RUSSIAN MARITIME REGISTER OF SHIPPING

Электронный аналог печатного издания,
утвержденного 18.11.04

RULES

FOR THE CLASSIFICATION AND CONSTRUCTION OF MANNED SUBMERSIBLES, SHIP'S DIVING SYSTEMS AND PASSENGER SUBMERSIBLES

НД No 2-020201-005-E

2004

The Rules for the Classification and Construction of Manned Submersibles, Ship's Diving Systems and Passenger Submersibles have been approved in accordance with the established approval procedure and come into force since 1 January 2004.

The Rules establish specific requirements for the manned submersibles, ship's diving systems and passenger submersibles and supplement the Rules for the Classification and Construction of Sea-Going Ships, Rules for the Equipment of Sea-Going Ships and Rules for the Cargo Handling Gear of Sea-Going Ships.

With this in view, all the applicable requirements of the above Rules cover the manned submersibles, ship's diving systems and passenger submersibles, unless other requirements are contained in the Rules. Where the above Rules are applied to the manned submersibles, ship's diving systems and passenger submersibles, to be meant under the term "ship" are also the manned submersibles, ship's diving systems or passenger submersibles.

ISBN 5-89331-120-5

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GENERAL REGULATIONS FOR THE CLASSIFICATION AND OTHER ACTIVITY RELATING TO MANNED SUBMERSIBLES, SHIP'S DIVING SYSTEMS AND PASSENGER SUBMERSIBLES[1]

1 DEFINITIONS AND EXPLANATIONS

The following definitions have been adopted in the Rules for the Classification and Construction of Manned Submersibles, Ship's Diving Systems and Passenger Submersibles[2] of Russian Maritime Register of Shipping[3].

Emergency reserve of buoyancy means the additional buoyancy corresponding to the mass of solid ballast in water and other equipment of the manned submersible or diving bell external to the pressure hull, which may be dropped in emergency depending on the manned submersible or diving bell design.

Self-sustained manned submersible means a manned submersible not linked to an attendant ship.

Compression chamber means a pressure vessel for human occupancy under a breathing gas mixture pressure with means of controlling the differential pressure between the inside (habitable) part and the environment, as well as with a life support system and other systems and equipment. The compression chambers are subdivided in fixed (surface) compression chambers permanently installed on the ship and submersible compression chambers (diving bells).

Towed manned submersible means a tethered manned submersible designed to operate while towed.

Displacement of a manned submersible means the displacement corresponding to the buoyancy volume.

Diving bell means a submersible compression chamber for transfer of diving personnel from surface compression chambers installed on board a support ship of the manned submersibles and ship's diving systems to the underwater work location (with exit of divers directly into the water) and vice

[1] Hereinafter referred to as "the General Regulations".
[2] Hereinafter referred to as "the Rules".
[3] Hereinafter referred to as "the Register".

versa. It belongs to suspended submersibles. It may be used (if structurally provided) as an observation chamber.

Diving system means the whole plant and equipment designed for the conduct of diving operations using saturation diving technique.

Lock-out submersible means a manned submersible designed to transfer the divers and to provide the diving operations.

Reserve buoyancy of a manned submersible means the buoyancy corresponding to the watertight volume above the effective waterline of the manned submersible when afloat (it is expressed in per cent as the ratio of the ballast tanks volume to the buoyancy volume of the manned submersible).

Tightness tests mean testing of welds of the hull, bulkheads, hatches, covers, viewports, pipe connections and fittings by a soap solution or other means approved by the Register under the following conditions:

at an internal air pressure equal to the working pressure – for compartments of the lock-out submersibles and tanks under the internal pressure, and for ship's diving systems;

at an internal air pressure specified by the Designer and approved by the Register – for the manned submersibles, lock-out submersible compartments and tanks under the external pressure;

at an internal working medium pressure equal to the working pressure, no matter what the pressure (internal or external) they work under on the manned submersibles or ship's diving systems – for pipes joined to fittings.

Tightness tests for the manned submersibles and diving bells may be performed by an external hydraulic pressure.

Strength tests mean testing of pressure hulls of the manned submersibles or ship's diving systems in assembly with welded-in component parts by a test pressure (or a pressure corresponding to the test depth) using, if approved by the Register, one of three potential means[1]:

by an external pressure in a test chamber (for a diving bell, if provision is made for its use as an observation chamber, and for the manned submersible);

by submersion into the sea (for a diving bell, if provision is made for its use as an observation chamber, and for the manned submersible);

[1] Tests of diving bells and lock-out submersible compartments, if provision is made for their use as an observation chamber, are carried out by an external and internal pressure.

by an internal hydraulic pressure (for compression chambers of ship's diving systems and for lock-out submersible compartments operating under an internal pressure, and for diving bells).

Test depth of a manned submersible/diving bell means the depth, to which the manned submersible (a diving bell if its use as an observation chamber is provided) dives in the process of tests after construction, repair or modification, as well as the surveys performed during service.

Test team means a group of experts performing checking in operation of the equipment to be surveyed by the Register according to the program approved by the Register.

Test pressure of a ship's diving system means the internal pressure, which is created during hydraulic tests, to which the pressure-resistant structures of the compression chambers and diving bells (of a lock-out submersible compartment) are subjected and which exceeds the working pressure.

Umbilical means a link of cables and hoses, which connects the support ship of the ship's diving system with the diving bell and may include hoses of the life support system (breathing gas mixture and hot water for heating divers) and gas mixture composition control, communication cables and electric power supply cables.

Competent bodies mean organizations effecting supervision of the manned submersibles and ship's diving systems in the areas not regulated by the Rules.

Mass of a diving bell means the mass of a diving bell including the crew and equipment.

Manned submersible means a submersible being capable of moving in the bulk of water and/or over the bottom or seabed, and fitted for accommodation of people therein.

Suspended manned submersible means a tethered manned submersible designed to operate during lowering, surfacing and while submerged at a specified operational depth.

Buoyancy volume of a manned submersible means the volume of water displaced by all the watertight structures of the manned submersible.

Lifting mass of a manned submersible means the mass of the manned submersible recovered from the water with due regard to the momentary values of the masses of water remaining in non-watertight parts.

Tethered manned submersible means a manned submersible linked to an attendant ship.

Pressure-resistant structures of a manned submersible/ship's diving system mean a pressure hull, pressure tanks and other components of the manned submersible, as well as the diving bells, compression chambers and other components of the ship's diving system, which directly take up the loads due to an excessive pressure corresponding to the diving depth of the manned submersible/diving bell over the entire range of the depths.

Operating (diving) depth of a manned submersible/diving bell means the maximum depth, to which the manned submersible/diving bell can dive the secured number of times and remain there during the specified period of time.

Operating pressure of a ship's diving system means the maximum pressure of a breathing gas mixture, which can be built up in the compression chambers and diving bells (lock-out submersible compartment) the secured number of times and maintained during the specified period of time.

Ship's diving system means a diving system permanently installed on the ship.

Ship's diving system <12 means the ship's diving system designed for diving operations at depths not more than 12 m and comprising, as a minimum, the diving equipment and means of gas supply.

Ship's diving system <60 means the ship's diving system designed for diving operations at depths not more than 60 m and comprising, as a minimum, the diving equipment, compression chamber and means of gas supply.

Ship's diving system $\geqslant$60 means the ship's diving system designed for diving operations at depths of 60 m and over and comprising, as a minimum, one (two compartments, as a minimum, in this case) or more compression chambers, the diving bell or lock-out submersible and handling system.

Launching mass of a manned submersible means the mass of the manned submersible ready for launching with its crew and equipment.

Handling system means the plant and equipment designed to lower a manned submersible and raising it on board an attendant ship or to transport a diving bell to the underwater work location and vice versa.

Standards, for the purpose of the Rules, mean various standards or normative documents of any State approved or recognized by the Register.

M a t i n g d e v i c e means the equipment necessary for tight connection of a diving bell, lock-out submersible or an evacuation compression chamber (if provision is made for such in the ship's diving system) to a compression chamber of the ship's diving system.

S u p p o r t s h i p means a ship or another floating structure for transfer of the manned submersibles and ship's diving systems to a diving area, conduct of diving operations and attendance of the manned submersibles and ship's diving systems in the process of their operation.

E v a c u a t i o n s y s t e m means a complex of equipment intended for evacuation of divers being under pressure from a the deck compression chamber or diving bell to the decompression site. The evacuation system comprises the evacuation compression chamber (hyperboat), handling system and life-support system.

C r e w o f a m a n n e d s u b m e r s i b l e means all the personnel attending the manned submersible, as well as the scientists and other experts directly participating in the diving of the manned submersible.

C r e w o f a s h i p ' s d i v i n g s y s t e m means the divers being in the compression chambers of the ship's diving system.

2 CLASSIFICATION AND OTHER ACTIVITY

2.1 The Register is a State body of classification of civil ships and floating structures, as well as the manned submersibles and ship's diving systems. Besides, the Register duly authorized by the State Government or on behalf of the governments of other States monitors within its competence the fulfillment of the requirements of international conventions and agreements, to which the States mentioned are Parties.

2.2 The Register effects survey of all the types of the manned submersibles having a pressure hull to protect the personnel from the environment, and civil ship's diving systems.

2.3 Survey of the manned submersibles and ship's diving system comprises:

examination and approval of technical documentation;

survey during manufacture of materials and products specified in the nomenclature and intended for use in construction and repairing of the manned submersibles and ship's diving systems;

supervision during construction, reconstruction and conversion of the manned submersibles and ship's diving systems;

survey of the manned submersibles and ship's diving systems in service; assignment, renewal and reinstatement of the class.

2.4 The items of the Register survey and the form of survey during their manufacture at the works, installation and tests of the manned submersibles and ship's diving systems are established by the Nomenclature of Items Surveyed by the Register during Construction, Installation and Testing of Manned Submersibles, Ship's Diving Systems and Passenger Submersibles[1] (see Appendix 1 to Part I "Classification"). Technical requirements for the surveyed items are set forth in the relevant parts of the Rules.

Supervision of the items of the manned submersibles and ship's diving systems, which are not regulated by the Rules, is performed by the relevant competent bodies.

2.5 The Register effects supervision of life support systems of the manned submersibles and ship's diving systems as regards their strength, tightness, watertightness and fire safety, as well as their functioning within the limits of specification parameters of the systems machinery surveyed by the Register. Supervision of life support systems as regards the materials used and their compatibility with the working media, choice of qualitative and quantitative parameters of the breathing mixtures and gas medium, as well as the medical, physiological and professional diving aspects is not the Register competence and shall be effected by the relevant competent bodies.

2.6 The Register establishes technical requirements for safe operation of the manned submersibles and ship's diving systems, supervises their fulfillment and classifies the manned submersibles and ship's diving systems.

2.7 Survey activities are based on the Rules published by the Register and aimed to determine whether the manned submersibles and ship's diving systems subject to the survey, as well as materials and products intended for construction and repair of the manned submersibles and ship's diving systems and their equipment comply with the Rules and additional requirements.

The responsibility for fulfillment of the Rules and additional requirements rests with designers, owners of the manned submersibles and ship's diving systems, builders and manufacturers of materials and products subject to the Register survey.

The Register survey does not supersede the activities of technical inspection bodies of the manned submersibles and ship's diving systems owners, builders and manufacturers of materials and products.

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

2.8 The Register surveys all handling systems of the manned submersibles and ship's diving systems installed on the support ships subject to the Register survey.

2.9 Research equipment, working tools and other equipment fitted in the manned submersibles and ship's diving systems for the process purposes are not subject to the Register survey.

3 RULES AND OTHER NORMATIVE DOCUMENTS

3.1 APPLICATION

3.1.1 During survey of the manned submersibles and ship's diving systems the Register applies the following Rules and other normative documents:

.1 Rules for the Classification and Construction of Manned Submersibles, Ship's Diving Systems and Passenger Submersibles;

.2 Rules for the Classification and Construction of Sea-Going Ships;

.3 Rules for the Equipment of Sea-Going Ships;

.4 Rules for the Cargo Handling Gear of Sea-Going Ships;

.5 Rules for the Classification, Construction and Equipment of Mobile Offshore Drilling Units and Fixed Offshore Platforms;

.6 IMO Safety Code for Diving Systems;

.7 IMO Guidelines for the Design, Construction and Operation of Passenger Submersible Craft.

3.1.2 In addition to the normative documents listed in 3.1.1 the Register applies the following documents during survey of the manned submersibles and ship's diving systems:

.1 Guidelines on Technical Supervision During Construction of Manned Submersibles and Ship's Diving Systems and Manufacture of Materials and Products;

.2 Guidelines on Technical Supervision of Manned Submersibles and Ship's Diving Systems in Service;

.3 Guidelines on Technical Supervision During Construction of Ships and Manufacture of Materials and Products;

.4 Guidelines on Technical Supervision of Ships in Service.

3.2 APPLICATION OF THE RULES TO MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS UNDER CONSTRUCTION AND THEIR PRODUCTS

3.2.1 Newly adopted Rules and amendments thereto come into force six months after the date of publication unless other terms are specified in separate cases. The Rules are considered as recommendations until they come into force.

3.2.2 The manned submersibles, ship's diving systems and products, which design are submitted to the Register for approval after the date of coming into force of the Rules or amendments thereto shall comply with the requirements of the Rules or amendments.

Manned submersibles and ship's diving systems under construction and products, which technical documentation has been approved by the Register prior to coming into force of the Rules or amendments thereto, shall comply with the Rules that were in force at the time of approval of that documentation.

3.3 APPLICATION OF THE RULES TO MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS IN SERVICE

3.3.1 Manned submersible and ship's diving system in service shall meet the requirements of those Rules of a classification body recognized by the Register, to which they have been built.

3.3.2 Reconstruction or conversion of the manned submersibles and ship's diving systems in service shall be carried out in compliance with these Rules as far as practicable and technically reasonable.

3.4 DEPARTURES FROM THE REQUIREMENTS OF THE RULES

3.4.1 The Register may allow any materials, structures of the manned submersibles and ship's diving systems or individual arrangements and articles to be fitted on the manned submersibles or ship's diving systems that are other than those required by the Rules, provided they are as effective as those specified by the Rules; as regards the manned submersibles and ship's diving systems subject to the provisions of international conventions or agreements, such departures from the Rules may only be allowed by the Register if they are also allowable under those conventions and agreements. In the above cases, the Register shall be supplied with the particulars, which would enable it to ascertain that such materials, structures, arrangements and products meet the requirements, which ensure safety of the manned submersible and ship's

diving system and safety of life at sea.

3.4.2 If the structure of the manned submersible and ship's diving system, their machinery, arrangements, units, equipment and outfit or materials used cannot be recognized as being adequately proved in service, the Register may require special tests to be held during construction and, when in service, may reduce the intervals between periodical surveys or extend the scope of these surveys.

If the Register finds it necessary, appropriate restrictive entries may be made in the classification or other documents issued by the Register.

Those restrictions are lifted after positive results have been obtained in course of service.

4 DOCUMENTS

4.1 As a result of survey of the manned submersibles and ship's diving systems the Register issues the appropriate documents.

4.2 The documents, which confirm the compliance with the requirements of the Rules, are:

.1 Classification Certificate for the manned submersible;

.2 Classification Certificate for the ship’s diving system;

.3 Register of Ship's Cargo Handling Machinery and Gear of the Support Ship of the Manned Submersible and Ship’s Diving System confirming the compliance with the Rules requirements for the handling system of the manned submersible, ship’s diving system and their support ship;

.4 Passenger Certificate (for passenger submersibles);

.5 Safety Compliance Certificate, which confirms the fulfillment of the requirements of the IMO Guidelines for the Design, Construction and Operation of Passenger Submersible Craft.

4.3 The document confirming safety at sea of the manned submersible and ship's diving system is a Seaworthiness Certificate, which is issued subject to the condition that the requirements of the Rules for the manned submersibles, ship's diving systems, handling systems, communication means fitted on the support ship and fire protection of the spaces where the manned submersible, ship’s diving system are sited, are complied with. The Certificate is issued in case the manned submersible, ship’s diving system are granted the documents referred to in 4.2.

4.4 The documents referred to in 4.2.1, 4.2.2, 4.2.5 and 4.3 are issued for a

period of five years and shall be confirmed annually within three months either way of the survey anniversary date. The Certificate mentioned in 4.2.5 is issued for a period of a year.

The issue (renewal) and endorsement of the documents mentioned in 4.2 are based on reports, records and certificates.

4.5 The documents, which confirm the compliance of materials and products (including parts and equipment of the handling system), manufactured under the Register supervision, with the Rules and additional requirements, or the performance of the necessary tests, are:

.1 certificates of the Register issued for materials and products;

.2 documents of the Register confirming performance of the tests;

.3 documents approved by the Register, issued by manufacturers for materials and products fabricated by them or by laboratories for the tests conducted.

4.6 The Register issues the documents on the basis of the satisfactory results of technical condition assessment of the object, obtained in the course of surveys and tests.

4.7 The Register may recognize fully or partially the documents of other classification societies, technical inspection bodies and other organizations.

4.8 The documents issued by the Register to the manned submersible and ship's diving system shall be kept on board the manned submersible or the support ship.

4.9 The Seaworthiness Certificates of the manned submersible and ship's diving system and their Classification Certificates, the Safety Compliance Certificate, as well as the Passenger Certificate for a passenger submersible cease to be valid in the following cases:

.1 on expiry of validity;

.2 if the manned submersible or ship’s diving system has not been submitted to the prescribed survey in due terms;

.3 after an accident resulting in damage of structural members and equipment of the manned submersible or ship’s diving system, which ensure safety at sea and are subject to the Register survey;

.4 after repairs or conversions of the parts of the manned submersible or ship’s diving system covered by the Rules, which have been carried out at ship repairing yards without the Register supervision;

.5 violation of operating conditions stated in the Seaworthiness Certificate;

.6 if terms or instructions of the Register have not been followed;

.7[1] when the manned submersible or ship's diving system is resited to the support ship that has no documents of the Register;

.8[1] when the manned submersible or ship's diving system is resited to the support ship, which handling system has no Register documents or which, by technical characteristics, is not intended for handling operations with the manned submersible or ship's diving system concerned;

.9 when the area of excursions provided by the passenger submersible is changed.

4.10 The Register may renew the validity of documents if the reasons of losing the validity are eliminated.

[1] As regards the Seaworthiness Certificate only.

PART I. CLASSIFICATION

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to all the types of the manned submersibles having a pressure hull for protection of the crew from the environment and to the ship's diving systems.

1.1.2 The Rules specify the requirements for the manned submersibles and ship's diving systems, which are to be met in order that they may be assigned a class of the Register.

2 CLASS OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS

2.1 CHARACTER OF CLASSIFICATION OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS BUILT UNDER THE REGISTER SUPERVISION

The character of classification of the manned submersible or ship's diving system built according to the Rules and under supervision of the Register consists of a distinguishing mark ⍟, character letters **КМ** or **К** inserted before it and character letters **ОПА** or **СВК** entered after it:

КМ⍟ОПА – for self-propelled (having their own means of propulsion for movement in water) manned submersibles (self-sustained and tethered);

К⍟ОПА – for suspended and towed manned submersibles;

К⍟СВК – for ship's diving systems, which diving bell has no own means of propulsion;

КМ⍟СВК – for ship's diving systems, which diving bell has own means of propulsion;

К⍟СВК < 12 – for ship's diving systems intended for operation at depths not more than 12 m;

К⍟СВК < 60 – for ship's diving systems intended for operation at depths not more than 60 m.

2.2 CHARACTER OF CLASSIFICATION OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS BUILT WITHOUT THE REGISTER SUPERVISION

If the manned submersible or ship's diving system has been built according to the Rules and under supervision of another classification body and then classed by the Register, the character of classification consists of character letters **КМ** or **К** followed by a symbol ★ and character letters **ОПА** or **СВК** thereon.

If the manned submersible or ship's diving system has been built without supervision of a classification body and then classed by the Register, the character of classification consists of character letters **(КМ)** or **(К)** followed by a symbol ★ and character letters **ОПА** or **СВК** thereon.

2.3 TYPE NOTATIONS FOR MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS

Depending on the manned submersible and ship's diving system type and with the proviso that the relevant requirements of the Rules are met, one of the following descriptive notations is appended to the character of classification:

self-sustained, tethered, suspended, towed, passenger.

3 CLASSIFICATION SURVEYS OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS UNDER CONSTRUCTION

3.1 The Register carries out survey on the basis of the General Regulations for the Classification and Other Activity Relating to Manned Submersibles, Ship's Diving Systems and Passenger Submersibles. It includes examination and approval of technical documentation, supervision during manufacture of materials and products at the works, as well as supervision during construction of the manned submersibles and ship's diving systems.

3.2 The items of the Register survey and its forms during production at the works, installation and testing of the manned submersibles and ship's diving systems are specified in the Nomenclature (see Appendix 1). Technical requirements for the surveyed items are set forth in the relevant parts of the Rules.

3.3 The form of the Register survey is established in the Nomenclature reasoning from the necessity to provide control permissible for the given material or product over fulfillment of the Register requirements. Depending

on the specific conditions of production and the compliance of the surveyed items with the Register requirements, the survey form established in the Nomenclature may be changed by the Register Head Office.

