of potential control measures to reduce the risk to an acceptable level;
analysis of factors affecting the selection of risk reduction measures;
establishment of risk control options;
assessment of efficiency of risk control options;
suggestions on additional control measures.

3.1.2 The MO risk control according to IMO resolution MSC-MEPC.2/Circ.12 (8 July 2013) takes into account the exact quantitative or objective and reasonable qualitative safety sufficiency criteria (SSC) using the ALARP principle.

3.1.2.1 When establishing SSC, some standardized parameters are determined, to which risk levels may be related. The list of accident risk indicator estimates is developed based on risk assessment tasks and specific features of the MO design.

3.1.2.2 SSC allows for selection of the preferred MO approach and potential control measures to reduce the risk to an acceptable level in the course of comparison assessment of safety/risk for various MO options.

3.1.3 The effective risk reduction measures during MO are selected with regard to factors affecting the selection of risk reduction measures, which include the following (according to GOST ISO R 17776-2012):
technical feasibility;
contribution of measures to risk reduction;
costs and risks related to implementation of measures;
consideration of uncertainties including human-related effects.

3.1.4 When preparing the risk reduction options, the measures taken shall:
meet regulatory and legal requirements;
meet requirements of the company engaged in MO and the object owner.

3.1.4.1 Recommendations on accident risk reduction shall not contradict to the IMO recommendations and IACS approaches and meet the effective Rules of the Register and Register approved operating standards.

3.2 Cost-benefit analysis of MP risk reduction measures

3.2.1 The effects of measures taken shall be compared to costs for the measures themselves using cost-benefit analysis.

For determination of priority risk reduction measures, a maximum specific efficiency (which is an effect-to-cost ratio) shall be used rather than maximum effect or minimum cost.

3.2.2 For risk assessment from socio-economical perspective, a cost effectiveness analysis (CEA) shall be used.

3.2.3 The estimates of expected socio-economical and ecological loss suffered from accidents during MO shall be considered as the ground for calculation of the amount of financial security for civil liability for possible damage to personnel, public, third parties, property, environment, and also as the amount of damage already prevented at the MO design stage with regard to human-related effects, natural and technogenic impacts that might otherwise result in an accident.

APPENDIX 1

DESCRIPTION OF MO RISK ASSESSMENT METHODS

No.	Method	Description and application	Type	Referenced standards
		Analytical modeling		
1	Checklists	A simple form of risk identification. This method allows the user to be provided with sources of uncertainty to be considered. Users apply the previously developed list, codes (rules and regulations) and standards	Qualitative	GOST R ISO/IEC 31010-2011
2	Structured What If Technique (SWIFT)	It is a systematic, team-based study utilising a set of 'prompt' words or phrases that help team members within a workshop to identify hazards and create their scenarios. The facilitator and team use standard "what-if' type phrases in combination with the prompts to investigate how a system, plant item, organization, or procedure will be affected by the hazard	Qualitative	GOST R ISO/IEC 31010-2011
3	Expert judgment (Delphi technique)	It is a technique to obtain expert estimations that may help at identification of sources and hazard effects, assessment of probability and consequences and overall risk assessment It is a technique to summarize the expert opinions. This technique allows for independent analysis and voting of experts	Qualitative	GOST R ISO/IEC 31010-2011
4	Risk matrix	A risk matrix of consequences and probabilities is a tool to combine qualitative or mixed assessments of consequences and probabilities and is used for determination or ranking of risk level	Mixed	GOST R ISO 17776-2012, GOST R ISO/IEC 31010-2011
5	Hazard identification (HAZID)	It is a simple inductive analysis technique aimed at identification of basic hazards, hazard factors and events that can affect the operation or cause harm for a given activity or the whole process system of the object	Mixed	GOST R ISO 17776-2012, GOST R ISO/IEC 31010-2011 GOST R 51901.2-2005
6	Failure mode and effect analysis (FMEA)/ failure mode, effect and criticality analysis (FMECA)	It is a method for systematic analysis of the system to identify potential failure modes, their causes and consequences as well as their effects on the system operation (as a whole or its components and processes). FMECA extends FMEA and includes methods of ranking of failure severities. This technique allows for establishment of the priority countermeasures	Mixed	GOST R 51901.12-2007 GOST R ISO 17776-2012 GOST R ISO/IEC 31010-2011