4 CLASSIFICATION SURVEYS OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS IN SERVICE

4.1 GENERAL

4.1.1 The initial survey to assign a class is aimed at determination of a possibility to classify the passenger submersible, manned submersible and ship's diving system initially submitted to the Register for classification.

4.1.2 The scope of the initial survey is determined in each case based on the scope of special survey with due regard to the technical condition of the surveyed items.

4.1.3 Special survey for class renewal is intended to ascertain that the technical condition of the passenger submersible, manned submersible and ship's diving system complies with the Rules and the Register additional requirements. Special survey is performed at the intervals not more than five years with class renewal for the next five years.

4.1.4 Annual survey for class confirmation is intended to ascertain that the passenger submersible, manned submersible and ship's diving system complies with the conditions of retaining the class to a satisfactory degree, as well as to check the operation of separate arrangements, systems and equipment covered by the requirements of the Rules. Annual surveys are performed within a period between special surveys (or between initial and special surveys) during three months before and after survey anniversary date.

4.1.5 At the request of the owner, the Register may perform the initial survey of the passenger submersible, manned submersible and ship's diving system for class reassignment if their Classification Certificate has become invalid in accordance with 4.9 of the General Regulations. The scope of that survey is subject to special consideration by the Register in each case.

4.1.6 The scope of special and annual surveys and their periodicity are given in Appendix 2. The scope of those surveys may be changed according to the instructions in force and specific conditions.

4.1.7 Occasional surveys of the passenger submersibles, manned submersibles and ship's diving systems are performed in all cases except for

initial and periodical (special and annual) surveys. Occasional surveys are performed for control of the elimination of imperfections or damages identified, after an accident, while confirming reclamation reports, granting the postponement of the prescribed survey, renovating the hull, substantially changing survey items, during conversion or repair, which does not coincide with periodic survey prescribed, time chartering of the passenger submersible, manned submersible and ship's diving system or in their redelivery, on the initiative of the Surveyor to the Register and in other cases.

The scope of occasional surveys and their procedure are determined by the Register depending on the purpose of survey, age and technical condition of the passenger submersible, manned submersible and ship's diving system.

4.1.8 The Register may class the passenger submersible, manned submersible and ship's diving system holding the class of another classification society – non-IACS member, or having no class, provided the passenger submersible, manned submersible and ship's diving system are submitted to initial survey to assign the class. In this case, technical documentation within the scope required by Section 5 shall be submitted to the Register for consideration.

For the passenger submersibles, manned submersibles and ship's diving systems built under supervision and classed by another classification society - IACS member, and having a valid Classification Certificate of that society, initial survey consists of the assessment of the technical condition of the passenger submersibles, manned submersibles and ship's diving systems. In this case, the scope of the technical documentation to be submitted to the Register for consideration is determined in each particular case with due regard to structural features and operational conditions of the item submitted to survey.

4.2 SURVEY OF PASSENGER SUBMERSIBLES IN SERVICE IN ACCORDANCE WITH THE PROVISIONS OF THE GUIDELINES FOR THE DESIGN, CONSTRUCTION AND OPERATION OF PASSENGER SUBMERSIBLE CRAFT[1]

4.2.1 Surveys.

4.2.1.1 Each passenger submersible shall be subject to the following surveys:

.1 initial survey before the Safety Compliance Certificate specified in 4.2.5 of the General Regulations is issued to the submersible for the first time. The survey shall include a complete and thorough examination of the passenger submersible, equipment, fittings, arrangements, means and

[1] See IMO Circular MSC/Circ. 981 of 29 January, 2001.

materials. This survey shall ensure full compliance of the passenger submersible with the applicable provisions of the Rules;

.2 annual survey to confirm the compliance of the passenger submersible, arrangements, fittings, means and equipment with the applicable provisions of the Rules, as well as to confirm that the surveyed items are in good working order. Such survey shall be endorsed in the Safety Compliance Certificate. Annual survey shall include a test dive to the rated depth. Annual surveys shall be performed within three months either way of the anniversary date of the previous dry-docking survey or the anniversary date specified in the Safety Compliance Certificate if dry-docking surveys have not yet been performed. The Safety Compliance Certificate is renewed at annual survey.

.3 dry-docking survey to be performed at intervals specified by the Flag State Administration, but not less than every three years. Dry-docking survey of the passenger submersible is, as a rule, combined with annual survey. It shall be a complete and thorough examination of the passenger submersible, equipment, arrangements, fittings, means and materials, and shall ensure full compliance with the applicable provisions of the Rules. Additional dry-docking survey(s) may be required on the Register discretion where underwater components during annual surveys performed are inaccessible.

4.2.1.2 Docking surveys shall be performed within three months prior to the due date to avoid the changing of the due date prescribed. When dry-docking surveys are commenced more than three months prior to due date, it shall be completed within three month since the day of its commencement. At request of a shipowner/operator, when performing such additional dry-docking surveys, due date of subsequent dry-docking survey may be changed accordingly.

4.2.1.3 Occasional survey (overall or partial examination according to the circumstances) shall be performed every time a defect is discovered or an accident occurs, which affects the safety and certificates issued to the passenger submersible. The examination shall verify that the repairs or replacements carried out have been done effectively and are in all respects in full compliance with the applicable provisions of the Rules.

4.2.1.4 After any survey or inspection in accordance with this Section has been completed, no changes, which affect the passenger submersible safety or certification excepting those required for the purpose of repair or maintenance, shall be made in the passenger submersible without the agreement by the Register, Administration or any person or organization duly authorized by the Administration. The management of passenger submersible operations shall comply with the requirements of the International Safety Management (ISM) Code.

4.2.2 Certificates and documentation for passenger submersibles.

4.2.2.1 Design and Construction Document.

4.2.2.1.1 The Design and Construction Document shall be issued by the Register, Administration or any person or organization duly authorized by the Administration after the construction of the passenger submersible has been completed. The Document shall include the list of standards used in design and construction of main components, view ports, piping, electric systems and life support systems. This Document shall be attached to the Safety Compliance Certificate.

4.2.2.1.2 Any exemptions granted to the passenger submersible shall be clearly noted in the Safety Compliance Certificate.

4.2.2.2 Safety Compliance Certificate.

4.2.2.2.1 The Administration, Register or any person or organization duly authorized may issue the Safety Compliance Certificate after initial survey of the passenger submersible. This Certificate may be renewed after annual survey in accordance with the requirements in 4.2.1.1.2. In any case the Administration shall assume full responsibility for the Certificate.

4.2.2.2.2 The Certificate shall be drawn up in the official language of the Administration. If the language used is neither English nor French nor Spanish, the text shall include a translation into one of these languages.

4.2.2.2.3 The Certificate ceases to be valid if modifications, which affect the safety of the passenger submersible, have been made without the agreement of the Administration or Register, except for the purpose of repair or maintenance, or if the surveys and inspections required in 4.2.1 have not been carried out.

4.2.2.2.4 The Safety Compliance Certificate shall be issued for a period not exceeding one year and its validity may be extended for not more the three months at the discretion of the Register.

4.2.3 Approvals.

It is recommended the owner of the passenger submersible and the Administration (or the Register on behalf of it) commence discussions at the earliest possible stages, so that the Administration (Register) may evaluate design of the submersible and determine if any additional requirements are necessary to achieve the required level of safety.

4.2.4 Port State Control.

The provisions of the Rules are without any prejudice to any rights of the Port State under the international law to review the Design and Construction Document and Safety Compliance Certificate and impose its own requirements relating to the regulations, surveys and inspections of the passenger

submersibles operating in the waters, over which the State is entitled to exercise its sovereign rights.

4.2.5 Organizational arrangements ensuring the safety of the passenger submersible operation.

4.2.5.1 General.

4.2.5.1.1 Apart from the safety issues associated with system design and operation, there are some issues dealing with the crew qualification, the management of passengers and contingency planning for dealing with inadequate emergencies.

4.2.5.1.2 The selection of unreliable and unqualified crew, inadequate training or inadequate licensing procedures may adversely affect the safe operation of the passenger submersible. The safety of passengers and the crew, as well as protection of property involved in tourist submersible operations requires careful attention to the crew selection, training program and licensing procedures.

4.2.5.2 Chain of commands.

Chain of commands shall be well defined for each operation so that each member of the crew knows who is in charge, his individual responsibilities and those of crew members and other personnel external to the passenger submersible to be contacted in emergency. The chain of commands shall be well documented and readily available for inspection.

4.2.5.3 Operational preparation and planning.

4.2.5.3.1 An Operation Manual shall be prepared, in which normal and emergency working procedures are described. It shall be kept on board and be available for everybody concerned. Such a Manual shall include (if applicable):

.1 working checklists including checklists prior to and after diving;

.2 emergency procedures for situations like loss of power, break of life support system hoses, pumping/jettisoning of ballast, loss of communications, faults in the life support system, fire, entanglement, high level of hydrogen, high level of oxygen, internal and external leakages of oxygen, landing on bottom, insignificant flooding and characteristics of specific emergency situations for special type systems;

.3 operational possibilities with regard to the diving time and depth;

.4 permissible sea state;

.5 geographic restrictions with regard to the diving location;

.6 procedures for lifting and launching;

.7 communications with support ships;

.8 special restrictions associated with the uniqueness of the project and operational conditions;

.9 manning levels.

4.2.5.3.2 For each passenger submersible in service an Emergency Plan shall be developed. It shall be kept on board and be available for everybody concerned.

4.2.5.3.3 Emergency drills shall be regularly conducted and clearly demonstrate the effectiveness of the procedures.

4.2.5.3.4 A Maintenance Manual containing procedures for periodical inspections and scheduled maintenance of equipment and arrangements shall be provided and promptly submitted for verification. The Manual shall include the expected lifecycle of the pressure hull and other main components/equipment (view ports, batteries, etc.), as well as instructions for maintenance of components requiring special attention. The Manual and the documents on operation and maintenance shall be available at the work location of the submersible.

4.2.5.3.5 Procedures for normal operation and emergency actions, as well as main drawings shall be available onboard the submersible.

4.2.5.4 Certification of a pilot of the passenger submersible.

The pilot of the passenger submersible shall be certified for operation of the specific passenger submersible. The certificate is issued after successful completion of the training course, set number of diving's being at the control panel of the submersible and passing an examination.

4.2.5.5 Training.

4.2.5.5.1 The shipowner/operator is responsible for ensuring that the personnel (including the pilot, crew and maintenance staff) are at all times adequately trained. Such training shall include theoretical, practical and operational aspects of the passenger submersibles and the procedures to be adopted in emergency situations. Where applicable, the training shall include the following subjects as deemed necessary to suit the particular type of the passenger submersible:

.1 life support;

the properties and effects of carbon dioxide, high and low level of oxygen, carbon monoxide and other gases, which may be present in the submersible, gas concentration, oxygen systems, colour coding of gas bottles, methods of carbon dioxide removal and effects of humidity and shelf life period on the efficiency of carbon dioxide absorbent;

.2 buoyancy and stability;

buoyancy, payload, basic stability and factors affecting stability in both normal and emergency situations;

.3 navigation;

the use of surface and underwater navigational equipment, effects of currents and tides, seamanship and the Regulations for Prevention of Collisions at Sea;

.4 communications;

surface and underwater communication systems, effects of thermal laying on underwater communications and the use of standard communication vocabulary;

.5 power sources and electric arrangements;

batteries and their charging; explosive hazards and sources of ignition, particularly, in battery compartments; circuit protection devices; emergency power sources; ground/earth fault detection; fault currents from batteries; pressure compensating arrangements for batteries exposed to sea water;

.6 emergency planning;

fires and their causes, fire extinguishing systems and their environmental effects, flooding, entanglement, available life support, toxic hazards, loss of communication, loss of power, physical and physiological effects on passengers and the crew subject to prolonged periods of underwater resulting in sensory perceptive or thermal deprivation, control of passengers and means to avoid panic, claustrophobia and hypothermia;

.7 personnel responsibilities;

allocation of duties, chain of commands in normal and emergency situations, familiarization with local, national and international requirements;

.8 practical and operational training;

the operational training of crew members shall be under the direct supervision of an experienced pilot and culminate practical and operational tests including simulation of emergency situations.

4.5.2.6 Certificate of Competence.

Each pilot shall undergo the training course established by the shipowner/operator in all the aspects relevant to safe operation of the passenger submersibles in normal and emergency situations. After passing all the examinations according to the shipowner/operator requirements, a Certificate of Competence shall be issued to each pilot.

4.5.2.7 Reporting.

Information on incidents associated with potential injuries, accidents, damages of the submersible or equipment failures shall be accumulated and reviewed by the shipowner/operator. Preventive measures shall be taken to avoid their recurrence.

The incidents affected the safety of passengers and/or the passenger submersible shall be reported to the Register and the Flag State Administration.

5 TECHNICAL DOCUMENTATION OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS

5.1 TECHNICAL DESIGN OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS UNDER CONSTRUCTION

5.1.1 General.

Before construction of the manned submersible and ship's diving system is commenced, technical design documentation proving that the requirements of the Rules applicable to the manned submersible and ship's diving system concerned are met, shall be submitted to the Register. The approximate lists of technical design documentation to be submitted to the Register for examination are given in 5.1.2 to 5.1.11.

5.1.2 General part:

.1 specification of the manned submersible and ship's diving system (no approval stamps are needed);

.2 general arrangement plans of the manned submersible and ship's diving system;

.3 drawings showing location of the manned submersible and ship's diving system on the support ship (they may be submitted as a part of the design documentation of support ship);

.4 requirements for the support ship of the manned submersible and ship's diving system (no approval stamps are needed);

.5 list of the main associated equipment and materials with indication of the basic particulars, manufacturer and availability of the Register approval (no approval stamps are needed);

.6 competent body conclusion on the specific electric resistance of the materials used inside the diving bells, diving compartment of the lock-out submersible and compression chambers (see 2.4, Part V "Fire Protection").

5.1.3 Hull documentation:

.1 structural drawings (longitudinal and transverse sections) of the pressure and external hulls of the manned submersible, diving bell and compression chambers;

.2 drawings of end and intercompartment bulkheads[1];

[1] To be submitted at the stage of consideration of working documentation.

.3 drawings of reinforcements of cutouts for hatches, view ports and cable penetrators;

.4 drawings of supports and/or suspensions of the manned submersible, diving bell and compression chambers[1];

.5 drawings of foundations for the equipment installed in pressure hulls;

.6 drawings of pressure tanks;

.7 description of the main production process for manufacture of hulls of the manned submersibles, diving bells and compression chambers (with indication[1] of permissible displacement of joint plate edges in butt welds of cylindrical and spherical components, permissible deviations from the regular cylindrical, spherical or conic shape of the pressure hull, heat treatment, scope and methods of non-destructive inspection);

.8 data on all external loads possible in operation including external and/or internal, working and test pressures;

.9 calculations of thicknesses and/or stresses in pressure-resistant structural members including the analysis of their stress state, checking of stability in the elastic and/or plastic zones, the fatigue stress analysis of main structural assemblies;

.10 calculations of supports and/or suspensions of the manned submersibles, diving bells and compression chambers;

.11 stress calculations of pressure tanks.

5.1.4 Documentation on equipment, arrangements and outfit:

.1 arrangement plan of openings in the pressure hull and pressure bulkheads of the manned submersibles and ship's diving systems with indication of the type of closing devices;

.2 strength calculations of closing devices;

.3 general arrangement plans of emergency release devices for jettisonable ballast and other equipment external to the pressure hull; the mating device for connection of the diving bell to the compression chambers and the compression chambers to one another; an emergency release arrangement for the suspension wire rope and the umbilical of the diving bell; signal and emergency signal means; emergency quick-release gear;

.4 general arrangement plan of lifting lugs of the manned submersible and diving bell;

.5 calculations of emergency devices and means referred to in 5.1.4.3;

.6 calculations of lifting lugs and lifting gear of the manned submersible and diving bell;

.7 drawings of parts and assemblies, provided they are not manufactured according to the standards or specifications approved by the Register.

5.1.5 Documentation on buoyancy and stability of the manned submersibles and diving bells (no approval stamps are needed):

.1 lines drawing;

.2 weight load;

.3 summary table of permanent buoyancy volume;

.4 calculation of buoyancy and initial stability, buoyancy and initial stability curves;

.5 summary table of buoyancy and initial stability in different positions (including emergency surfacing);

.6 table of the Bonjean curves and the displacement curve;

.7 summary table of the tank elements and tank element curves;

.8 longitudinal statical stability curves;

.9 transverse statical and dynamical stability curves for the manned submersible afloat under normal loading and with tanks blown out;

.10 initial transverse stability curve in case of interrupted submergence and surfacing of the manned submersible under normal load;

.11 compensation calculation of the manned submersible buoyancy change;

.12 justification of permissible wind and wave characteristics providing safe operation of the manned submersible and diving bell;

.13 arrangement plan of buoyancy units.

5.1.6 Documentation on fire protection:

.1 arrangement plan of fire-proof structures in the support ship spaces intended for control, communications and siting of the manned submersible and ship's diving system, as well as in the spaces for positioning of ancillary equipment of the manned submersible with indication of doors, closing devices, passageways, etc. (it may be submitted together with the support ship design documentation);

.2 diagrams and calculations of fire-fighting systems for the spaces referred to in 5.1.6.1 (they may be submitted together with the support ship design documentation);

.3 diagrams and calculations of fire-fighting systems of the manned submersibles and ship's diving systems;

.4 diagram of fire alarm system for the spaces referred to in 5.1.6.1 (it may be submitted together with the support ship design documentation);

.5 detailed description of fire protection with indication of insulating and finishing materials, their location and a degree of combustibility for the spaces referred to in 5.1.6.3 and diving bells;

.6 similarly to listed in 5.1.6.5, but for the spaces referred to in 5.1.6.1 (it may be submitted together with the support ship design documentation);

.7 list of materials used for fabrication of structural components and equipment inside the diving bell and compression chamber compartments with indication of main technical particulars and availability of the Register approval (no approval stamps are needed);

.8 list of fire-fighting outfit;

.9 diagram of fire alarm system for the compartments of the manned submersibles and compression chambers.

5.1.7 Documentation on machinery and systems:

.1 general arrangement of machinery and equipment;

.2 description with basic details or specifications for propelling units;

.3 general views with sections of the propelling units elucidating their design, sealing and stopping arrangements and their materials;

.4 drawings of the propelling unit attachments;

.5 strength calculations of the handling system machinery and their main parts;

.6 hydraulic system diagram;

.7 submergence and surfacing, compensating and trim system diagrams;

.8 life-support system diagram:

system of transfer of single-component gases from one bottle to another;

system of regeneration and conditioning of gas medium in the compression chambers and manned submersibles;

system of supplying gas mixture to the diving bells, manned submersibles and compression chambers;

heating system of the manned submersibles, diving bells and divers;

distribution boards of single-component gases and gas mixtures;

.9 emergency life-support system diagram;

.10 diagrams of other systems not listed in 5.1.7.6 to 5.1.7.9 (no approval stamps are needed);

.11 calculations on systems and piping confirming fulfillment of the requirements of the Rules;

.12 drawings and calculations for the life-support system pressure vessels proving the fulfillment of the requirements of the Rules.

5.1.8 Documentation on electrical equipment:

.1 circuit diagrams of power distribution from the main and emergency sources of electrical power: power networks and lighting system (to section switchboards);

.2 circuit diagrams and general arrangement plans of main and emergency switchboards, control panels and distribution switchboards of non-standard design;

.3 calculation results of the required output of electrical power plant for all operating conditions of the manned submersibles and ship's diving systems, substantiation of choice of the number and output of electric power emergency sources, as well as power calculation thereof (no approval stamps are needed);

.4 results of calculation and selection of cables with indication of their types, currents and protection (no approval stamps are needed);

.5 circuit or detailed diagrams of the main current excitation, control, signalling, protection and interlocking of the electric propulsion system;

.6 general arrangement plans of essential electrical equipment;

.7 diagrams of cable runs, fastening and penetrators;

.8 circuit diagrams of electric drives of machinery used in submergence, surfacing, compensating, trim and handling systems, pumps, compressors and blowers of the life-support system;

.9 circuit diagrams of the telephone communication and signalling systems listed in 1.3.3.4, Part VII "Electrical Equipment";

.10 circuit diagrams of lighting supplied from section switchboards;

.11 list of spare parts;

.12 list of essential electrical equipment items to be installed on the manned submersibles and ship's diving systems with indication of their technical characteristics and particulars of approval thereof by the Register or another competent body.

5.1.9 Documentation on radio and sonar equipment:

.1 basic electric circuit diagrams with indication of power sources if the Register does not approve the above equipment;

.2 arrangement plans of radio equipment;

.3 arrangement plans of main and emergency power sources for radio equipment;

.4 arrangement plans of aerials.

5.1.10 Documentation on navigational equipment:

.1 electric circuit diagrams with indication of power sources;

.2 arrangement plans;

.3 arrangement plans of main and emergency power sources.