No.	Method	Description and application	Type	Referenced standards
7	Hazard and operability study (HAZOP)	This study is performed by a group of specialists and aimed at detailed investigation and identification of hazard problems and operability of the system. HAZOP is intended for identification of potential deviation from the design targets, expert review of their potential causes and assessment of their consequences	Mixed	GOST R 51901.11-2005 (IEC 61882:2001) GOST R ISO 17776-2012 GOST R ISO/IEC 31010-2011
8	Preliminary Hazard Analysis (PHA)	It is an inductive method of analysis whose objective is to identify the hazards and hazardous situations and events that can affect the operation or cause harm for a given activity, equipment or system. This analysis is often a precursor to further studies or is aimed to provide information for development of specifications to the system under design	Qualitative	GOST R ISO 17776-2012 GOST R ISO/IEC 31010-2011
9	Human Reliability Analysis (HRA)	This analysis deals with the impact of humans on the system and can be used to evaluate human error influences on the system performance	Qualitative	GOST R ISO 17776-2012 GOST R ISO/IEC 31010-2011
10	Physical effect modeling (PEM)	This method allows for prediction of scenarios of physical processes under incident conditions using computer-based mathematical modeling. This method is widely used in a great deal of other assessment techniques that require mathematical modeling for assessment of consequences of a hazardous event whose frequency may be unknown or roughly known	Mixed	GOST R ISO/IEC 31010-2011
11	Quantitative risk analysis (QRA)	This method is aimed at risk assessment for a specific activity in numerical values rather than in relative qualitative values. It is used for assessment of all risk including those to personnel, environment, offshore installation	Quantitative	GOST R ISO 17776-2012
		Physical modeling		
12	Fault tree analysis (FTA)	It is a graphical modeling technique showing various combinations of failures of equipment and human errors that may contribute to a hazardous event usually called the "top event" (main event)	Mixed	GOST R 27.302-2009 GOST R ISO 17776-2012 GOST R ISO/IEC 31010-2011
13	Event tree analysis (ETA)	It is a graphical technique for representing the mutually exclusive sequences of events following an initiating event according to the functioning/failures of systems designed to mitigate the consequences of a hazardous event	Mixed	GOST R IEC 62502-2014 GOST R ISO 17776-2012 GOST R ISO/IEC 31010-2011

No.	Method	Description and application	Type	Referenced standards
Statistical modeling				
14	Monte Carlo simulation	It is an analysis of effects of system parameter assessment uncertainties in a wide range of situations. This method is usually used for assessment of variation range of outcomes and relative frequency of values within this range for quantified values. The modeling may be used for two different purposes: transformation of uncertainty for common analytical models and calculation of probabilities when analytical methods cannot be used	Qualitative	GOST R ISO/IEC 31010-2011
15	Bayesian analysis	It is a graphical model that represents variables and their probabilistic relationships. Bayesian networks may be used for studying causal links, in-depth understanding of the problem area and prediction of effects of intervention to the system. This analysis allows for obtaining quantitative outputs	Qualitative	GOST R ISO/IEC 31010-2011
Note. Qualitative technique is a descriptive analytical risk assessment method not utilising numerical indicators or statistical quantities. Quantitative technique is a design analytical risk assessment method utilising numerical indicators and/or statistical quantities. Mixed technique is a descriptive analytical risk assessment method partially utilising numerical indicators and/or statistical quantities.				

APPENDIX 2

EXAMPLES OF RISK ASSESSMENT FOR MARINE OPERATIONS

1 Examples of risk assessment for towing the object to the installation site

1.1 Risk assessment for towing the object, refer to Table 1.1.

Table 1.1

Risk assessment for towing the object

No.	Potential accidents	Frequency rating	Accident effect rating				Risk value
			Personnel safety	Environmei	Project timeframes	Max.	
1. Delivery of the object to the installation site							
1	Object sinking	1	1	1	4	4	High
2	Tug impact on the object involving structural damage	2	2	2	3	3	High
3	Ground contact/grounding	1	1	1	3	3	Medium
4	Damage to the ship power plant, malfunction of propulsion and/or steering components	2	1	1	2	2	Medium
5	Damage to tug structures	2	2	2	2	2	Medium
6	Damage to navigation and/or radio equipment	3	1	1	1	1	Medium
7	Towline winding onto propeller	2	1	1	2	2	Medium
8	Breakage/failure of towing arrangement	2	1	1	1	1	Low
2. Object positioning, submersion and setting down							
1	Object sinking	1	2	2	4	4	High
2	Tug/workboat impact with the object involving structural damage	2	1	1	3	3	High
3	Damage to pump, towing winch, anchoring gear	2	1	1	2	2	Medium
4	Damage to radio equipment	3	1	1	1	1	Medium
5	Breakage of water pumping hose	2	1	1	1	1	Low