5.1.11 Documentation on handling system of the ship's diving systems (for the manned submersibles, documentation on handling system components located on the manned submersible shall be submitted and the remaining documentation on the handling system is submitted together with the support ship design documentation). The scope of technical documentation to be submitted to the Register shall comply with the requirements of 1.4 of the Rules for the Cargo Handling Gear of Sea-Going Ships.

5.2 TECHNICAL DOCUMENTATION OF CONVERTED OR RECONSTRUCTED MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS

5.2.1 Prior to conversion or reconstruction of the manned submersible and ship's diving system, technical documentation shall be submitted in the scope established by the Register in each case.

5.2.2 When a new machinery or arrangements are installed for operation on the manned submersible and ship's diving system, which substantially differ from those fitted initially and which are covered by the requirements of the Rules, the technical documentation associated with installation of these machinery items or arrangements shall be submitted within the scope as required for the manned submersible and ship's diving system under construction (see the requirements of 5.1).

5.3 WORKING DRAWINGS OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS UNDER CONSTRUCTION

5.3.1 For all the structures, systems and equipment listed in 5.1, assembly drawings, calculations, as well as drawings of assemblies and components, if they are not manufactured according to the standards or specifications approved by the Register, shall be submitted to the Register.

5.3.2 To be submitted are programs of mooring and sea trials (for ship's diving systems, programs of bench tests and tests under operating conditions), as well as strength and tightness tests of separate structures and systems in the process of their fabrication; welding table and weld inspection scheme; list of spare parts; operating manual.

5.3.3 When model and/or full-scale trials of the manned submersible or ship's diving system are carried out (to support technical approach used in the design), the results or these trials shall be submitted.

APPENDIX 1

NOMENCLATURE OF ITEMS SURVEYED BY THE REGISTER DURING CONSTRUCTION, INSTALLATION AND TESTING OF MANNED SUBMERSIBLES, SHIP'S DIVING SYSTEMS AND PASSENGER SUBMERSIBLES

S y m b o l s :

P — survey by the Surveyor to the Register;

C — certificate for the product issued and signed by the Surveyor to the Register;

C3 — certificate issued by the works and authenticated by the Inspectorate possessing with the works an agreement on survey;

CTO — Type Approval Certificate;

K — branding.

Nos.	Item of survey	Register survey					
		prototype	at the manufacturer's with established production		during construction of the manned submersibles, ship's diving systems and passenger submersibles		
			document to be issued	branding	installation	mooring trials of the manned and passenger submersibles; bench tests of ship's diving systems at the manufacturer's	sea trials of the manned and passenger submersibles; tests of ship's diving systems under operating conditions on support ship
1	2	3	4	5	6	7	8
1	**MANNED SUBMERSIBLES**	P	C^3	—	P	P	P
2	**SHIP'S DIVING SYSTEMS**	P	C^3	—	P	P	P
3	**HULL**						
3.1	Pressure hull (spherical, conical and cylindrical shells and stiffening, heads)	P	C^2	K	P	—	P
3.2	Pressure tanks	P	C^2	K	P	—	P
3.3	Tight enclosures of external electrical equipment of the manned submersibles, ship's diving systems and passenger submersibles: power sources, switchboards, etc.	P	C^2	K	P	—	P
3.4	Parts fitted on the pressure hull (welded-in pieces and flanges of	P	C^2	—	P	—	P

1	2	3	4	5	6	7	8
	hatches, view ports, tight penetrators)						
3.5	Foundations for main equipment	P	C[2]	—	P	—	—
3.6	External hull:	P	C3[2]	—	P	—	—
.1	ballast tanks	P	C[2]	—	P	—	P
3.7	Buoyancy units	P	C	—	P	—	—
4	**ARRANGEMENTS**						
4.1	Hatch covers	P	C[2]	K	P	P	P
4.2	View ports in assembly	P	C	K	P	P	P
4.3	View port glasses	P	C	K	P	P	P
4.4	Hatch cover drives	P	C[2]	K	P	P	P
4.5	Steering gear	See Section "Steering Gear" of Appendix 1 to Part I "General Regulations for the Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Shipboard Materials and Products (code of the surveyed item 03010000)					
4.6	Emergency release devices for jettisonable ballast and other equipment external to the pressure hull	P	C[2]	K	P	P	P
4.7	Emergency release devices of the support wire rope and umbilical on the diving bell	P	C[2]	K	P	P	P
4.8	Emergency fast-release gear	P	C[2]	K	P	P	P
4.9	Mating devices for connection of diving bells and lock-out submersibles with compression chambers, and compression chambers to one another	P	C[2]	K	P	P	P
4.10	Lifting lugs and lifting gear of the manned submersibles, ship's diving systems and passenger submersibles	P	C[2]	K	P	P	P
4.11	Signal and emergency signal means	P	C	K	P	P	P
5	**FIRE PROTECTION**	See Section "Fire Protection" of Appendix 1 to Part I "General Regulations for the for Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Shipboard Materials and Products (code of the surveyed item 06000000)					
6	**PROPELLERS**	P	C	K	P	P	P
7	**SYSTEMS AND PIPING**						
7.1	Life support systems:						
.1	system of transfer of single-components gases from one bottle to another	—	—	—	P	P	P

1	2	3	4	5	6	7	8
.2	system of regeneration and conditioning of gas medium in the compression chambers	—	—	—	P	P	P
.3	system of supplying gas mixture to the diving bell and compression chambers	—	—	—	P	P	P
.4	heating system of the manned submersibles, diving bells and divers	—	—	—	P	P	P
.5	emergency life support system	—	—	—	P	P	P
.6	distribution boards of single-component gases and gas mixtures	P	C3	—	P	P	P
7.2	Hydraulic system:						
.1	hydraulic motors and pumps	P	C, C3	—	P	P	P
7.3	Submergence and surfacing system	—	—	—	P	P	P
7.4	Compensating system	—	—	—	P	P	P
7.5	Trimming system	—	—	—	P	P	P
7.6	Ventilation and air conditioning system	—	—	—	P	P	P
7.7	Piping	P	C3	—	P	P	P
7.8	Other systems[1]	—	—	—	P	P	P
7.9	Safety valves	P	C3	K	P	P	P
7.10	Fittings on the pressure hull	P	C3	K	P	P	P
7.11	Pipe and other regulating fittings	P	C3	—	P	P	P
7.12	Hoses (of the umbilical)	P	C3	—	P	P	P
8	**MACHINERY**						
8.1	Compressors (air, gas, refrigerant)	P	C	—	P	P	P
8.2	Pumps of the life support system	P	C	—	P	P	P
9	**PRESSURE VESSELS AND APPARATUS[1]**						
9.1	Containers on the support ship of the manned submersibles and diving bells for storage of gases and breathing gas mixtures	P	C	K	P	P	P
9.2	Pressure vessels and apparatus in the life support system	P	C	K	P	P	P
9.3	Vessels and apparatus in sewage, drinking and washing water supply systems of compression chambers	P	CTO	—	P	P	P
9.4	Fittings for pressure vessels and apparatus:						
.1	safety valves	P	C3, CTO	—	P	P	P
.2	other fittings	P	C3, CTO	—	P	P	P

1	2	3	4	5	6	7	8
10	**MEASURING INSTRUMENTS (PRESSURE GAUGES AND DEPTH METERS)**	—	CTO	—	P	P	P
11	**ELECTRICAL, RADIO, NAVIGATIONAL AND SONAR EQUIPMENT**						
11.1	Electric propulsion plant:	—	—	—	P	P	P
.1	generators	P	C	K	—	—	—
.2	accumulator batteries	P	C	—	—	—	—
.3	electric motors	P	C	K	—	—	—
.4	switchboards and panels	P	C	—	—	—	—
11.2	Electric power sources (main and emergency):	—	—	—	P	P	P
.1	generators with power output:						
	P > 75 kW	P	C	—	—	—	—
	P ⩽ 75 kW	P	C3	—	—	—	—
.2	accumulators and accumulator batteries	P	C	—	—	—	—
11.3	Transformers:	—	—	—	P	P	P
.1	power and lighting	P	C3	—	—	—	—
.2	measuring and for other purposes	P	CTO	—	—	—	—
11.4	Converters:						
.1	rotating	P	C3	—	P	P	P
.2	static (rectifiers, inverters, frequency converters) at the rated current:						
	> 25 A	P	C3	—	P	P	P
	⩽ 25 A	P	CTO	—	P	P	P
11.5	Electric drives of essential machinery referred to in Section 8 and in 7.1.1 and of handling system machinery:	—	—	—	P	P	P
.1	electric motors with power output:						
	P > 75 kW	P	C	—	—	—	—
	P ⩽ 75 kW	P	C3	—	—	—	—
.2	starting and control gear	P	C3	—	—	—	—
11.6	Stationary lighting fixtures of interior, exterior and emergency lighting, and connecting devices	P	CTO	—	P	P	P
11.7	Distribution gear:	—	—	—	P	P	P
.1	main and emergency switchboards	P	C	—	—	—	—
.2	section and navigation lights boards	P	C3	—	—	—	—
.3	switchgear, protection, control and measuring devices	P	C3	—	—	—	—
11.8	Cable network:	—	—	—	P	P	P

1	2	3	4	5	6	7	8
.1	cables and wires	P	C3	—	—	—	—
.2	cables as part of the umbilical	P	C3	—	—	—	—
.3	electrical deep-water plug-and-socket units, connectors and cable penetrators	P	CTO	—	—	—	—
11.9	Earthing devices and cathodic protection	—	—	—	P	—	—
11.10	Heating appliances	P	C3	—	P	P	P
11.11	Charging facilities for accumulator batteries	P	C3	—	—	—	—
11.12	Means of communication with support ship:	—	—	—	P	P	P
.1	service telephone communication (telephone sets, switchboards)	P	C3	—	—	—	—
.2	radio telephone communications (radio telephone VHF station)	P	C	—	—	—	—
.3	sonar communications (telephone sonar systems)	P	C	—	—	—	—
.4	speech unscramblers	P	C	—	—	—	—
.5	signal buoys	P	C	—	—	—	—
11.13	Navigational equipment (sonar and radar equipment)	P	C	—	P	P	P
11.14	Electrical control and signalling systems (actual and limiting values) for fire detection, depth of submergence, concentration and other parameters of breathing gas mixture, position of remotely controlled valves of submergence, surfacing and trimming systems, liquid levels, accumulator battery discharge, insulation resistance of electric circuit:	—	—	—	P	P	P
.1	receiving devices	P	C	—	—	—	—
.2	detectors and sensors	P	C	—	—	—	—
11.15	Monitoring and alarm systems of propulsion plant, machinery and devices of the life support system	P	C	—	P	P	P
12	**HANDLING SYSTEMS OF THE MANNED SUBMERSIBLES, SHIP'S DIVING SYSTEMS AND PASSENGER SUBMERSIBLES**	P	C	K	P	P	P
12.1	Cargo handling gear	See Section "Cargo Handling Gear" of Appendix 1 to Part I "General Regulations for the Supervision" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Shipboard Materials and Products					

1	2	3	4	5	6	7	8
12.2	Steel wire ropes for handling systems	P	C3	—	P	—	P
12.3	Vertical and horizontal motion compensators of the manned submersibles (diving bells)	P	CTO	—	P	P	P
12.4	Transportation platforms on the support ship for movement and mating of lock-out submersible to ship's diving system	P	CTO	—	P	P	P

[1] Portable bottles are not subject to survey.

[2] Certificate is issued only when the product is supplied to the manufacturer by cooperation.

[3] The Register documents indicated in Section 4 of the General Regulations.

APPENDIX 2

SCOPE OF PERIODICAL SURVEYS OF MANNED SUBMERSIBLES, SHIP'S DIVING SYSTEMS AND PASSENGER SUBMERSIBLES

Symbols:
O — detailed examination with access, opening-up and dismantling provided if necessary;
C — external examination;
M — measurement of wears, clearances, insulation resistance, etc.;
H — pressure tests (for strength and tightness);
P — testing of machinery, equipment and arrangements in operation, external examination included;
E — review of documentation and/or brands on performance of mandatory periodical inspections by a competent body;
И — tests by a proof load;
З — replacement.

Nos.	Item of survey	Survey of the manned submersibles, ship's diving systems and passenger submersibles														
		1st annual	2nd annual	3rd annual	4th annual	1st special	1st annual	2nd annual	3rd annual	4th annual	2nd special	1st annual	2nd annual	3rd annual	4th annual	3rd special
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	**HULL**															
1.1	Pressure hull (spherical, conical and cylindrical shells and stiffening, heads)	CH[1]	CH[1]	CH[1]	CH[1]	OMH[2]	CH[1]	CH[1]	CH[1]	CH[1]	OMH[3]	CH[1]	CH[1]	CH[1]	CH[1]	OMH
1.2	Pressure tanks	CH[1]	CH[1]	CH[1]	CH[1]	OMH[2]	CH[1]	CH[1]	CH[1]	CH[1]	OMH	CH[1]	CH[1]	CH[1]	CH[1]	OMH
1.3	Tight enclosures of exterior electrical equipment of the	C	C	C	C	OH[4]	C	C	C	C	OH	C	C	C	C	OH[4]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	manned submersibles, diving bells and passenger submersibles: power sources, switchboards, etc.															
1.4	Parts fitted on the pressure hull (welded-in pieces and flanges of hatches, view ports, tight penetrators)	C	C	C	C	OM	C	C	C	C	OM	C	C	C	C	OM
1.5	Foundations for main equipment	C	C	C	C	OM	C	C	C	C	OM	C	C	C	C	OM
1.6	External hull	C	C	C	C	O	C	C	C	C	O	C	C	C	C	O
.1	ballast tanks	O	O	O	O	OH[5]	O	O	O	O	OMH	O	O	O	O	OMH
2	**ARRANGEMENTS**															
2.1	Hatch covers	OH[6]	OH[6]	OH[6]	OH[6]	OH[2]	OH[6]	OH[6]	OH[6]	OH[6]	OH	OH[6]	OH[6]	OH[6]	OH[6]	OH
2.2	View ports	CH[6]	CH[6]	CH[6]	CH[6]	OH[2]	CH[6]	CH[6]	CH[6]	CH[6]	OH	CH[6]	CH[6]	CH[6]	CH[6]	OH
2.3	Hatch cover drives	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
2.4	Steering gear	See 2.2 of Table 2.1.1, Part II "Survey Procedure and Scope" of the Rules for the Classification Surveys of Ships														
2.5	Emergency release devices for jettisonable ballast and other equipment external to the pressure hull	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
2.6	Emergency release devices of the support wire rope and umbilical on the diving bell	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
2.7	Emergency fast-release gear	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
2.8	Mating devices for connection of diving bells and lock-out submersibles with compression chambers, and	HP	HP	HP	HP	OHP	HP	HP	HP	HP	OHP	HP	HP	HP	HP	OHP

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	compression chambers to one another															
2.9	Lifting lugs and lifting gear of the manned submersibles, diving bells and passenger submersibles	C	C	C	C	CM	C	C	C	C	CM	C	C	C	C	CM
2.10	Signal and emergency signal means of the manned submersibles, diving bells and passenger submersibles	P	P	P	P	OH^2P	P	P	P	P	OHP	P	P	P	P	OHP
3	**FIRE PROTECTION**	See Section 3 of Table 2.1.1, Part II "Survey Procedure and Scope" of the Rules for the Classification Surveys of Ships														
4	**PROPELLERS**	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
5	**SYSTEMS AND PIPING**															
5.1	Life support systems:															
.1	system of transfer of single-component gases from one bottle to another	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
.2	system of regeneration and conditioning of breathing gas medium	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
.3	system of supplying gas mixture to the diving bell and compression chambers	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
.4	heating system of the manned submersibles, diving bells, passenger submersibles and divers	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
.5	emergency life support system	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
.6	distribution boards for single-component gases and gas mixtures	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
5.2	Hydraulic systems	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
.1	hydraulic motors and pumps	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
.2	piping	PH[6]	PH[6]	PH[6]	PH[6]	OH[2]P	PH[6]	PH[6]	PH[6]	PH[6]	OHP	PH[6]	PH[6]	PH[6]	PH[6]	OHP
5.3	Submergence and surfacing system	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
5.4	Compensating system	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
5.5	Trimming system	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
5.6	Piping and fittings of other systems and systems listed in 5.1, 5.3—5.5; hoses as part of the umbilical:	PH[6]	PH[6]	PH[6]	PH[6]	OH[2]P	PH[6]	PH[6]	PH[6]	PH[6]	OHP	PH[6]	PH[6]	PH[6]	PH[6]	OHP
.1	safety valves	P	P	P	P	OH[2]P	P	P	P	P	OHP	P	P	P	P	OHP
5.7	Ventilation and air conditioning system	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
6	**MACHINERY**															
6.1	Compressors (air, gas)	See 4.6.2 of Table 2.1.1, Part II "Survey Procedure and Scope" of the Rules for the Classification Surveys of Ships														
6.2	Refrigerant compressors of the breathing gas mixture conditioning system of compression chambers	P	P	P	P	OP	P	P	P	P	OH[7]P	P	P	P	P	OH[7]P
6.3	Pumps of the life support system	P	P	P	P	OP	P	P	P	P	OP	P	P	P	P	OP
7	**PRESSURE VESSELS AND APPARATUS**[8]															
7.1	Containers on the support ship of the manned sub-	P	P	P	P	OH[4]P	P	P	P	P	OHP	P	P	P	P	OH[4]P

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	mersibles and diving bell for storage of gases and gas mixtures															
7.2	Pressure vessels and apparatus in the life support system and their fittings:	P	P	P	P	OH[4]P	P	P	P	P	OHP	P	P	P	P	OH[4]P
.1	safety valves	P	P	P	P	OH[2]P	P	P	P	P	OHP	P	P	P	P	OHP
7.3	Vessels and apparatus in sewage, drinking and washing water supply systems of compression chambers and their fittings:	P	P	P	P	OH[2]P	P	P	P	P	OHP	P	P	P	P	OHP
.1	safety valves	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
8	**MEASURING INSTRUMENTS (PRESSURE GAUGES AND DEPTH METERS)**	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
9	**ELECTRICAL, RADIO, NAVIGATIONAL AND SONAR EQUIPMENT**															
9.1	Electric propulsion plant:															
.1	generators	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
.2	accumulators and accumulator batteries	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
.3	electric motors	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
.4	switchboards and panels	P	P	P	P	OMP	P	P	P	P	OMP	P	P	P	P	OMP
9.2	Electric power sources (main and emergency):															
.1	generators	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
.2	accumulators and accumulator batteries	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
9.3	Converting equipment intended to feed essential services	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
9.4	Electric drives of the machinery referred to in 2.2, 5.1.1.6 and 10.4 and their monitoring and protective devices	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
9.5	Stationary lighting fixtures of interior, exterior and emergency lighting, and connecting devices	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
9.6	Distribution gear:															
.1	main and emergency switchboards	MP	MP	MP	MP	OEMP	MP	MP	MP	MP	OEMP	MP	MP	MP	MP	OEMP
.2	section and navigation lights boards	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
9.7	Cable network:															
.1	cables and wires, including cables as part of the umbilical	MC	MC	MC	MC	OM	MC	MC	MC	MC	OM	MC	MC	MC	MC	OM
.2	electrical deep-water plug-and-socket units, connectors and cable penetrators	C	C	C	C	O	C	C	C	C	O	C	C	C	C	O
9.8	Earthing devices and cathodic protection	C	C	C	C	OM	C	C	C	C	OM	C	C	C	C	OM
9.9	Heating appliances	MC	MC	MC	MC	OM	MC	MC	MC	MC	OM	MC	MC	MC	MC	OM
9.10	Charging facilities for accumulator batteries	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
9.11	Means of communication with support ship:															
.1	service telephone communication (telephone sets, switchboards)	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
.2	radiotelephone communication (radiotelephone VHF station)	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
.3	sonar communication (telephone sonar systems)	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
.4	speech unscramblers	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
.5	signal buoys	EMP	EMP	EMP	EMP	EOMP	EMP	EMP	EMP	EMP	EOMP	EMP	EMP	EMP	EMP	EOMP
9.12	Navigational equipment (sonar and radar equipment)	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
9.13	Electrical monitoring and signalling systems (actual and limiting values) for fire detection, depth of submergence, concentration and other parameters of breathing gas mixture, position of remotely controlled valves of submergence, surfacing and trimming systems, liquid levels, accumulator battery discharge, insulation resistance of electric circuit	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP
9.14	Monitoring and alarm systems of propulsion plant, machinery and devices of the life support system	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP	MP	MP	MP	MP	OMP

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	**HANDLING SYSTEMS OF THE MANNED SUBMERSIBLES, DIVING BELLS AND PASSENGER SUBMERSIBLES**															
10.1	Structures with permanently fitted fixed components (masts, posts, ties of counter-weights, foundations, etc)	C	C	C	C	ОИР	C	C	C	C	ОИР	C	C	C	C	ОИР
10.2	Loose gear (blocks, axles, eyes, catches, etc.)	C	C	C	C	ОИР	C	C	C	C	ОИР	C	C	C	C	ОИР
10.3	Steel wire ropes for handling systems	СМ	СМ	СМ	СМ	З	СМ	СМ	СМ	СМ	З	СМ	СМ	СМ	СМ	З
10.4	Machinery (including emergency machinery) for hoisting and lowering, luffing, slewing and motion of the handling system	Р	Р	Р	Р	ОИР	Р	Р	Р	Р	ОИР	Р	Р	Р	Р	ОИР
10.5	Lead screws, rollers, racks, arresting devices	Р	Р	Р	Р	ОИР	Р	Р	Р	Р	ОИР	Р	Р	Р	Р	ОИР
10.6	Safety devices (stops, limit switches, outreach indicators, hose and rope length indicator, brakes, etc.)	Р	Р	Р	Р	ОР	Р	Р	Р	Р	ОР	Р	Р	Р	Р	ОР
10.7	Handling system control panel	Р	Р	Р	Р	ОР	Р	Р	Р	Р	ОР	Р	Р	Р	Р	ОР
10.8	Compensators of vertical and horizontal motions of the manned submersibles,	Р	Р	Р	Р	ОР	Р	Р	Р	Р	ОР	Р	Р	Р	Р	ОР

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	diving bells and passenger submersibles															
10.9	Transportation platforms on the support ship for transportation and mating of lock-out submersible to ship's diving system	P	P	P	P	ОИР	P	P	P	P	ОИР	P	P	P	P	ОИР
11	**LIFE-SAVING APPLIANCES OF THE PASSENGER SUBMERSIBLE**															
11.1	Inflatable lifejackets	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]	CE[9]
11.2	Lifebuoys and rigid lifejackets	C	C	C	C	CE[9]	C	C	C	C	CE[9]	C	C	C	C	CE[9]
12	**MEASURING INSTRUMENTS (WATER LEAKAGE, INDICATION OF AVAILABLE POWER, AMOUNT OF WATER BALLAST, VOLTAGE OF EACH ELECTRICAL SOURCE OF POWER)**	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E

N o t e. After survey of the ship's diving system or manned submersible in service, when afloat, by the Surveyor to the Register, the diving bell, manned and passenger submersibles shall be tested under water by a test team according to the program approved by the Register, anappropriate entry shall be made in the ship's diving system, manned and passenger submersibles certificate. In the intervals between the Register surveys of the manned submersibles, ship's diving systems and passenger submersibles, the responsibilityfor supervision of their compliance with the issued ship's documents and valid normative documents of the Register, observance of the established service restrictions and control over the maintenance of the submersibles and diving systems in a condition, which ensures their safe operation, rests with the owner.

The results of examinations and checks conducted by the owner shall be entered in the ship's diving system, manned and passenger submersibles certificate.

[1] During annual survey the hull is tested by diving the manned submersible (diving bell if provision is made for its use as an observation chamber) into the sea to the operating depth (this depth requirement is applicable to self-sustained manned submersible at annual survey as far as reasonable and technically feasible). Besides, the diving bell, diving compartment of the lock-out submersible and compression chamber shall be tested by an internal pressure corresponding to the working one. In so doing, the functional reliability of connecting flanges and transfer hatches shall be checked.

[2] At the discretion of the Register, the scope of the 1st special survey for the manned submersibles, ship's diving systems and passenger submersibles built under supervision of the Register or a foreign classification body, may be reduced. If not specially reasoned, strength tests of the manned submersibles, ship's diving systems and passenger submersibles, hydraulic tests of pipes, pressure vessels and systems assembled (replaced by tightness tests) may be omitted, and external examination and internal survey of the manned submersibles, ship's diving systems and passenger submersibles may be carried out without removal of insulation.

The above reduction in the scope of surveys may be permitted if not more than five years have elapsed since the date of construction of the manned submersibles, ship's diving systems and passenger submersibles.

[3] Strength tests may be omitted if it is proved during external examination and internal survey (without removal of insulation) and by non-destructive inspection that such tests are not justified.

[4] Only for apparatus and vessels inaccessible for internal survey.

[5] At the discretion of the Register, hydraulic tests may be omitted.

[6] Tightness tests.

[7] Pneumatic strength tests during each special survey beginning from the 2nd survey after construction.

[8] Portable bottles are not subject to survey by the Register.

[9] Review of documentation on performance of periodical surveys and tests of inflatable life-saving appliances at servicing stations and other specialized survey stations recognized by the Register, tests and repair of individual life-saving appliances.

PART II. HULL

1 GENERAL

1.1 APPLICATION

The requirements of the present Part of the Rules apply to steel welded hulls of the manned submersibles both with isobaric and hyperbaric internal pressure, tethered suspended manned chambers (observation and working chambers with isobaric internal pressure, diving bells), as well as evacuation chambers of the ship's diving systems.

Besides steel, glass-reinforced plastic may be used for construction of the external hull in accordance with the recommendations of Appendix 1.

Use of non-ferrous metals, various alloys and composite materials other than the glass-reinforced plastic, as well as use of the glass-reinforced plastic for construction of the pressure hull and equivalent structures may be allowed subject to special agreement with the Register.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to the general terminology of the Rules are given in the General Regulations for the Classification and Other Activity Relating to Manned Submersibles, Ship's Diving Systems and Passenger Submersibles, and in Part I "Classification" of the Rules for the Classification and Construction of Sea-Going Ships.

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

Allowable stresses $[\sigma]$ mean the maximum values of stresses, under which strength is maintained and normal operation of the manned submersible, chamber, etc. is ensured.

Critical pressure P_c means an external pressure, at which the hull or its elements can be fractured (buckled) under single loading.

Design temperature T_d means the lowest temperature, at which normal operation of the submersible is possible. T_d is specified proceeding from the expected operating conditions. The requirements of the Rules for materials have been worked out for $T_d \geqslant -5$ ºC. If, due to the operating conditions, $T_d \leqslant -5$ ºC is possible, the requirements for the materials used are

subject to special consideration by the Register in each case.

External hull means a totality of the hull structures outside the pressure hull having no enclosed volumes, which take up the external sea water pressure (main ballast tanks, external frame structures, their attachments to the pressure hull, etc).

General membrane streses σ_0 mean the through-the-thickness average stresses encompassing the most part of the hull volume, average stresses in the smooth cylindrical or spherical shell, average stresses at the mid-point of the spacing of a cylindrical shell stiffened by frames, etc.

Local membrane stresses σ_1 mean the through-the-thickness average increased stresses typical for small areas (e.g. in way of openings).

Mechanical properties of material mean the ultimate strength (tensile strength) R_m, yield stress R_{eH}, Young's modulus E, Poisson's ratio v. The value equal to the proof stress $R_{p0,2}$ is introduced in calculations for materials lacking an yield area. For the purpose of the present Part of the Rules, it is assumed that for metal hulls $v = 0,3$, and for steel $E = 2 \times 10^5$ MPa.

Operating depth H_{op} means the maximum depth, at which normal operation of the submersible is possible.

It is assumed that the total number of submergences to the operating depth during the operation of the manned submersible shall not exceed 1000. Calculating the conventional number of submergences, proceeding from the above condition, on the basis of the number of submergences to different depths the following formula shall be used:

$$n_{conv} = \sum_i n_{H_i} (H_i / H_{op})^{m_i} \leqslant 1000, \qquad (1.2)$$

provided that $\sum_i n_{H_i} \leqslant 50000$

where H_i = the maximum depth in the narrow range of depths (e.g. from $0,8H_{op}$ to $0,9H_{op}$);
n_{Hi} = number of submergences in the narrow range of depths;
m_i = exponent determined by the formula $m_i = 3/(2H_i/H_{op}+1)$.

Summation in Formula (1.2) is made with respect to all the depth ranges.

When counting up the number of cycles at the repeatedly changed depth in the course of sailing without surfacing, the real spectrum shall be reduced to the simplified one with an obvious error on the safe side.

Where it is necessary to ensure the conventional number of submergences over 1000, the possibility of doing it shall be supported by a special calculation for the cyclic loading according to the procedure approved by the Register. In this case, to prevent corrosion cracking of the hull under cyclic loading, only those hull materials are allowed for use, which have proved their effectiveness

under sea conditions during at least 5 years as part of other ship's hull structures repeatedly loaded. The appropriate supporting documents shall be submitted to the Register by the Designer of the submersible.

Operating pressure P_{op} for the submersible means the seawater pressure exerted on the submersible and corresponding to the operating depth.

Operating pressure P_{op} of the diving bell, compression chambers of the ship's diving system, diving compartment of the manned submersible means the maximum pressure, up to which their normal operation shall be ensured. It is assumed in these Rules that the number of loadings by internal pressure is restricted in the same manner as the number of submergences to the operating depth (H_{op} in Formula (1.2) shall be replaced by $P_{op}H_i$ - p_i).

Pressure-resistant structures of the manned submersible and ship's diving system mean the pressure hull, pressure tanks and other elements of the manned submersible and ship's diving system carrying and balancing loads due to excessive pressure.

Specified pressure P_s means the pressure given in the specification, up to which the structure concerned shall function properly. P_s is usually used to fit the structures, which strength is not designed for the operating pressure, e.g. as applied to the main ballast tanks. Unlike P_{op}, it is an occasional load associated, though with possible, but rare situations (e.g. for the main ballast tanks with emergency blowing thereof).

Test pressure P_t means the maximum pressure, by which the structure is tested after construction and periodically in service to assure safe operation at the operating and specified pressure.

Total stresses σ^t mean the maximum stresses, which take into account the stresses due to the hull structure bending on stiff members, e.g. in way of frames. The local concentration of stresses near bores, weld reinforcements, etc. are ignored.

1.3 SCOPE OF SURVEYS

1.3.1 The general provisions for the survey of the hull are set forth in the General Regulations.

1.3.2 The following hull structures are subject to the Register survey during manufacture:

.1 pressure hull (shell plating, framing, reinforcements of all openings, end and intercompartment bulkheads, attachments of the external and internal structures to the pressure hull, hatch covers);

.2 external hull (framing or load-bearing frame, shell plating);

.3 foundations for securing equipment with a mass more than 15 kg (regardless of the position).

1.3.3 In the process of manufacture, the structures specified in 1.3.2 are subject to survey with respect to fulfillment of the requirements set out in Sections 2—4.

1.4 SYMBOLS

1.4.1 Performance characteristics:

H_{op} = operating depth;

H_i = the maximum depth within the narrow range of depths;

n_{Hi} = number of submergences within the narrow range of depths;

ΔH = depth marging;

P = design pressure;

P_{op} = operating pressure;

P_s = specified pressure;

P_t = test pressure;

P_c = critical pressure;

T = operating temperature;

T_d = design temperature;

T_t = test temperature.

1.4.2 Geometric characteristics:

.1 shells:

f_1 = initial camber of the cylindrical and conical shells;

f_2 = deviation of the cylindrical and conical shells from the regular round form;

f_s = the maximum deviation of the spherical surface from the regular round form;

L_d = design length of the cylindrical shell;

L = spacing length;

N_1 = number of measuring points of the deviations f_1 on the cylindrical and conical shells, taken over a circumference;

N_2 = number of points for measuring deviations f_2 on cylindrical and conical shells, taken around a circumference;

R = radius of the median surface of the spherical shell;

r = radius of the median surface of the cylindrical shell;

S = thickness of the cylindrical and conical shells;

S_s = thickness of the spherical shell;

r_{min}, r_{max} = the minimum and the maximum radii of the median surface of the conical shell;

γ = bend angle of the conical shell;

δ = maximum possible measurement error;

θ = angle between the conical shell surface and frame web;

.2 frames:

b = width of the frame flange;

F = cross-sectional area of the frame web;

I_0 = intrinsic moment of inertia of the frame web section;

S_{fr} = thickness of the frame web;

S_{fl} = thickness of the frame flange;

Z = distance of the frame center of gravity from the median surface of shell plating (to be included in calculation with its own sign);

Z_{fr} = depth of the frame measured from the median surface of the shell up to the free edge (to be included in calculation with its own sign);

.3 openings and reinforcements:

a = radius of the opening:

d = diameter of the clear opening;

b_b = length of the thickened plate;

b_{bi} = length of the transition portion from the thickened plate to the basic one;

h_1 = height of the reinforcement above shell;

h_2 = height of the reinforcement under shell;

I = moment of inertia of the reinforced portion;

S_A = thickness of the reinforced plate;

S_r = thickness of the reinforcement;

r_1, r_{H_0}, r_{cg}, r_B, r_H, α, β = dimensions defining the openings for hatches and view ports to be inserted (see Fig. 3.7.8);

.4 heads and covers:

a_k = width of the flange;

b_k = thickness of the flange;

D_a = outside diameter of the head;

h_a = height of the head;

l_1 = distance from the butt joint to the nearest frame;

R_b = the maximum radius of the inner surface curvature;

R = the maximum radius of the median surface curvature.

1.4.3 Mechanical properties of materials:

A_5 = elongation of the test piece;

E = Young's modulus;

KV = impact energy;

R_{eH} = yield stress. The value equal to the proof stress $R_{p0,2}$ is introduced in calculations for materials lacking the yield area;

R_{eH}^{fr} = yield stress of the frame material;

R_m = ultimate strength;

Z = reduction of area;

ν = Poisson's ratio.

1.4.4 Loads and stresses:

n_b, n_T = safety factors;

n_s = safety factor for stability;

p_{1c} = critical buckling pressure of shell plating between frames;

p'_1 = theoretical critical buckling pressure of shell plating between frames;

p_{2c} = critical buckling pressure of shell plating together with frames;

p'_2 = theoretical critical buckling pressure of shell plating together with frames;

p_{sc} = critical buckling pressure of the sphere;

p'_s = theoretical buckling pressure of the sphere;

Θ_1 = force equivalent to the load applied to coaming on the shell side;

Θ_2 = force equivalent to the load applied to coaming on the view port side;

Θ_3, Θ_4 = forces due to pressure exerted on the coaming surface;

$[\sigma]$ = allowable stresses;

σ_0 = general membrane stresses;

σ_1 = local membrane stresses;

σ_t = total stresses;

σ^t = tensile stresses;

σ_c = compressive stresses.

1.4.5 Design factors:

k, k_1, k_2, k_2^0 = correction factors used in stress calculations;

m = correction factor in Formula (1.2);

n = number of buckling waves;

u = spacing parameter;

α_1 = number of camber half-waves along the meridian;

β_1 = spacing parameter;

η', η'' η_1, η_c, η_{1c} = correction factors to the formulae for critical pressure calculations.

2 MATERIALS AND WELDING

2.1 STEEL FOR HULL STRUCTURES

2.1.1 Steel intended for construction of pressure hulls of the manned submersibles and ship's diving systems shall be approved by the Register for use according to its designated purpose. Steel shall meet the requirements of Part XIII "Materials" of the Rules for the Classification and Construction of Sea-Going Ships and additional requirements of the present Section.

Use of steel with yield stress $R_{eH} > 690$ MPa is subject to special consideration by the Register in each case.

2.1.2 Steel for pressure hulls of the submersibles and diving systems shall meet the following additional requirements, which shall be confirmed during its approval:

.1 reduction of area of steel with yield stress $R_{eH} > 490$ MPa shall be not less than 50 per cent;

.2 impact energy KV_L on longitudinal specimens depending on the purpose of the structure, use of heat treatment after welding, steel strength level and thickness of structural members shall be not less than that given in Table 2.1.2.2; in this case, impact testing temperature T_t is determined from the formula

$$T_t = T_d - 20\,^{\circ}\mathrm{C} \qquad (2.1.2.2)$$

where T_d is assumed according to 1.2.

Table 2.1.2.2

Type of loading, availability of heat treatment	Yield stress of steel R_{eH}, MPa, max	Impact energy KV_L, J, depending on the thickness of structural members, mm		
		up to 20	21—40	41—60
Loaded by internal pressure	390	35	45	52
	490	40	52	64
	590	45	60	72
	690	50	64	80
Loaded by internal pressure, heat-treatable	390	35	40	45
	490	37	42	47
	590	40	45	52
	690	45	50	60
Loaded by external pressure	390	35	37	37
	490	37	37	37
	590	40	40	40
	690	40	45	45

.3 anisotropy of the steel plate properties in longitudinal and transverse directions is defined by impact testing, the ratio KV_T/KV_L in this case shall be not less than 0,8;

.4 for the steel plate of 40 mm thick and more, impact tests are carried out on test specimens cut out from the middle of the plate thickness; in this case, impact energy KV shall be not less than that required in Part XIII "Materials" of the Rules for the Classification and Construction of Sea-Going Ships and specified in Table 2.1.2.2 of the present Part;

.5 for the steel plates, static fracture tests are carried out on notched specimens of the full-scale thickness with determination of the amount of fiber component in the fracture, which shall be not less than 70 per cent. The tests are carried out according to the procedure approved by the Register;

.6 properties of the material used in the structure (after bending, die forming, etc.) shall be not lower than those required in this Section. Among the controlled characteristics are R_{eH} (at compression and tension), R_m, A_5, Z and KV.

2.2 WELDING CONSUMABLES AND WELDING JOINTS FOR HULL STRUCTURES

2.2.1 Welding consumables for construction of pressure hulls of the submersibles and diving systems shall comply with the requirements of Part XIV "Welding" of the Rules for the Classification and Construction of Sea-Going Ships, as well as the following additional requirements:

.1 welding consumables shall ensure strength and plastic characteristics of the weld metal not lower than those required for the base metal by these Rules;

.2 all welding consumables shall ensure impact energy not less than that required for the base metal under 2.1.2, and those intended for making tee welded joints shall ensure impact energy KV not less than 30 J with R_{eH} of deposited metal being < 390 MPa, and not less than 35 J with R_{eH} of deposited metal within 390—590 MPa, as well as not less than 40 J with R_{eH} of deposited metal within 590—690 MPa;

.3 impact energy of the metal of the heat-affected zone (along and 2 mm away the fusion line) shall be not less than that required in Part XIII "Materials" of the Rules for the Classification and Construction of Sea-Going Ships for the base metal in testing on longitudinal specimens (KV_L);

.4 impact test temperature is taken according to 2.1.2.2;

.5 for weld metal of the butt-welded joint, tests according to 2.1.2 shall be carried out, and the amount of fiber component shall be at least 30 per cent.

2.2.2 For steel with R_{eH} > 490 MPa use may be made of welding consumables not ensuring strength characteristics at the base metal level. In this case, R_{eH} of the deposited metal shall not be less than 0,8 R_{eH} of the base metal and impact energy KV – not less than 60 J. The strength of the welded joint shall be ensured by the weld reinforcement.

2.2.3 Welded joints and assemblies shall be made in compliance with the requirements of the relevant parts of the Rules with due regard to the following additional requirements:

.1 all the welded joints of the pressure hulls and the structures equated thereto shall be made by welding with full penetration, symmetric edge preparation and symmetric weld reinforcements.

Use of welded joints with full penetration and one-sided edge preparation may be approved in exceptional cases, when applying welding techniques ensuring defect-free formation of the root zone of weld, and shall be accompanied by the analysis of the local loading of the structural member and the possibility of occurrence of the fatigue failures. Load-free light structures (enclosures, etc.), as well as fasteners of not more than 10 mm in thickness (diameter) may be welded on without penetration, provided the welds have a leg of not more than 6 mm and not more than one-fourth of the thickness of the pressure hull member, to which the above items are welded on. No use of the overlap joints and joints with intermittent welds is permitted.

Coamings reinforcing openings shall be welded in the pressure hull members in accordance with 3.7;

.2 when performing welding operations, edge preparation for welding shall be effected by mechanical or thermal cutting with subsequent mechanical dressing;

.3 for the welds of the welded outfitting components (see Fig. 3.7.2, *a*, *b*), the distance between their edges and the edges of other welded joints shall be not less than 120 mm when the thickness of the hull shell plating $S \leqslant 40$ mm and not less than $(120 + 0{,}5(S - 40))$ when $S > 40$ mm.

In case of symmetrical and near-symmetrical arrangement of welded components on different sides of the member to be welded on (frame, etc.), distance between the weld edges of the components to be welded in and those of the member to be welded on shall be increased to the value not less than 180 mm when $S \leqslant 40$ mm, and not less than $(180 + 0{,}5(S - 40))$ when $S > 40$ mm.

For all the welds of outfitting components fitted into openings in the pressure hull plating, distance between their edges shall be not less than 2,5 S when $S \leqslant 40$ mm (but not less than 25 mm) and not less than 100 mm when $S > 40$ mm.

For welds of welded-on components, distance between their edges, as well as between the edges of welds of the components fitted into openings in the pressure hull plating shall be not less than 1,5 S when $S \leqslant 40$ mm (but not less than 25 mm) and not less than 60 mm when $S > 40$ mm;

.4 provision shall be made for special technological arrangements to increase cyclic life of structures, e.g. washing of weld reinforcements by argon-arc welding, grinding of weld reinforcements, plastic deformation, etc.

3 STRENGTH CALCULATIONS

3.1 GENERAL

3.1.1 The requirements of this Section apply to pressure resistant structures of the manned submersibles, ship's diving systems and passenger submersibles.

The basic formulae given below make it possible to evaluate the strength and also to check the stability of stiffened and unstiffened cylindrical and conical shells, as well as spherical hulls and tanks, hemispherical and near-hemispherical ends.