1.2 Risk assessment using expert judgment technique, refer to Table 1.2.

Table 1.2

Expert judgment of typical accident scenarios for object towing design

No.	Scenario	Probability	Expert conclusions		Consequences
1	Loss of integrity, water leakage into ballast system (pipes, plugs, valves) through welded or flanged joints	Extremely unlikely (1)	Extremely unlikely event after all proper tightness tests	Negligible (1)	Water leakage/ seal failure consequences are negligible
2.	Failure in components of the towing and mooring arrangement. Breakage of the towline	Extremely unlikely (1)	Extremely unlikely event when MO are carried out under safe weather conditions and when the specified towing speed is observed	Significant (3)	Upon breakage of the towline, the object may be subject to uncontrolled drift in the narrow channel that may result in significant damage to structures of the installation and long-term suspension of MO (up to 2 days)
3	Failure of the tug	Extremely unlikely (1)	Extremely unlikely event, provided that proper safety precautions are observed and experienced crew is available on board the tug.	Minor to significant (2-3)	Failure of the tug will suspend MO (for 1 – 2 days) (repair or involvement of a new tug)
4	Damages due to falling/displacement of equipment, structures, foundations, cargo, etc. inside the object	Extremely unlikely (1)	Extremely unlikely event since all structural members shall be properly secured	Negligible to minor (1-2)	Damages may cause a short-term interruption of MO (up to 1 day)
5	Damages to the object due to falling of external objects (helicopter, aircraft, cargo)	Extremely unlikely (1)	Practically unlikely event	Vary widely	It is difficult to determine
6	Damages due to ground contact	Unlikely (2)	The event which is unlikely to occur provided that towing mode and safe navigation regulations are observed but may occur if the above mentioned is not observed.	Negligible (1)	Ground contact will not cause any severe damages to the object and will not affect the MO plan

No.	Scenario	Probability	Expert conclusions		Consequences
7	Stranding	Unlikely (2)	Similarly to item 6.	Significant (3)	Stranding will require ships and craft to remove the object from soil that will result in MO suspension
8	Damages due to collision with other ship/hazardous drifting object	Extremely unlikely (1)	This event is very unlikely considering the fact that navigation within the channel will be suspended for the period of MO	Vary (1-3)	Possible damages to the object structures including significant ones in case of such an event
9	Tug impact with the object	Extremely unlikely (1)	This event is unlikely to occur, but does sometimes occur in practice due to navigation errors within restricted areas and channels	Minor (2)	Where the towing speed is within the specified limit, such an impact will not cause any damage to the object

2 Example of risk assessment for object ballasting, moving from the yard water area, and towing

2.1 Risk assessment for object towing to the yard ballasting site, refer to Table 2.1.

Table 2.1

Risk assessment for object moving from the yard water area, towing through channel

No.	Potential accidents	Frequency rating	Accident effect rating				Risk value
			Personnel safety	Environment	Project timeframes	Maximum	
1	Tug impact with the object	2	2	1	3	3	High
2	Breakage/failure of towing arrangement Towline winding onto propeller	1	1	1	2	1	Low
3	Ground contact/grounding	2	1	1	2	2	Medium
4	Damages of ship power plant. Malfunction of propulsion and/or steering components	1	1	1	2	2	Medium
5	Damage to navigation and/or radio equipment	2	1	1	1	1	Medium
Note. During risk assessment, the highest priority was given to most hazardous effects of each accident.							

3 Example of risk assessment for towing of the platform substructure

3.1 Risk assessment for substructure undocking, refer to Fig. 3.1 and Table 3.1.

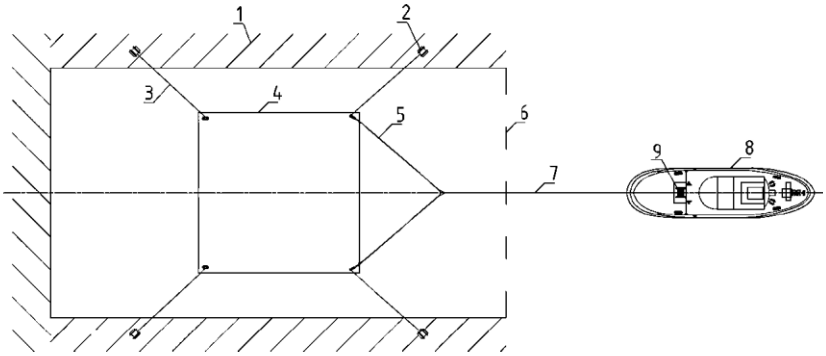

Fig. 3.1
The location of the MOs during the output of the support structure (SS):
1 — dry dock wall; *2* — dry dock winch; *3* — mooring rope; *4* — support structure;
5 — towing bridle; *6* — dry dock gate; *7* — towing line; *8* — tug; *9* — towing winch

Table 3.1

Risk assessment for substructure undocking

No.	Potential accident	Probability of event *P*	Severity of effects *I*	Risk assessment *P × I*	Person in charge	Risk mitigation/elimmation measures
1	Impact on object (grounding/collision)			High		
1.1	Breakage of the rope	1	2	2	LTO	Ship specification; Survey of tugs for fitness; Survey of chartered tugs; Inspection of towing and mooring equipment/system; Personnel training; Meeting with the leader of the towing operation; Operation methods. References: 1) Tug specification; 2) Ship fitness report; 3) Guidelines on undocking the substructure 4) Safety Guide
1.2	Uncontrolled disconnection of a mooring line	1	2	2	LTO	Personnel training Meeting with the leader of the towing operation Operation methods. References: 1) Guidelines on undocking the substructure

No.	Potential accident	Probability of event *P*	Severity of effects *I*	Risk assessment *P* × *I*	Person in charge	Risk mitigation/elimmation measures
1.3	Unbalanced mooring system during disconnection	1	2	2	LTO	Operation methods Tension check Testing the response to disconnection of the mooring line. References: 1) Guidelines on undocking the substructure
1.4	Damage to the ship power plant	1	2	2	LTO	Ship specification. Survey of tugs for fitness. Survey of chartered tugs. Inspection of towing and mooring equipment/system. Personnel training. Meeting with the leader of the towing operation. Operation methods. References: 1) Tug specification. 2) Ship fitness report. 3) Guidelines on undocking the substructure. 4) Safety Guide
1.5	Ship winch accident	2	4	8	LTO	Inspection of the towing winch and towing arrangement/system. Meeting with the leader of the towing operation. Operation methods. References: 1) Tug specification. 2) Ship fitness report. 3) Guidelines on undocking the substructure
1.6	Absence of communication language	2	3	6	LTO	Personnel training. Meeting with the leader of the towing operation. Operation methods. References: 1) Guidelines on undocking the sub-structure. 2) Safety Guide
1.7	Intervention to the port traffic	2	3	6	LTO	Daytime operations. Information contact with port office. Keeping the port office informed during operations. Transmission of safety-related radio messages. Operation methods. References: 1) Guidelines on undocking the substructure

No.	Potential accident	Probability of event *P*	Severity of effects *I*	Risk assessment *P* × *I*	Person in charge	Risk mitigation/elimmation measures
2	Personnel impact			High		
2.1	Breakage of the line during winch operation	1	4	4	LTO	Startup and check of all preliminary installed equipment. Inspection and check of towlines/winch lines of tugs. Inspection and check of the towing winch Inspection and check of tug mooring lines. Certified equipment. Safety briefing of personnel. Meeting with the leader of the towing operation. References: 1) Substructure mooring and positioning specification. 2) Documentation/certification. 3) Guidelines on undocking the substructure. 4) Safety Guide
2.2	Language/ communication problem	2	3	6	LTO	Personnel training. Meeting with the leader of the towing operation. Operation methods. References: 1) Guidelines on undocking the sub-structure. 2) Safety Guide
2.3	Injuries during personnel transportation	2	4	8	LTO	Personnel training. Meeting with the leader of the towing operation. Operation methods. References: 1) Guidelines on undocking the substructure. 2) Safety Guide
2.4	Lack of passages and emergency exits for personnel	2	4	8	LTO	Personnel training. Meeting with the leader of the towing operation. Operation methods. References: 1) Guidelines on undocking the sub-structure. 2) Safety Guide
Symbol. LTO — Leader of towing operations.						

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