3.1.2 Calculations.

3.1.2.1 Considering that the thickness of structural members shall be calculated, in most cases, by several formulae, strength calculations shall be made as checking calculations for selected dimensions of the hull structural members.

3.1.2.2 The calculation presented for consideration shall include:

.1 design models of structures with indication of dimensions and thicknesses of all elements being calculated;

.2 details of materials (certificates with details on yield stress, ultimate strength, Young's modulus, etc.);

.3 conversion from the specified thicknesses to design ones with justification, if necessary, of the corrections used (for rolled edge, thinning in the process of die-forming, etc.);

.4 allowable stress values;

.5 details of fabrication accuracy (with explanation of the tolerance values selected, if necessary);

.6 strength calculations proper, with the hull member dimensions selected;

.7 summary table of the results (comparison of the actual stresses with allowable ones, of the operating pressure with the critical one for hull members, divided by n_s).

3.1.2.3 For the purpose of the strength calculations, pressures, stresses, yield stress, ultimate strength and elastic modulus of material are expressed in MPa, structure dimensions, in cm, and accordingly, cross-sectional areas, in cm^2, moments of inertia, in cm^4.

3.1.2.4 All calculations shall be accompanied by indication of manufacturing tolerances for deviations from the ideal shape, to which these calculations are applicable. Allowable deviations of all basic pressure hull structural members from the regular shape shall be given in the working technical documentation.

3.1.2.5 Dimensions of the structural members, for which methods of the strength calculation are not given in the Rules, are determined using the proven theoretical calculation techniques and experimental data, and are subject to special consideration by the Register in each particular case. In this case, the design models, as a rule, shall be based on the theory of bars (beams, rings), plates and shells.

3.1.2.6 Thicknesses of the members obtained from calculations are the minimum permissible ones for the normal operating conditions. The standards and methods of calculations ignore processing tolerances for thicknesses during manufacture (rolled edge of plates, elongation due to die-forming, possible thinning in the process of sandblasting or pickling, machining tolerance zone, etc.). They shall be determined on the basis of intended fabrication practice and documentation for delivery of semi-finished items, and taken into account in the form of appropriate additions to design thicknesses.

3.1.2.7 For structures, which cannot be thoroughly attended (periodically cleaned, painted and examined) in the process of operation, provision shall be made for an additional increase of thickness to compensate for corrosion (approximately 0,3 mm per year of operation without painting, with special consideration of this matter based on the operating experience and corrosion tests of the material selected). In addition, when the hull is designed to be in seawater for over 2000 h without inspection and restoration of anticorrosive coating, to prevent the risk of corrosion cracking the hull shall be fabricated only of those materials, which have already been proven to be effective in operation at sea during not less than 5 years, being part of similar hull structures. The above increase in thickness is permissible as an exception.

In the general case, structures shall be so designed that an access is provided to all parts thereof.

3.2 DESIGN PRESSURE

3.2.1 The design external pressure exerted on the pressure hull during submergence is determined by the formula

$$P = (H_{op} + \Delta H)/100 \qquad (3.2.1)$$

where H_{op} = operating depth, m;
ΔH = depth margin for casual overimmersion during manoeuvring of the manned submersible at the operating depth, m.

The value ΔH is specified by the Customer and revised by the Designer proceeding from the specific operating conditions of the submersible and its control systems.

If another value has no special substantiation, it is recommended to assume $\Delta H \geqslant 50$ m. When specifying ΔH for tethered manned submersibles and diving bells, consideration shall be given to emergency situations caused by cutting of the umbilical, and for towed manned submersibles and diving bells, also to the risk level of crew errors or the control systems malfunction when towed at high speed.

3.2.2 Formula (3.2.1) approximately takes account of the influence of the water temperature and salinity, and ignores the water compressibility. The relevant errors (approximately 2 per cent for a depth of 6000 m and not more than 1 per cent for depths up to 1000 m) are compensated by the selected safety factors and test loads.

3.3 ALLOWABLE STRESS LEVELS

3.3.1 The allowable tensile stresses $[\sigma_t]$ for hulls and compartments under the internal pressure are taken equal to the least of the following values:

.1 general membrane stresses σ^0:

$$[\sigma_t^0] = \min(R_{eH}/n_T - P/2;\ R_m/n_b - P/2). \qquad (3.3.1.1\text{-}1)$$

The safety factor n_b is taken equal to 2,4.

The safety factor n_T for hyperbaric manned compartments and chambers is determined by the formula

$$n_T = 1{,}5(R_{eH} - 400)/400 \leqslant 2{,}0 \qquad (3.3.1.1\text{-}2)$$

where the 2nd addend is accounted for at $R_{eH} > 400$ MPa. When $n_T > 2{,}0$ is obtained from the formula, n_T shall be taken equal to 2;

.2 local membrane σ^l and total σ^t stresses:

$$[\sigma_t^l,\ \sigma_t^t] = 1{,}2[\sigma_t^0]; \qquad (3.3.1.2)$$

.3 where stresses (tensile σ^t and compressive σ_c)[1] different in sign and acting in different in sign and acting in different directions are present at some point of the hull loaded by internal pressure, the following conditions shall be met at $|\sigma_0| > p$:

$$|\sigma_t^0| + |\sigma_c^0| \leqslant \min(R_{eH}/n_T;\ R_m/n_b); \qquad (3.3.1.3\text{-}1)$$

$$|\sigma_t^l| + |\sigma_c^l| \leqslant 1{,}2\min(R_{eH}/n_T;\ R_m/n_b); \qquad (3.3.1.3\text{-}2)$$

$$|\sigma_t^t| + |\sigma_c^t| \leqslant 1{,}2\min(R_{eH}/n_T;\ R_m/n_b) \qquad (3.3.1.3\text{-}3)$$

where n_b and n_T are specified as indicated in 3.3.1.1.

When $|\sigma_c| \leqslant P$ the influence of compression is ignored.

3.3.2 The allowable stresses for the hulls and compartments under the external pressure are taken equal to:

.1 general membrane stresses $[\sigma_0]$:

compressive $[\sigma_c^0]$:

$$[\sigma_c^0] = R_{eH}/n_{T_c}; \qquad (3.3.2.1\text{-}1)$$

tensile $[\sigma_t^0]$:

$$[\sigma_t^0] = R_{eH}/n_{Tt}; \qquad (3.3.2.1\text{-}2)$$

.2 local membrane stresses$[\sigma^l]$:

$$[\sigma^l] = 1{,}1[\sigma^0]; \qquad (3.3.2.2)$$

.3 total stresses $[\sigma^t]$:

$$[\sigma^t] = 1{,}2[\sigma^0]. \qquad (3.3.2.3)$$

The safety factors are taken equal to:

$n_{Tc} = 1{,}5$;

$n_{Tt} = 2{,}0$.

3.3.3 Where stresses (tensile σ_t and compressive σ_c) different in sign are present at some hull section loaded by external pressure, the following conditions shall be met[1]:

$$\sigma_t \leqslant [\sigma_t]; \qquad (3.3.3\text{-}1)$$

[1] For example, for torospherical heads, when under action of internal pressure, compressive stresses can arise and, in case of small thickness, even local buckling can take place in the tor.

$$|\sigma_t| + |\sigma_c| \leqslant |\sigma_c|. \qquad (3.3.3\text{-}2)$$

3.4 CALCULATION OF CYLINDRICAL SHELLS

3.4.1 Stiffened shells are checked for strength:

.1 against general membrane stresses at the longitudinal section at the mid-point of frame spacing (point *A* in Fig. 3.4.1.1) by the formula

$$\sigma_2^0 = k_2^0 P_r / S \leqslant |\sigma^0|; \qquad (3.4.1.1)$$

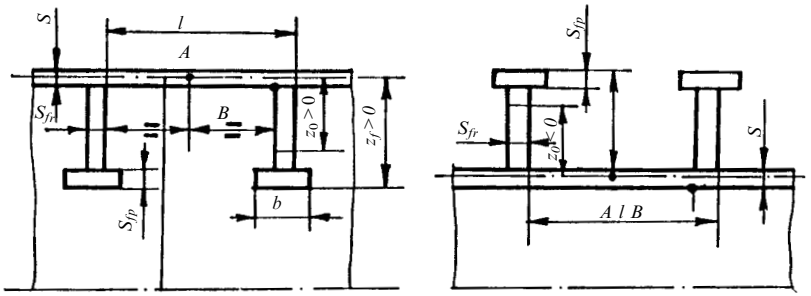


Fig. 3.4.1.1:
a — internal frames; *b* — external frames

.2 against total stresses at the transverse section in way of the frame (point *B* in Fig. 3.4.1.1) by the formula

$$\sigma_1^t = k_1 P_r / S \leqslant |\sigma^t|; \qquad (3.4.1.2)$$

.3 against stresses at the cross-section of the internal frame flange (no such check is required for external frame) by the formula

$$\sigma_{fr}^0 = \frac{k}{1 - Z_{fr}/r} \frac{P_r}{S} \leqslant [\sigma^0]; \qquad (3.4.1.3)$$

.4 against radially acting stresses at the internal frame web in way of shell plating by the formula

$$\sigma_{fr}^0 = k \frac{P}{1 - Z_0/r} F/S \cdot S_{fr} \leqslant \frac{1}{2} [\sigma^0]; \qquad (3.4.1.4)$$

.5 against difference of principal stresses at the external frame web in way of shell plating by the formula

$$\sigma_{fr}^{0} = k\frac{P_r}{S}\ (1 + \frac{F}{rS_{fr}\ (1 + Z_0/r)}) \leqslant [\sigma^0]. \qquad (3.4.1.5\text{-}1)$$

In Formulae (3.4.1.1)—(3.4.1.5-1) the value of the distance of the frame center of gravity from the median plating Z_0 shall be taken with its own sign (see Fig. 3.4.1.1).

The coefficients k_2, k_1 and k are determined as functions of the parameters:

$$u = 0{,}642\ l/\sqrt{rS}; \qquad (3.4.1.5\text{-}2)$$

$$\beta = ls(1 - Z_0/r)/F \qquad (3.4.1.5\text{-}3)$$

in accordance with the recommendations of Appendix 2 from diagrams or by calculations.

3.4.2 Check of unstiffened shells for strength.

3.4.2.1 Where the shell is loaded by internal pressure only, frames are either not fitted or fitted to take up local loads, to increase flexural stiffness of the shell, etc. As a rule, they are to be widely spaced ($u > 4.5$, i.e. $l > 7\sqrt{rS}$). In such case, the design thickness is determined from the formula

$$S = P_r/[\sigma^0] \qquad (3.4.2.1)$$

and the frames are so selected that checking by Formula (3.4.1.2) does not require thickening of the shell.

3.4.2.2 Strength of the shell without frames outside the head-affected zone is checked only by Formula (3.4.1.1) at $k_2^0 = 1$.

3.4.3 Checking for buckling strength under external pressure.

The design pressure P for hulls loaded by external pressure shall not generate stresses in the structural members, which exceed the allowable ones. Besides, the following conditions shall be met:

$$P \leqslant P_{1c}/n_s;\ P \leqslant P_{2c}/n_s \qquad (3.4.3)$$

where P_{1c} = critical pressure of buckling for plating between frames;
P_{2c} = the same, together with frames;
n_s = 1,5.

3.4.3.1 Buckling of plating between frames is determined by the formula

$$P_{1c} = \eta' P'_{1.} \qquad (3.4.3.1\text{-}1)$$

P'_1 is determined by the formulae:

$$P'_1 = 0{,}944E(S/r)^2 \text{ at } u \leqslant 1; \qquad (3.4.3.1\text{-}2)$$

$$P'_1 = 0{,}59E(S/r)^2(1 + 0{,}4/u + 0{,}2/u^2)/u \text{ at } 1 < u < u_g; \qquad (3.4.3.1\text{-}3)$$

$$P'_1 = 0{,}275E(S/r)^3 \text{ at } u > u_g. \qquad (3.4.3.1\text{-}4)$$

In Formulae (3.4.3.1-3) and (3.4.3.1-4) $u_g = 2{,}15r/S$ is the value of the parameter u, at which shell buckling strength no longer depends on the shell length.

The correction factor η' is determined by the formulae given in Table 3.4.3.1.

Table 3.4.3.1

Value u	Formula for η'
$u \leqslant 0{,}1u_g$	$\eta' = \eta_k = \eta_1 / \sqrt[4]{1 + \frac{2}{3}[\eta_1(1 + \bar{f}_1)\sigma]^4}$
$0{,}1u_g < u < u_g$	$\eta' = \dfrac{\eta_k}{1 + 3(\eta_k/\eta_g - 1)[(u - 0{,}1u_g)/0{,}9u_g]^2[1 - \frac{2}{3}(\frac{u - 0{,}1u_g}{0{,}9u_g})]}$
$u \geqslant u_g$	$\eta' = \eta_g = \frac{1}{2}\left\{\left[1 + (1 + 5\bar{f}_1\bar{\sigma})/\sqrt[4]{1 + (2/3)\bar{\sigma}^4} - \right.\right.$ $\left.\left. - \sqrt{[1 + (1 + 5\bar{f}_1\bar{\sigma})/\sqrt[4]{1 + (2/3)\bar{\sigma}^4}]^2 - 4/\sqrt[4]{1 + (2/3)\bar{\sigma}^4}}\right\}\right]$

where $\bar{f}_1 = f_1/S;$ (3.4.3.1-5)

$$\eta_1 = \frac{1}{1 + 1{,}35[\bar{f}_1/(1{,}57\bar{f}_1 + 1)]^{2/3}}; \qquad (3.4.3.1\text{-}6)$$

$$\sigma = k_2^0 P'_1 r/SR_{eH}. \qquad (3.4.3.1\text{-}7)$$

3.4.3.2 Buckling of the shell together with frames.

The critical pressure of buckling together with frames is determined from the formula

$$P_{2c} = \eta'' P'_2 \qquad (3.4.3.2\text{-}1)$$

where $P_2' = \dfrac{E}{n^2 - 1 + \alpha_1^2/2}\Big[\bar{I}_0(n^2-1)^2/r^3 l + S^3(n^2 - 1 + \alpha_1^2)^2/10{,}9r^3 + (S/r)\alpha_1^4/(n^2+\alpha_1^2)^2 +$

$+ [F(1 - Z_0/r)/l_r]\{[Z_0/(r - Z_0)](n^2-1) + [(0{,}3n^2 - \alpha_1^2)\alpha_1^2/(n^2+\alpha_1^2)^2]\}\Big]$. (3.4.3.2-2)

In Formula (3.4.3.2-2):

n is number of buckling waves along the circumference, which is determined sequentially for n = 2, 3… until the minimum P_{2c} is obtained;

$$\alpha_1 = \pi r / L_d \tag{3.4.3.2-3}$$

where L_d = design length of the cylindrical shell (see Fig. 3.4.3.2);

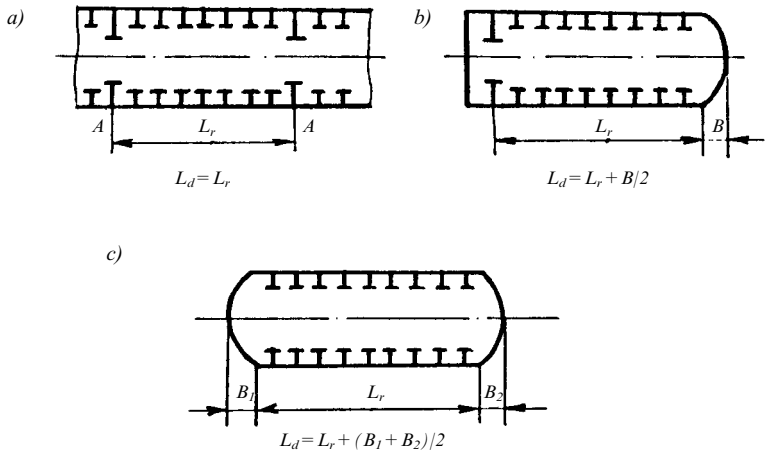


Fig. 3.4.3.2

$$\bar{I}_0 = I_0(1 + 3(1 + 3Z_0/r + 6Z_0^2/r^2)) \tag{3.4.3.2-4}$$

where Z_0 = distance of the frame center of gravity from the median surface of plating (with its own sign – see Fig. 3.4.1.1);

$$\beta_1 = (l_{np}S)/[F(1 - Z_0/r)] \tag{3.4.3.2-5}$$

where l_{np} is determined from Table 3.4.3.2;

$$\eta'' = \frac{1}{2}\Big[1 + (1+m)\sqrt[4]{1 + (2/3)\bar{\sigma}^4} - \sqrt{(1 + (1+m)\sqrt[4]{1 + (2/3)\bar{\sigma}^4})^2 - 4\sqrt[4]{1 + (2/3)\bar{\sigma}^4}}\Big]; \tag{3.4.3.2-6}$$

Table 3.4.3.2

Value u	Internal frame ($Z_0 > 0$)	External frame ($Z_0 < 0$)
$u \leqslant 0{,}75$	$l_{np} = l$	$l_{np} = l$
$0{,}75 < u \leqslant 1$	$l_{np} = l$	$l_{np} = l/[1 + H_1^2(u - 0{,}75)]$
$u > 1$	$l_{np} = 1{,}55\sqrt{rS}$	$H_1 = 1 + [\lvert Z_0\rvert/(r + \lvert Z_0\rvert](n^2 - 1)^1$
[1] l_{np}, at $Z_0 > 0$, is calculated for each n.		

$$m = 0{,}75\,\frac{E|f_2 Z_1|(n^2-1)s}{kP_2' r^3}\,C_1; \qquad (3.4.3.2\text{-}7)$$

$$Z_1 = Z_{fr} - [Z_0/(1+\beta_1)][(1 - Z_{fr}/r)/(1 - Z_0/r)]; \qquad (3.4.3.2\text{-}8)$$

$\overline{\sigma}$ is taken equal to the greatest values of $\overline{\sigma}_1$, $\overline{\sigma}_2$

where $\overline{\sigma}_1 = k_2^0 P_2^1 r / SR_{eH}$; (3.4.3.2-9)

$$\overline{\sigma}_2 = \sqrt[4]{3/2}\,\frac{kP_2' r}{(1 - Z_{fr}/r)SR_{eH}^{fr}}. \qquad (3.4.3.2\text{-}10)$$

C_1 is specified depending on $\overline{\sigma}$ and R_{eH}/R_{eH}^{fr}:

at $\overline{\sigma} = \overline{\sigma}_1 \geqslant 1$ $\quad c_1 = R_{eH}/R_{eH}^{fr}$; (3.4.3.2-11)

at $\overline{\sigma} = \overline{\sigma}_1 > 1$ $\quad c_1 = \overline{\sigma} R_{eH}/R_{eH}^{fr}$; (3.4.3.2-12)

at $\overline{\sigma} = \overline{\sigma}_2 \geqslant 1$ $\quad c_1 = 1$; (3.4.3.2-13)

at $\overline{\sigma} = \overline{\sigma}_2 < 1$ $\quad c_1 = \overline{\sigma}$. (3.4.3.2-14)

3.4.4 Where both external and internal frames are provided within the compartment, calculation is made twice: for compartment fitted only with external frames and for compartment only with internal frames. The least value is taken as the design one.

3.4.5 Buckling strength of shells without frames is checked only by the formulae for plating between frames, but calculating the parameter u by Formula (3.4.1.5-2), the design length of the compartment L_d shall be inserted therein instead of the spacing l, according to Fig. 3.4.3.2, *c* (assuming that no frames are provided in the compartment).

3.4.6 Buckling strength of deep frames is also checked by Formulae (3.4.3.2-2), (3.4.3.2-3) and (3.4.3.2-6), in which l shall be substituted for a half-sum of portions L_d adjacent to the frame, and α_1 in Formula (3.4.3.2-3) shall be taken equal to zero.

3.4.7 Strength of plating in way of a deep frame is checked by Formula (3.4.1.2) with l specified as above. If necessary, plating in way of a deep frame is thickened, the length of thickened portion being at least $3\sqrt{rS_A}$ (where S_A = increased thickness). Strength in this case is checked without regard to the finiteness of the thickening length.

3.4.8 For approximate assessment (as the first approximation) of the required thickness with expected $1 < u < u_g$, it is recommended to use the formula

$$S \geqslant 0{,}76(1+\overline{f_1})k_2^0 n_s Pr/R_{eH}. \qquad (3.4.8\text{-}1)$$

At the same time, the strength condition in the following form shall be met:

$$S \geqslant k_2^0 Pr/[\sigma^0]. \qquad (3.4.8\text{-}2)$$

with k_2^0 taken initially as 1, a value of l shall be specified, and when determining u, a value of S shall be taken according to Formula (3.4.8-2). With a known value of f_1 (given, proceeding from the expected technology), all the values on the right side of Formula (3.4.8-1) are determined and a value of S can be found.

At $u \geqslant 2$ such calculation gives almost exact value of S and at $u < 2$ the resulted value of S is somewhat excessive.

Calculating shells without frames, value of k_2^0 shall be taken equal to 1.

3.4.9 The frame web is checked for buckling strength by the formulae given in Table 3.4.9. In this case, the following conditions (see also Fig. 3.4.1.1) shall be met:

$$5S_{fr} \leqslant b \leqslant 8S_{fl};$$

$$S_{fl} \leqslant S.$$

3.5 CALCULATION OF CONICAL SHELLS

3.5.1 The calculation of a conical shell with permanent taper (see Fig. 3.5.1) is made using formulae given in 3.4.1, 3.4.2 and 3.4.3 with substitution of a number of values as specified in Table 3.5.1.

Table 3.4.9

Pressure	Frame	S_{fr}/S	Value of P shall not exceed the lesser value determined by the formulae below
External	External	$\leqslant 2/3$	$P \leqslant 0{,}6ESS_{fr}^2/[kr(\lvert Z_{fr}\rvert - S_{fl})^2]$
		$>2/3$	$P \leqslant (4/15)\{ES^2/[kr(\lvert Z_{fr}\rvert - S_{fl})^2]\}$
	Internal	$\leqslant 2/3$	$P \leqslant 0{,}6[ESS_{fr}^2/[kr(\lvert Z_{fr}\rvert - S_{fl})^2]] \dfrac{1}{1+5{,}4[F/(rS_{fr}) - (2/3)(\lvert Z_{fr}\rvert/r)]}$
		$>2/3$	$P \leqslant (4/15)\{(ES^3)/[kr(\lvert Z_{fr}\rvert - S_{fl})^2]\} \dfrac{1}{1+8{,}1[F/(rS_{fr}) - (2/3)\lvert Z_{fr}\rvert/r](S_{fr}/S)}$
Internal	External	$\leqslant 2/3$	$P \leqslant (9/80)ESS_{fr}^3)/[kF(\lvert Z_{fr}\rvert - S_{fl})^2] \dfrac{1}{1-(2/3)(\lvert Z_{fr}\rvert S_{fr})/F}$
		$>2/3$	$P \leqslant (1/30)\{ES^4/[kF(\lvert Z_{fr}\rvert - S_{fl})^2]\} \dfrac{1}{1-[(2/3)(\lvert Z_{fr}\rvert S_{fr})/F]}$
	Internal	Any	No checking

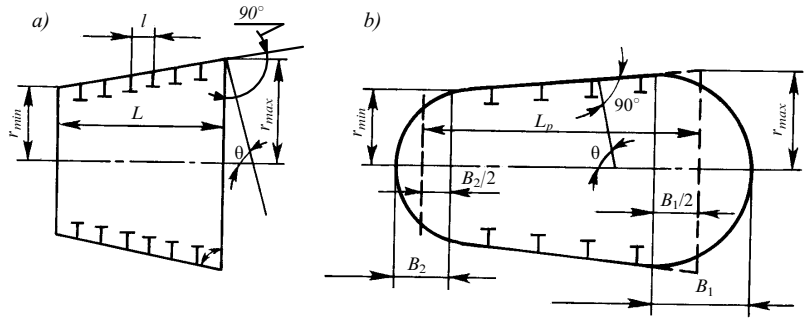


Fig. 3.5.1:
a – shells without torospherical or elliptical ends;
b – shells with torospherical or elliptical ends.

3.5.2 The formulae of Table 3.5.1 are applicable to:
shells unstiffened by frames
at $r_{max}/r_{min} \leqslant 1{,}5$ $\theta \geqslant 60^\circ$;
shells stiffened by frames
at $r_{max}/r_{min} \leqslant 1{,}5$, $\theta \geqslant 70^\circ$ within the spacing; and
at $r_{max}/r_{min} \leqslant 3$, $\theta \geqslant 70^\circ$ for the hull as a whole.

Table 3.5.1

No. of formula or table	Values in formula (cylinder)	Substitution in calculation of conical shells
1	2	3
Formulae (3.4.1.1), (3.4.1.2), (3.4.1.3), (3.4.1.5-1), (3.4.2.1)	Pr/S	$P\cdot\max(r/S\sin\theta)$ where $\max(r/S\sin\theta)$ is the maximum value of the ratio on the cone portion under consideration[1]
Formulae (3.4.1.5-2), (3.4.1.5-3)	$u=0{,}642l/\sqrt{rS}$ $\beta=(lS/F)(1-r_0/r)$	$u=0{,}642(l/r_{cp})\sqrt{\max(r/S\sin\theta)}$ $\beta=(lS/F\sin\theta)(1-Z_0/r)$
Tables 1 and 2 of Appendix 2. Formulae (3.4.3), (3.4.3.1-1), (3.4.3.1-6), (3.4.3.1-7), (3.4.3.2-1)	To be used unchanged	
Formulae (3.4.3.1-2) — (3.4.1.1-4)	S/r	$\sin\theta/\max(r/s)$
Formulae (3.4.3.2-2)	E $\alpha_1=\pi r/L_d$	$E\sin^3\theta$ $\alpha_1=\frac{\pi\cos\theta}{\ln(r_{max}/r_{min})}$ at $r_{max}/r_{min}\leqslant 1{,}3$ $\alpha_1=\pi r_{cp}\sin\theta/L_d$ may be taken
	I_0/r^3l F/lr $Z_0/(r-Z_0)$	The formulae do not change, but inserted therein are I_δ, F, l, Z_0, r of the frame, for which the value of $\bar{I}_0/lr^3+FZ_0^2/[lr(r-Z_0)^2(1+1/\beta_1)]$ is the least[1]
	$\beta_1=l_{np}S/F(1-Z_0/r)$	$\beta_1=l_{np}S/[F(1-Z_0/r)\sin\theta]$ where values F, Z_0, l (in l_{np}) are assumed as specified in Table 3.4.3.2
Tables 3.4.3.1, 3.4.3.2	To be used unchanged	
Formulae (3.4.3.2-6)	m, k_2^0, k Z_{fr}/r r/S	These values are calculated with unchanged formulae for the same frame, for which $\bar{I}_0$, F, Z_0 (see above) and the greatest $\max(r/S\sin\theta)$ were determined
Formulae (3.4.8-1), (3.4.8-2)	r	$r_{max}/\sin\theta$

Table 3.5.1 - continued

1	2	3
Table 3.4.9	To be used unchanged	

[1] For the hull of permanent thickness with equidistant frames of permanent section, $r = r_{max}$ shall be taken.

Where thickness and/or dimensions of frames change lengthwise, checking is made at the end (with the maximum r) of each portion with permanent stiffness.

Use of structures, the parameters of which fall outside these limits is allowed as an exception, provided the structure and method of calculation specially agreed upon with the Register in each particular case.

3.5.3 With shells having "external" bends, when the generatrix of the hull is a convex line (see Fig. 3.5.3), the calculation of local strength and buckling strength is made separately for each shell with permanent taper in the following way:

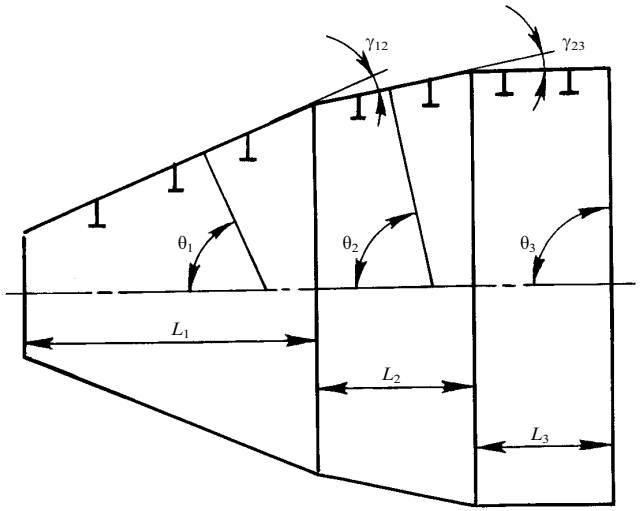


Fig. 3.5.3

.1 buckling strength calculation of the shell together with frames is made using formulae given in 3.4.3 and Table 3.5.1, but α_1 shall be determined by the formula

$$\alpha_1 = 1/\sum_{i=1}^{k}[\ln(r_{i\max}/r_{i\min})/\pi\cos\theta_i] \qquad (3.5.3.1)$$

where summation is carried out with respect to all portions of permanent taper.

At $r_{max}/r_{min} \leqslant 1{,}3$, the expression $\ln(r_{max}/r_{min})\cos\theta_i$ may be taken instead of $\ln(r_{i\,max}/r_{i\,min})\cos\theta_i$. The spacings, within which shells with different taper join, are calculated for the actual and greatest $r/\sin\theta$. The butt joint shall be located in the middle one-third of the spacing.

.2 local strength is checked against stresses in the cross-section at the connection of shells with different taper:

$$\sigma_1^t = (P_r/S\sin\theta)[0{,}5 + 0{,}6\sqrt{r/s}\,\mathrm{tg}\gamma] \leqslant [\sigma^t]. \qquad (3.5.3.2)$$

In Formula (3.5.3.2) the greatest values of r/S and $r/\sin\theta$ are taken for the shells being joined.

3.6 CALCULATION OF SPHERICAL AND NEAR-SPHERICAL SHELLS

3.6.1 Spherical hulls, semispherical and near-semispherical ends of cylindrical and conical hulls, as well as semispherical caps (see Fig. 3.6.1) are calculated by the formulae for checking:

strength:

$$\sigma^0 = PR/2S_s \leqslant [\sigma^0]; \qquad (3.6.1\text{-}1)$$

buckling strength:

$$P \leqslant P_{sc}/n_s; \qquad (3.6.1\text{-}2)$$

$$P_{sc} = \eta_s P'_s \qquad (3.6.1\text{-}3)$$

where $P'_s = 1{,}21E(S_s/R)^2$; (3.6.1-4)

$$\eta_s = \eta_{1s}/\sqrt{1 + [(1 + f_s)\eta_{1s}\delta]^2}; \qquad (3.6.1\text{-}5)$$

$$\bar{\delta} = P'_s R/2S_s R_{eH}; \qquad (3.6.1\text{-}6)$$

$$\eta_{1s} = 1/[1 + 2{,}8\bar{f}_s)\bar{f}_s^{2/3}]; \qquad (3.6.1\text{-}7)$$

$$\bar{f}_s = f_s/S_s. \qquad (3.6.1\text{-}8)$$

From Formulae (3.6.1-1)—(3.6.1-3) follows the formula for specifying thickness

$$S_s \geqslant n_s PR(1 + \bar{f}_s)/(2\sqrt{2}R_{eH}). \qquad (3.6.1\text{-}9)$$

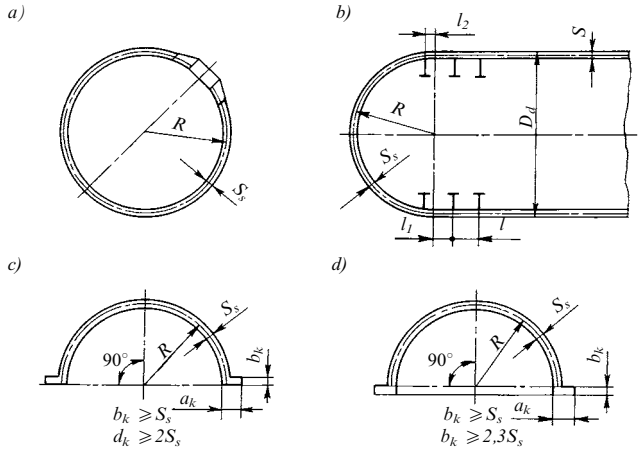


Fig. 3.6.1:
a – spherical hull; *b* – semispherical end of a cylindrical hull;
c and *d* – semispherical caps

The spherical end shall be mated with the cylindrical or conical hull in smooth manner without any bends. Distance between the frame nearest to the butt and the butt shall comply with the requirements:

$$l_1 < l/2,\ l_1 < \sqrt{rS} \ \text{ at } S_s \geqslant 0{,}8S.$$

3.6.2 Torospherical and elliptical ends and caps (see Fig. 3.6.2) are calculated by Formulae (3.6.1-1)—(3.6.1-3) with substitution of the greatest end or cap radius for the semisphere radius (see Fig. 3.6.2).

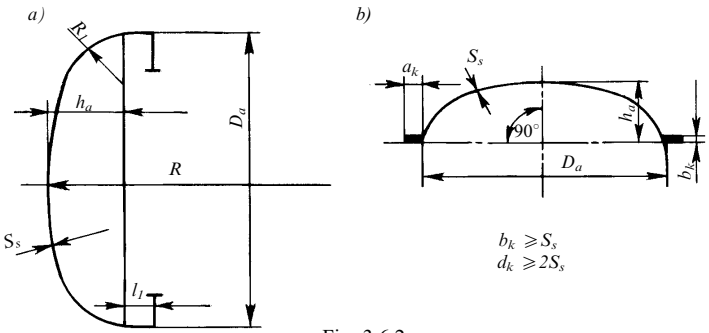


Fig. 3.6.2:
a – torospherical end; *b* – elliptical cap

The following conditions shall be met:

for torospherical ends and caps:

$$R \leqslant D_a - S_s; \tag{3.6.2-1}$$

$$R_1 > (D_a - S_s)/6; \tag{3.6.2-2}$$

for elliptical ends and caps:

$$h_a \geqslant (D_a - S_s)/4; \tag{3.6.2-3}$$

$$R = (D_a - S_s)^2/4h_a \leqslant D_a - S_s \tag{3.6.2-4}$$

where R = radius of curvature of the median surface on the axis of rotation.

At $R_1 \leqslant 0{,}65[(D_a - S_s)/2]$ for torospherical ends and at $h_a \leqslant 0{,}4(D_a - S_s)$ for elliptical ends, no frames are fitted thereon, but the distance between the butt and the nearest frame on the cylinder (if frames are fitted) shall be within $(1/3)l \leqslant l_1 \leqslant (1/2)l$. At $R_1 > 0{,}65[(D_a - S_s)/2]$ and $h_a > 0{,}4(D_a - S_s)$, the end shall be stiffened by the frame.

Where such ends are used for conical hulls, bend angle γ of the generatrix in way of the butt (see Fig. 3.5.3) shall not exceed 5°.

3.7 REINFORCEMENT OF OPENINGS

3.7.1 The reinforcements of openings in the pressure hull shall be so calculated that the strength standards specified in 3.3 are achieved. The calculation methods shall be approved by the Register.

Below are set forth the recommendations for selection of thickness and section shapes of the reinforcing members, for which calculations may be omitted.

3.7.2 Openings reinforced by cylindrical coamings without thickening of the hull plating (see Fig. 3.7.2) shall be so reinforced that the following conditions are met:

$$S_r \geqslant (3/2)S \text{ at } d \geqslant 3S; \tag{3.7.2-1}$$

$$S_r \geqslant (1/2)d \text{ at } d < 3S. \tag{3.7.2-2}$$

For cylindrical and conical shells:

$$h_1 \geqslant S_r + (1/2)a^2/r; \tag{3.7.2-3}$$

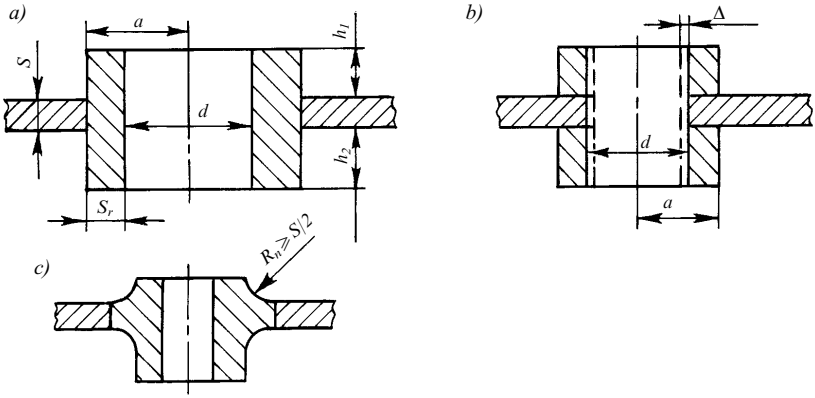


Fig. 3.7.2:
Δ — allowance for machining to remove a weld root; *a* — opening reinforcement with a coaming (a "socket"); *b* — opening reinforcement with a flange sleeve (coaming with a "collar"); *c* — opening reinforcement with a "half-socket"

$$h_2 \geqslant S_r + (1/2)a^2/r. \qquad (3.7.2\text{-}4)$$

For spherical shells:

$$h_1 \geqslant S_r; \qquad (3.7.2\text{-}5)$$

$$h_2 \geqslant S_r. \qquad (3.7.2\text{-}6)$$

The following condition shall be met for all shells:

$$2aS > S_r(h_{1np} + S + h_{2np}) \geqslant 1{,}5aS \qquad (3.7.2\text{-}7)$$

where $h_{1np} = h_1$ at $h_1 = 0{,}8\sqrt{aS_r}$; (3.7.2-8)

$h_{1np} = 0{,}8\sqrt{aS_r}$ at $h_1 > 0{,}8\sqrt{aS_r}$. (3.7.2-9)

h_{2np} is specified in the same manner.

Distance between the centers of the nearest openings shall not be less than the sum of their radii *a* (see Fig. 3.7.2) multiplied by 2,5.

3.7.3 Where an opening in a thickened plate is reinforced (see Fig. 3.7.3) the following conditions shall be met:

$$B_b \geqslant a \text{ (in all directions);} \qquad (3.7.3\text{-}1)$$

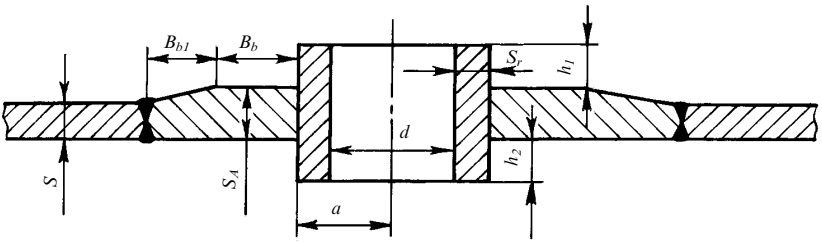


Fig. 3.7.3

$$B_b \geqslant 5(S_A - S); \tag{3.7.3-2}$$

$$S_r \geqslant S_A \text{ at } d \geqslant 2S_A; \tag{3.7.3-3}$$

$$S_r \geqslant (1/2)d \text{ at } d < 2S_A \tag{3.7.3-4}$$

where h_1 and h_2 are not less than those specified for the case without the thickened plate;

$$2aS_A > S_r(h_{1np} + S_A + h_{2np}) \geqslant 1{,}5aS^2/S_A. \tag{3.7.3-5}$$

Values of h_{1np} and h_{2np} are calculated in the same way as in Formula (3.7.2-7).

3.7.4 Coamings shall be welded on by a double-sided T-butt weld with full penetration (see Fig. 3.7.2, *a*) or a double-sided butt weld, when the coaming is made with a "collar" to ensure smooth transition (see Fig. 3.7.2, *b*). For openings of a small diameter, use may be made of "half-sockets" to be welded on by a single-sided weld and drilled out after welding to a value Δ that assures removal of the defective portion of the weld root (see Fig. 3.7.2, *c*).

3.7.5 Where the coaming shall be extended to the height exceeding the one allowable by Formulae (3.7.2-7) and (3.7.3-5), the design solutions shown in Fig. 3.7.5 shall be used.

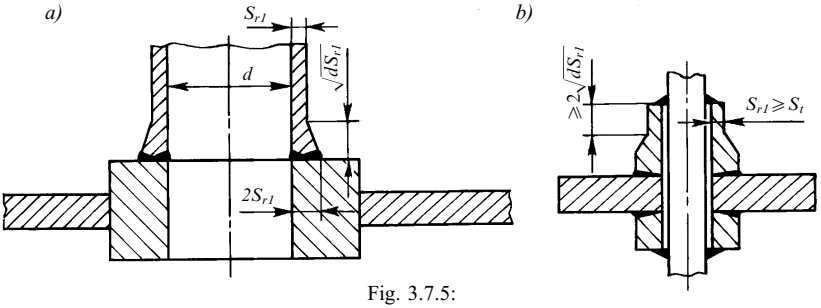


Fig. 3.7.5:
a – increase of height; *b* – passage of a pipe through the coaming of a small opening; S_{r1} – according to the strength calculation of a pipe with diameter *d*; S_t – pipe thickness

3.7.6 Where coamings intersect frames (no more than three frames may be intersected), the continuous frames nearest thereto on either side of the coaming (over a length not less than $3a$ in both directions away from the coaming axis – see Fig. 3.7.6) shall be so strengthened that the sum of the moments of inertia of the strengthened parts

$$\sum_{i=1}^{2} I = 2\{\bar{I}_0 + F_{Z_0}^2/[(1 + Z_0/r)^2(1 + 1/\beta_1)]\} \qquad (3.7.6)$$

is equal to the sum of the moments of inertia of ordinary frames and those not cut by the coaming (before strengthening). The moments of inertia of all the frames are calculated for frames with effective flanges equal to lS.

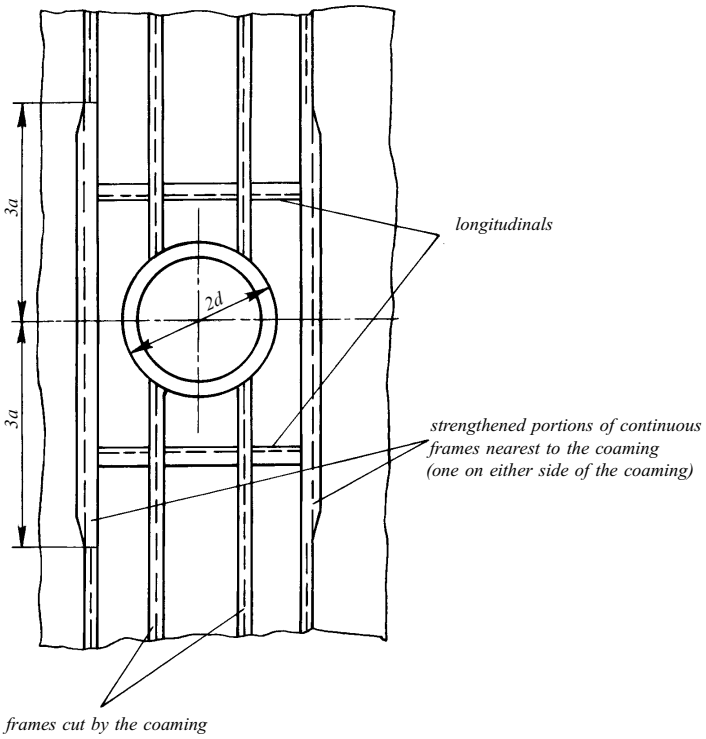


Fig. 3.7.6

Longitudinals with cross-sectional area equal to that of the frames are fitted on either side of the coaming between continuous frames at the distance not more than $2a/3$ from the outside of the coaming.

3.7.7 The angle between the axis of any opening and the normal at the hull axis shall not exceed 10° (see Fig. 3.7.7).

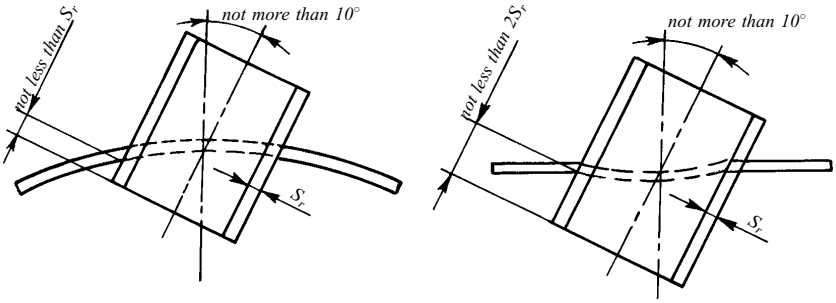


Fig. 3.7.7

3.7.8 The openings in spherical shells for hatches and view ports to be inserted are reinforced by the coamings shown in Fig. 3.7.8.

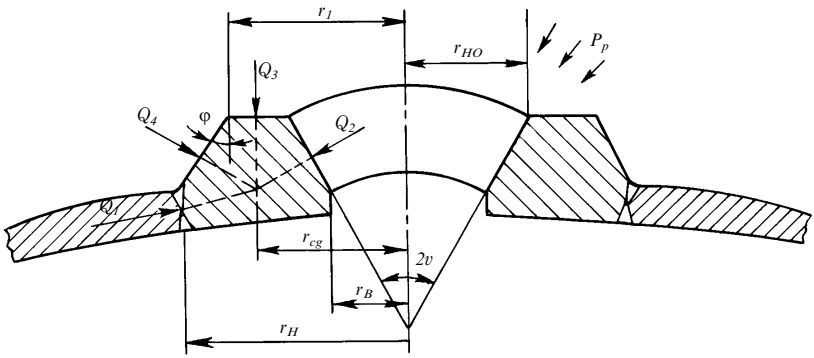


Fig. 3.7.8

The section shape shall be so selected that the moment about the center of gravity of the ring section due to forces Q_1, Q_2, Q_3 and Q_4 is as close as possible to zero

where $Q_1=P_c/2$; (3.7.8-1)

$$Q_2 = Pr_{HO}^2/[(r_{HO}+r_B)\sin v]; \quad (3.7.8\text{-}2)$$

Q_3, Q_4 are forces due to pressure exerted on the coaming surface.

The cross-sectional area F of the coaming shall be calculated within the range defined by the formulae:

$$3{,}2Q_\Sigma r_{cg}S/(PR) \geqslant F \geqslant 2{,}7Q_\Sigma r_{cg}S/(PR); \quad (3.7.8\text{-}3)$$

$$Q_\Sigma = P[\sqrt{R^2-r_H^2}\, r_H/2r_{cg} - r_{HO}^2 \mathrm{ctg}v/2r_{cg} + (r_H^2-r_1^2)\mathrm{ctg}\varphi/2r_{cg}]. \quad (3.7.8\text{-}4)$$

3.8 REQUIREMENTS FOR MANUFACTURE ACCURACY AND SHAPE MEASUREMENTS OF PRESSURE-RESISTANT STRUCTURES

3.8.1 Shape measurements of cylindrical and conical shells.

3.8.1.1 Deviations f_2 of cylindrical and conical shells from the regular round shape measured along the frame attachment lines, as well as deviations f_1 measured at the point halfway between them (at the midpoints of frame spacings) shall not exceed 1 per cent of the shell radius or one hull thickness at the section being measured, whichever is less.

3.8.1.2 Deviations from the regular round shape of each section shall be measured at N_2 equidistant points and N_2 shall not be less than

$$N_2 \geqslant N_{2\min} = 4(n+2) \quad (3.8.1.2)$$

where n = number of buckling waves corresponding to the least value of p_{2c}.

N_2 is recommended to be taken from a series of numbers: 16, 32, 64...

3.8.1.3 The measurement points may be shifted both sideways from the frame being measured (for the flange width or 1/8 spacing) and within the boundaries of the frame (up to 1/3 distance between the measurement points).

3.8.1.4 The values of f_1 and f_2 are determined as the measurement result multiplied by $(1+\sigma)$, where σ is the greatest possible relative measurement error that depends on the method used and accuracy of a measuring instrument. If necessary, the relative error may be replaced by an absolute one:

$$f_2 = f_{2meas} + \Delta meas.$$

3.8.1.5 Measurement of the deviations from the round shape f_1 at the midpoint of the frame spacing shall be only made at $u > 0{,}1u_g$.

3.8.1.6 The values of the out-of-flatness (of inverted-V shape) in way of the butts and seams of plating measured as shown on the sketch (Fig. 3.8.1.10) (the instrument is consecutively positioned on each side of the weld and the greatest reading is taken into account) shall not exceed the value of f_1 input in the strength calculation. The instrument base length for such measurements is taken equal to l or $3\sqrt{r\delta}$ or $0{,}5r$, whichever is less.

3.8.1.7 The variable wall difference is not to exceed $1{,}2f_1$ or $0{,}2S$, whichever is less.

3.8.1.8 Deviations of frames from the regular shape measured at the flange and web are shown in Fig. 3.8.1.8.

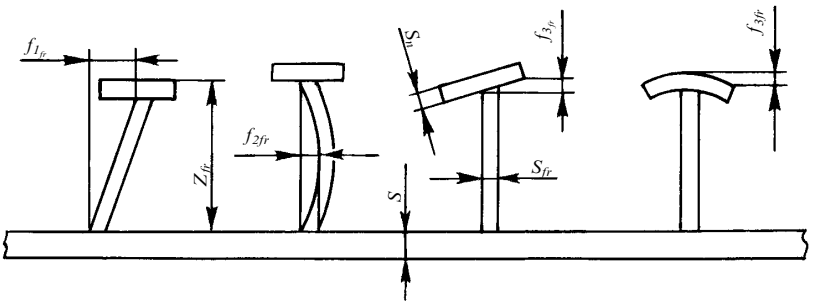


Fig. 3.8.1.8

The allowable values of f_{1fr}, f_{2fr} and f_{3fr} are given in Table 3.8.1.8 where f_1 is the value of local deviation input in the calculation in accordance with 3.8.1.10.

Table 3.8.1.8

Deviation to be measured	Allowable value to be determined as the least
f_{1fr}	$f_1 S_{fr}/S$; $1/25 Z_{fr}$
f_{2fr}	$(1/2) f_1 S_{fr}/S$; $(1/50) Z_{fr}$
f_{3fr}	$(1/25) b$

For the frames to be welded to the shell at $|Z_{fr}| < 50$ mm, in order to determine f_{1fr} and f_{2fr}, it is necessary to substitute 50 mm for the actual Z_{fr}. For welded sections at $b < 25$ mm, it is necessary to substitute 1 mm for 1/25.

3.8.1.9 Deviations of the spacing value shall not exceed 0,2l, and frame waviness – 0,02l or f_{1fr} (whichever is less). For a frame made of rolled section the deviations f_{1fr} and f_{2fr}, and waviness shall be checked.

3.8.1.10 Local deviations of cylindrical and conical shells from the regular shape f_1 shall not exceed the shell thickness. They are measured along the generatrix between the frames (see Fig. 3.8.1.10) on the frames attachment side or in accordance with 3.8.1.1—3.8.1.3.

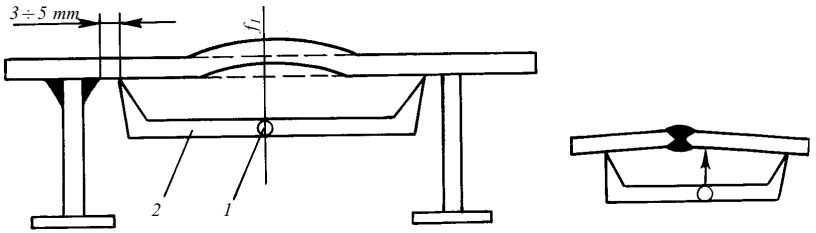


Fig. 3.8.1.10:
1 – instrument; *2* – instrument base

3.8.1.11 At $u \leqslant 0{,}1u_g$ local deviations are measured only in accordance with Fig. 3.8.1.10 for N_1 sections evenly spaced around the circumference. N_1 shall be not less than $N_{1\min}$; it is recommended to take N_1 from a series of numbers: 16, 32, 64...

$$N_{1\min} = 14(r/l)\sqrt{u}\,\sqrt{1-0{,}72/u+1/8u^2}. \qquad (3.8.1.11)$$

At $u < 1$, $u = 1$ shall be inserted in Formula (3.8.1.11), and at $N_{1\min} < 16$, it is necessary to take $N_{1\min}$=16.

At $0{,}1u_g < u < u_g$, f_1 shall be measured both in accordance with Fig. 3.8.1.10 and 3.8.1.1—3.8.1.3, and the greatest deviations measured shall be assumed. The number of measurement points according to both schemes is determined by Formula (3.8.1.11).

At $u \geqslant u_g$, measurements are carried out only in accordance with 3.8.1.1—3.8.1.3 with N_1=16.

3.8.2 Measurements of spherical shell shape.

3.8.2.1 Deviations from the theoretical surface measured from the gauge encompassing the shell from edge through pole to edge (or to the axis of rotation of the shell) or by the use of an end measuring rod, from a common center, shall not exceed after treatment the greatest of the values of $2f_s$ or 0,01R.

Deviations of the spherical, elliptical or torospherical bulkhead edge from the round shape shall be taken with due regard to the tolerances on mating with the cylindrical or conical shell.

3.8.2.2 Local deviations of spherical, elliptical and torospherical shells f_s shall not exceed the shell thickness. They are measured over the bass length $3\sqrt{RS_s}$ as shown in Fig. 3.8.2.2 in two mutually perpendicular directions across a net of points (point A in Fig. 3.8.2.2) covering the entire surface of the shell and spaced not farther than $1{,}5\sqrt{RS_s}$ apart.

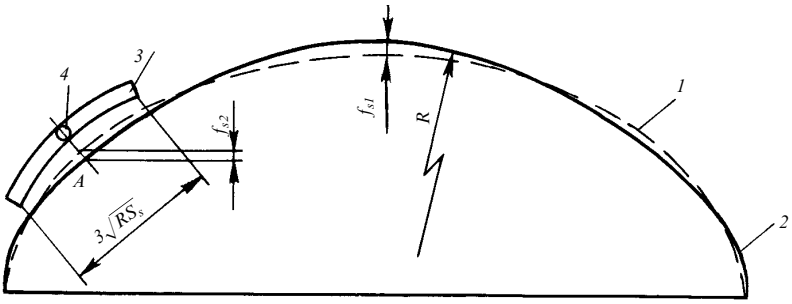


Fig. 3.8.2.2:
1 – theoretical shape of the shell meridian according to drawing; *2* – actual meridian shape; *3* – instrument base with base length of $3\sqrt{RS_s}$; *4* – instrument; *A* – measurement point; f_s – deviations (f_{s1} – bulge, f_{s2} – dent)

3.8.3 Shape measurements in way of openings.

The hull shape in way of coamings is checked by gauges with base length being the greatest of the values: $2a$, l, $3\sqrt{RS_s}$ for the cylinder or cone, and $2a$, $3\sqrt{RS_s}$ for the sphere and ellipsoid.

Checking is made at two mutually perpendicular sections (at each section on either side of the coaming). For shells stiffened by frames, the checking is made over the surface where the frames are not fitted. The maximum distance between the gauge and plating (see Fig. 3.8.3) shall not exceed:

allowable local camber f_1, f_s where no thickened plate is fitted;

allowable local camber multiplied by S_A/S where a thickened plate is fitted.

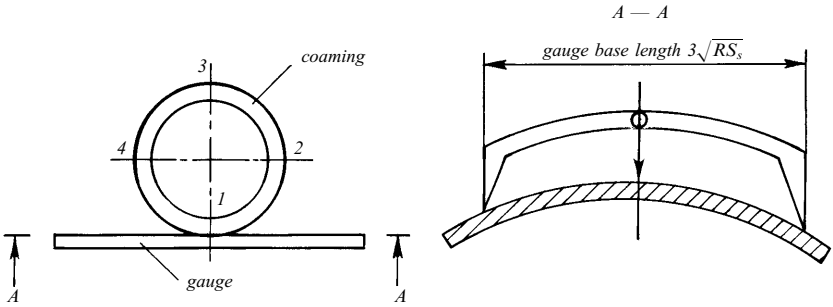


Fig. 3.8.3

3.9 EXTERNAL STRUCTURES

3.9.1 External pressure tanks and containers shall be designed using the same formulae as for the pressure hulls. Where joints are provided along the diameter of the said structures, structures of equivalent stiffness shall be bolted or studded together, structures of lesser stiffness shall rest upon those of greater stiffness (see Fig. 3.9.1), etc.

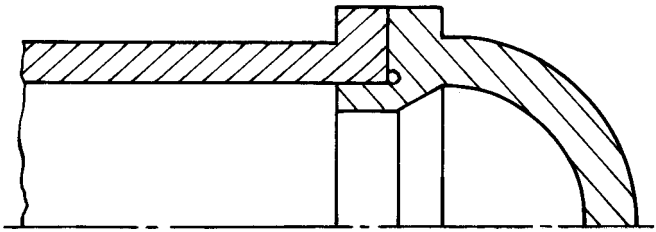


Fig. 3.9.1

The contact surfaces shall be fit together and preferably seated. Where it is impracticable, each mating flange shall be checked for buckling strength using the formulae for strengthened frame.

3.9.2 Attachments of external structures, lifting lugs, suspensions and other sources of concentrated forces acting on the hull shall be so designed that these forces are dispersed over areas of such size, at which the intensity of

additional load on the pressure hull does not exceed the acting working pressure.

It is advisable to transfer such loads to frames. Where no frames are fitted, smoothly tapered off brackets shall be fitted in two mutually perpendicular directions or the hull plating shall be thickened at the area where lugs and similar fittings are welded on. No doubling plates welded on all around shall be used for hull strengthening.

3.9.3 External structures, foundations and other hull structures not being part of the pressure hull shall be calculated for specified loads, which are adopted with due regard to salient features of their functioning.

Ballast tanks shall be calculated for strength proceeding from the pressures possible when blown through by compressed air, but not lower than 0,05 MPa.

3.9.4 Attachments of various equipment, "frame" skeleton members of the pressure hull and similar structures shall be calculated proceeding from the threefold overloading with respect to forces statically applied thereto.

3.9.5 Foundations and their machinery mounts, structures to ensure grounding of the manned submersible and other assemblies not carrying any considerable permanent load under normal operating conditions shall be calculated for conventional dynamic overloads due to jerks associated with lifting of the manned submersible and diving bell, mooring of the manned submersible, grounding, etc. If necessary, provision shall be made for local strengthening of the hull at places susceptible to impacts during lowering and lifting operations, mooring and grounding. Unless these conditions are specially stated, it is necessary to proceed from possible acceleration in any direction equal to 3*g*.

3.9.6 The manned submersibles shall be structurally protected to avoid damages to the pressure hull and other elements of vital importance like ballast systems. Externally mounted equipment such as thrusters, manipulators, etc. shall be designed to minimize risk of entanglement of fouling.

3.9.7 All elements of structural protection, which are designed for free flooding, shall be provided with openings in such a way that void spaces are fully flooded and vented.

4 HYDRAULIC TESTS

4.1 TESTING OF PRESSURE-RESISTANT STRUCTURES

4.1.1 All the pressure-resistant structures that are subject to external pressure P_t under operating conditions shall be tested upon manufacture by external pressure (in a chamber or by immersion into sea) equal to

$$P_t = 1{,}25p \text{ at } H_{op} \leqslant 300 \text{ m};$$

$$P_t = (1{,}25 - \frac{H_{op} - 300}{7000})p \text{ at } 300 < H_{op} \leqslant 1000 \text{ m};$$

$$P_t = 1{,}15p \text{ at } H_{op} > 1000 \text{ m}.$$

On special agreement with the Register, testing of the hull by external pressure before the equipment is installed may be replaced by two tests:

test of the manned submersible hull, prior to installation of the equipment, by internal pressure;

test of the manned submersible hull with the equipment installed by external pressure P_t.

In this case, information and substantiations, if necessary, on the selection of the internal test pressure value shall be submitted to the Register.

During two-stage tests, all the inspection operations as per 4.1.5 shall be performed after the internal pressure tests; following the external pressure tests, the visual examination of the manned submersible is carried out.

4.1.2 All the pressure-resistant structures, which can be under an internal pressure P_t in the course of operation, shall be tested by hydraulic internal pressure P_t equal to

$$P_t = (1{,}25 + \frac{R_{eH} - 400}{400})P \leqslant 1{,}5P$$

with the second addend in brackets taken into account only at $R_{eH} > 400$ MPa; where $P_t > 1{,}5p$ is obtained from the calculation, it shall be taken $P_t = 1{,}5p$.

Structures, in which pressure is generated by gas medium, shall be additionally tested by air pressure equal to P_t with pertinent safety precautions being observed. Where special gas mixtures are used, testing under the pressure P_t is carried out additionally with the equipment completely installed.

4.1.3 Hydraulic tests are carried out prior to installation of insulation and equipment with the possibility of inspecting the entire surface of the structure being provided.

For steel hulls, primer may be applied to the structures to be tested, excepting welds and adjacent portions of plating of not less than 80 mm wide.

4.1.4 Prior to hydraulic tests, all the welding operations on the pressure hull shall be completed. Any welding operations on the plating and reinforcements of the openings of hyperbaric hulls and compartments are forbidden. Upon completion of the hydraulic tests, only light structures and fasteners may be welded on to the plating, framing, reinforcements of openings and hull foundations subject only to external pressure, as well as to the framing and foundations of the hyperbaric compartments and hulls. The above structures shall be joined with the weld having the leg not more than the smallest of the values: 6 mm or 1/4 thickness of the pressure-resistant structure or foundation.

4.1.5 On completion of the hydraulic tests, the hull shape shall be remeasured and all the welds of the plating, reinforcements of openings and welds for connecting structures to the plating shall be subject to a liquid penetrant or magnetic particle inspection.

4.2 TESTING OF LIGHT STRUCTURES

Ballast tanks, enclosures and other structures that are not subject to the full working pressure are tested by water for pressure equal to 1,25 specified pressure, but not lower than 0,05 MPa.

5 STRUCTURE AND STRENGTH OF EXTERNAL HULLS MADE OF NON-METALLIC COMPOSITE MATERIALS

5.1 GENERAL

5.1.1 The requirements of this Chapter cover the external hulls made of non-metallic composite materials of the manned submersibles with the metal pressure hull and are applicable to the following structural components:

.1 main ballast tanks;

.2 keel region of the external hull of the submersible;

.3 superstructures and fencing arrangements of an access hatch;

.4 permeable parts providing streamlined form;

.5 fore and aft ends.

5.1.2 External hulls made of non-metallic composite materials are subject to the requirements of Part XVI "Hull Structure and Strength of Glass-Reinforced Plastic Ships and Boats" of the Rules for the Classification and Construction of Sea-Going Ships unless specifically stated otherwise in this Chapter.

5.1.3 The present Chapter specifies use of the glass-reinforced plastics of the types given in Appendix 1.

5.1.4 In addition to the materials mentioned, composite materials containing reinforcements and binders in alternative combinations, as well as with alternative reinforcement schemes may be used, provided that additional information on their mechanical properties and approval is submitted to the Register.

5.1.5 The transverse framing system is recommended for use in the external hulls. The longitudinal or combined system of framing is recommended for use in the structures contributing to the longitudinal strength. Selection of the framing system is substantiated by the Designer.

5.1.6 The frame spacing is specified by the Designer. In way of the pressure hull, where frames of the pressure and external hulls are in parallel planes, the frame spacing of the external hull shall be multiple to the pressure hull spacing.

In the fore and aft ends the frame spacing is recommended to be not more than 600 mm for the transverse and combined framing systems. For the longitudinal framing system the spacing is recommended to be not more than 1200 mm with the spacing of longitudinal stiffeners not more than 400 mm.

5.1.7 The glass-reinforced plastics given in lines 1 and 2 of Tables 1—3 of Appendix 3 are used for moulding shell plating, platforms, bulkheads, etc. The glass-reinforced plastics specified in lines 1 and 2 of Table 3 are used for the laminates of tank boundary structures.

5.1.8 The glass-reinforced plastics given in lines 2 and 3 of Tables 1 and 3 are used for framing members to be moulded in special devices and squeezed during manufacture.

5.1.9 Considering that in most cases structural members are dimensioned by the formulae, which include the member thickness, all the strength calculations are of checking nature demonstrating validity of the scantlings specified.

5.1.10 The main ballast tanks shall be provided with manholes to provide access to the tank. Such manholes may be dispensed with in independent tanks with capacity up to 100 l.

5.1.11 The external hull in way of the maximum half-breadth and alternating waterline shall be protected against accidental damages during mooring and handling operations. Such protection shall be provided in the form of side fenders.

Recommended design of side fenders is shown in Fig. 5.1.11.

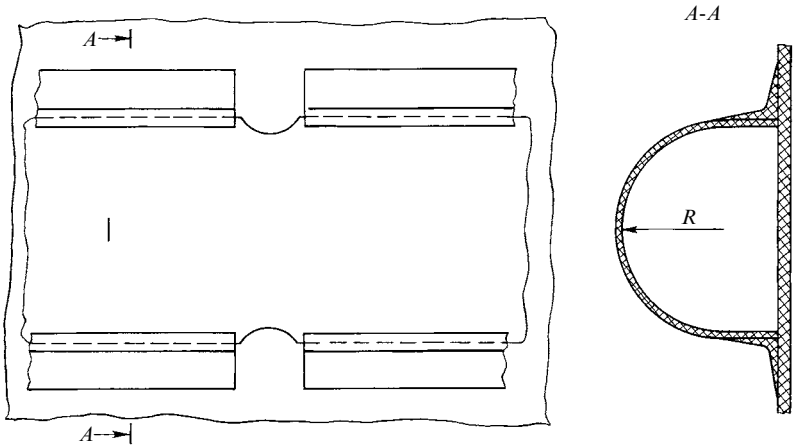


Fig. 5.1.11

Where the difference between the half-breadths on the maximum and alternating waterlines does not exceed 0,1 m, the side fender may be fitted in way of the alternating waterline only. In this case, the overall dimensions to the side fender are to overlap those on the maximum half-breadth.

5.1.12 In order to provide reliable operation of the main ballast tanks, their blowing system shall eliminate the possibility of exceeding the specified pressure.

5.1.13 Stated in the technical documentation for a glass-reinforced plastic structure shall be the thicknesses of structural members, as well as the number of layers and the warp orientation of the reinforcing material and the reinforcement scheme.

5.2 HULL LAMINATES

5.2.1 The minimum thickness of shell laminate shall be not less than 5 mm for a single-layer structure with any reinforcement scheme.

5.2.2 Any local increase in the hull laminate thickness shall be formed by additional reinforcing material layers alternated with the basic ones and uniformly distributed through the entire thickness of the laminate.

The warp of the additional layers, when the shell is moulded of types III and IV glass-reinforced plastics, is generally laid in the direction of layers with parallel orientation of the warp.

In some cases, local increase in the hull laminate thickness may be formed by additional glass fabric layers subject to special agreement with the Register.

5.2.3 Reduction in thickness shall be smooth. The extent of the thickness reduction zone shall exceed the difference of thicknesses by 4—10 times and be not less than 30 mm.

5.2.4 The minimum thickness of the watertight bulkhead laminates shall be not less than specified in 5.2.1.

5.3 FRAMING

5.3.1 T-shaped sections shall be used for external hull framing members.

Use may also be made of the inverted L-shaped section (see Fig. 5.3.1-1), rectangular section (see Fig. 5.3.1-2) and closed box section with filler if hydraulic strength of the filler complies with the specification requirements.

The framing members of inverted L-shapped and rectangular sections are designed so as to prevent buckling due to in-plane bending.

The filler material of the closed box section shall be approved by the Register.

5.3.2 The stiffener webs shall be bevelled at the edge in contact with the shell (see Fig. 5.3.2) to provide the reliable filling of the gap between the stiffener web and shell.

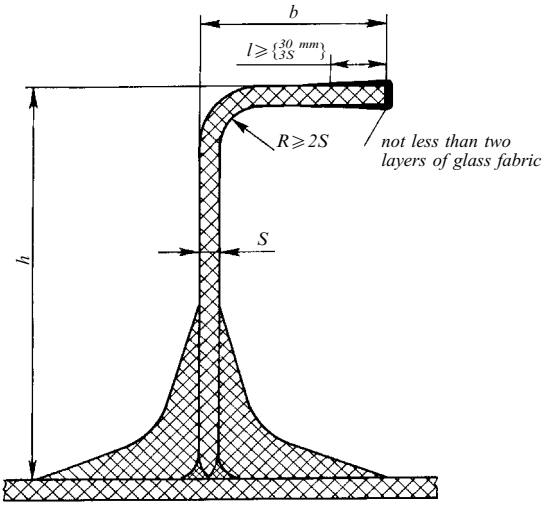


Fig. 5.3.1-1:

b	S
(0,5 . . . 1)h	(1/10 . . . 1/3)h

$h \geqslant 50$ mm

5.3.3 In all the hull framing members water courses and air holes (see Fig. 2.3.8, Part XVI "Hull Structure and Strength of Glass-Reinforced Plastic Ships and Boats" of the Rules for the Classification and Construction of Sea-Going Ships).

5.3.4 The ends of the hull framing members, edges of openings shall be moulded by not less than two layers of glass fabric laid over a distance of not less than three thicknesses of the structure, but not less than 30 mm from the edge.

The ends of the hull framing members, edges of small openings (of the maximum dimension not exceeding 100 mm) of the permeable structures, which do not contribute to the general longitudinal strength, may be coated by binding material.

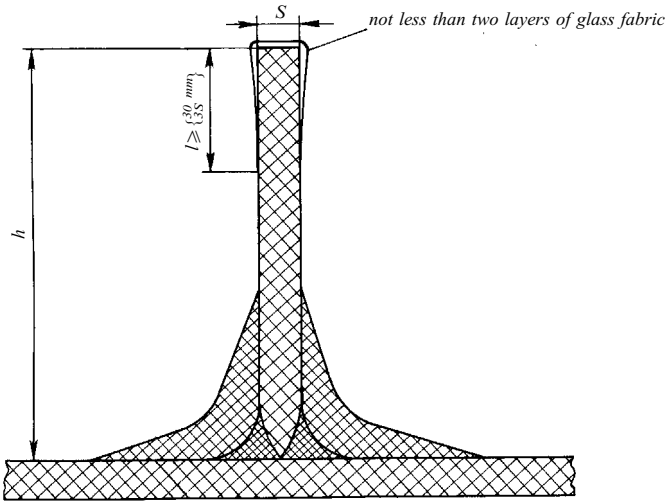


Fig. 5.3.1-2:
$S = (1/8+1/3)h$;
$h \geqslant 50$ mm

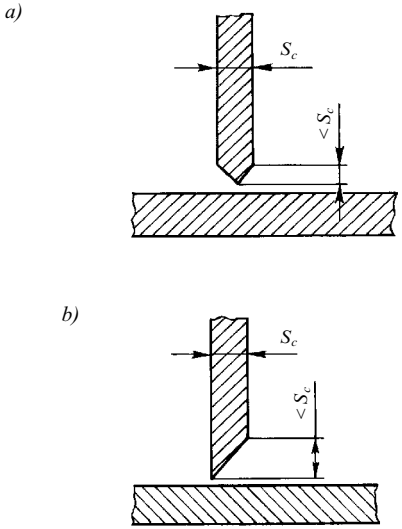


Fig. 5.3.2:
a — $S_c \geqslant 10$ mm; *b* — $10 \geqslant S_c > 3$ mm

5.4 OPENINGS IN STRUCTURES

5.4.1 Round openings cut in the shell, superstructure deck, stringers, platforms, external hull bulkheads with a diameter less than 100 mm are permitted to be not reinforced.

5.4.2 Round openings with a diameter of 100 mm and over shall be reinforced with additional layers of glass fabric of satin weave uniformly distributed between the basic layers so that the fabric warp is oriented in the same direction as the warp of the parallel glass fabric layers of the member being reinforced (see Fig. 5.4.2). The additional layers of glass fabric are permitted to be arranged in "packets" consisting of not more than three layers.

The thickness of the reinforcement shall be not less than that of the member being reinforced.

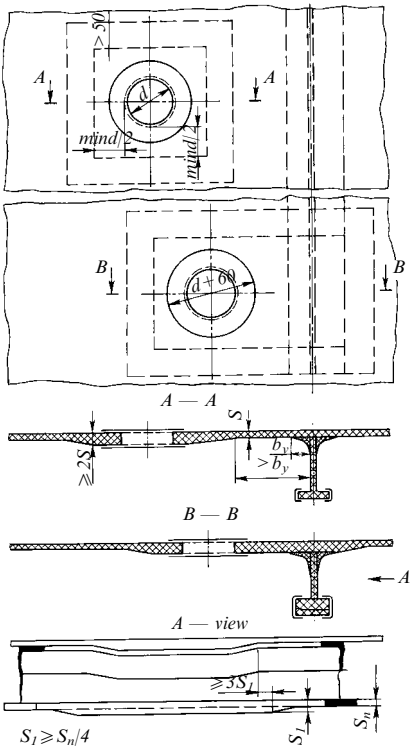


Fig. 5.4.2

Where the position of an opening is not specified beforehand, the reinforcement may be made with a strap of parallel reinforcement scheme.

The reinforcement design used for openings of other shape is subject to special consideration by the Register in each case.

5.4.3 Tank openings for installation of ventilation and blowing valves, regardless of their dimensions, shall be reinforced according to 5.4.2.

5.4.4 The design of ballast tank manholes and covers shall provide watertightness of the tanks. The manhole design may be made according to 5.4.2 or 2.8.6, Part XVI "Hull Structure and Strength of Glass-Reinforced Plastic Ships and Boats" of the Rules for the Classification and Construction of Sea-Going Ships.

5.4.5 Openings in framing member webs for the passage of cables, pipes, etc. having a diameter over 1/3 web depth shall be reinforced with straps according to 5.4.2.

5.5 JOINTS

5.5.1 Adopted classification of joints is given in Table 5.5.1.

Table 5.5.1

Class of joint	Type of members	Mutual arrangement (type of joint)	Material of structures to be joined Operational characteristic	adhe-sive joints
faste-nings	moulded	butt angle	glass-reinforced plastic structures joined together	strong-and-tight
	moulded and fastened	butt	glass-reinforced plastic structures joined with metal structures	strong-and-tight
	bolted screwed	butt angle	glass-reinforced plastic structures joined together or with metal structures	strong and strong-and-tight
	butt angle	butt angle		strong

5.5.2 Moulded connections of framing with the shell, as well as connections of bulkheads and platforms with the shell and with one another are made by means of matting-in angles:

.1 when a load of any intensity acts on the shell side;

.2 when a load with an intensity of no more than 0,05 MPa acts on the framing side;

.3 for connection of watertight bulkheads and platforms with one another and with the external hull shell, when a load with an intensity of not more than 0,05 MPa is applied.

5.5.3 Matting-in angles are formed in situ. A glass fabric of satin weave is used as reinforcement. The thickness of the matting-in angle is reduced towards the edges down to the thickness of one layer of the glass fabric. This reduction in thickness is achieved by a gradual increase in the width of the laid up tapes.One layer is permitted to be overlapped by the subsequent layer not less than 10 mm on each side.

5.5.4 The width of a matting-in angle flange shall be at least seven thicknesses of the framing member web or 30 mm, whichever is greater.

The design of the matting-in angle shall correspond to that shown in Fig. 5.5.4.

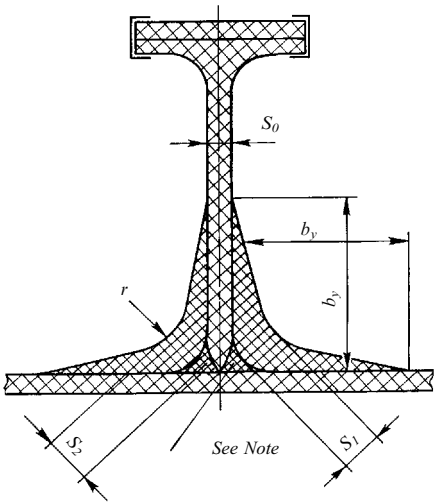


Fig. 5.5.4:
$b_y \geqslant 7S_0 \geqslant 30$ *mm*;
$S_1 \geqslant (1/8)b_y$;
$S_2 = (1/4)b_y$;
$r = S_2$

b_y, mm	30	40	50	60	70	80	90	100
S_1, mm	4	5	7	8	9	10	12	13
r, mm	8	10	13	15	18	20	23	25

N o t e . Space is filled with chopped fiber glass with binder.

5.5.5 The thickness of matting-in angles of bulkheads and platforms at connections with the shell or with one another shall be equal to the thickness of the bulkhead or platform laminate, whichever is greater.

The flange width and radius of the matting-in angle are determined by the formulae by $b_y > 100 + 7{,}5S$ and $r \geqslant S$, respectively, where S is the thickness of the bulkhead (platform) laminate.

5.5.6 The moulded connection of the shell up to 10 mm thick is made without edge preparation (see Fig. 5.5.6). Butts shall be located in the zone of the minimum bending moment at the general bending of the hull.

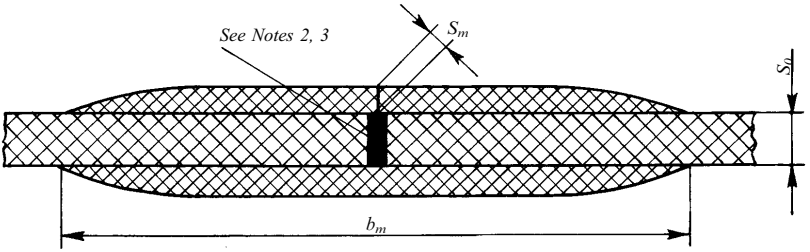


Fig. 5.5.6:
b_m = width of the matted-on strap; $b_m = 200 + 15S_0$, mm;
S_m = thickness of the matted-on strap; $0{,}8S_0 \geqslant S_m \geqslant 0{,}5S_0$; S_0 = thickness of the laminates to be connected.

Notes: 1. The glass fabric warp of the strap shall be oriented perpendicularly to the butt.
2. Space between the laminates is 1—2 mm.
3. Space is fully filled with chopped fiber glass with binder.

5.5.7 The moulded and fastened joints shall comply with the requirements of Fig. 5.5.7.

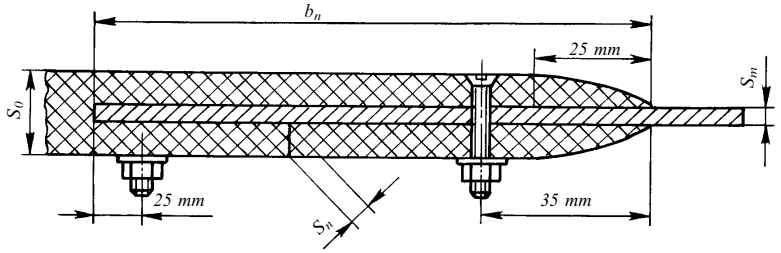


Fig. 5.5.7:
$b_n \geqslant 30S_n \geqslant 15S_0$;
$S_n \geqslant S_m \geqslant 0{,}5S_n > 3$ mm

In any case, the joint shall have two rows of bolts (screws) of 6—8 mm in diameter, spaced 100 mm apart and arranged in staggered order. Washers of not less than 2,5 times the bolt diameter and not less than 1 mm thick are fitted under the bolt head and nut.

Flush headed screws may be fitted without additional washers (plates).

5.5.8 Fastenings shall comply with the following requirements:

.1 diameter of the fastener is determined on the assumption that

$$S \geqslant d \geqslant 0{,}6S$$

where S is thickness of the thickest laminate of those to be joined;

.2 distance between the fastener axis and the laminate edge shall be not less than three fastener diameters for types I and II glass-reinforced plastics and not less than 2,5 times the fastener diameter, for types III and IV glass-reinforced plastics;

.3 fasteners shall be spaces within the range of 3—8 fastener diameters;

.4 fastening components shall be protected with an efficient anticorrosive coating or made of corrosion-resistant materials (see 3.16, Part XIII "Materials" of the Rules for the Classification and Construction of Sea-Going Ships);

.5 for bolted connections, metal straps of thickness being 0,1 times bolt diameter, but not less than 1,5 mm thick and of a width equal to that of the connection shall be fitted under the bolt head and nut (for connections of low-stressed structures, the washers of an increased diameter complying with the State standards in force may be fitted);

.6 for screw connections of glass-reinforced plastic structures with metal structures, a metal strap of a width equal to that of the connection is fitted under the screw head; for flush headed screws – of a thickness being to not less than the head height; for cup-head screws – of a thickness being not less than 15 mm thick; for cup-head bolts in low-stressed structures, metal washers of an increased diameter complying with the State standards in force may be fitted.

5.5.9 Strong-and-tight joints, as well as fastenings, which do not comply with the requirements of 5.5.8, are subject to special consideration by the Register.

RECOMMENDED TYPES OF GLASS-REINFORCED PLASTICS

The following types of glass-reinforced plastic on the basis of glass fabric of satin weave (harnessing 8/3) are recommended for use in the external hull structures:

type I – with parallel orientation of layers, i.e. all glass fabric layers are laid with their warp in one direction;

type II – with cross orientation of layers, i.e. 50 per cent of all layers are laid at 90° to the direction of the parallel warp portion, all the layers of parallel orientation being alternately laid throughout the entire thickness of the laminate.

type III – with parallel-and diagonal reinforcement, i.e. 50 per cent of the glass fabric layers are laid with their warp in one direction, while 25 per cent of the layers are laid at +45° to the direction of a parallel warp portion, 25 per cent of the layers are laid at −45° to same, all the layers of parallel orientation being uniformly distributed between the layers of diagonal orientation and alternate with the latter;

type IV – the same as the type III, but all the layers of diagonal reinforcement shall occupy the middle portion of the laminate thickness while those of parallel reinforcement shall form outer and inner faces of the laminate.

COEFFICIENTS FOR SHELL STRENTH CALCULATIONS

Table 1

u	K_2^0	K_1	K
> 4,5	1,00	$0,5+1,54u/(u+\beta)$	$0,85\beta/(u+\beta)$
0,6—4,5	$1-F_u/(1+\beta F_1)$	$0,5+F_2/(1+\beta F_1)$	$0,85\beta F_1/(1+\beta F_1)$
< 0,6	$(\beta+0,15)/(\beta+1)$	$0,5+1,03u^2/(1+\beta)$	$0,85\beta/(1+\beta)$

Table 2

Function	External pressure	Internal pressure
F_1	$\sqrt{1-1/4u^2}\ [(ch2u_1-\cos 2u_2)/(u_2 sh2u_1+ +u_1 \sin 2u_2)]$	$(ch2u-\cos 2u)/[u(sh2u+\sin 2u)]$
F_2	$1,54(u_2 sh2u_1-u_1 \sin 2u_2)/(u_2 sh2u_1+u_1 \sin 2u_2)$	$1,54(sh2u-\sin 2u)/(sh2u+\sin 2u)$
F_4, u_1, u_2	$1,7(u_1 chu_1 \sin u_2+u_2 shu_1 \cos u_2)/(u_2 sh2u_1+u_1 \sin 2u_2)$ $u_1=u\sqrt{1-1/2u}$, $u_2=u\sqrt{1+1/2u}$	$1,7(chu \sin u+shu \cos u)/(sh2u+\sin 2u)$

Instead of using the formulae of Table 1, the values of K_2^0, K, K_1, in case when an external pressure is exerted, may be obtained from Figs. 1, 2 and 3. Diagrams for K_2^0 and K_1 with an error on the safe side may also be used in case when an internal pressure is exerted.

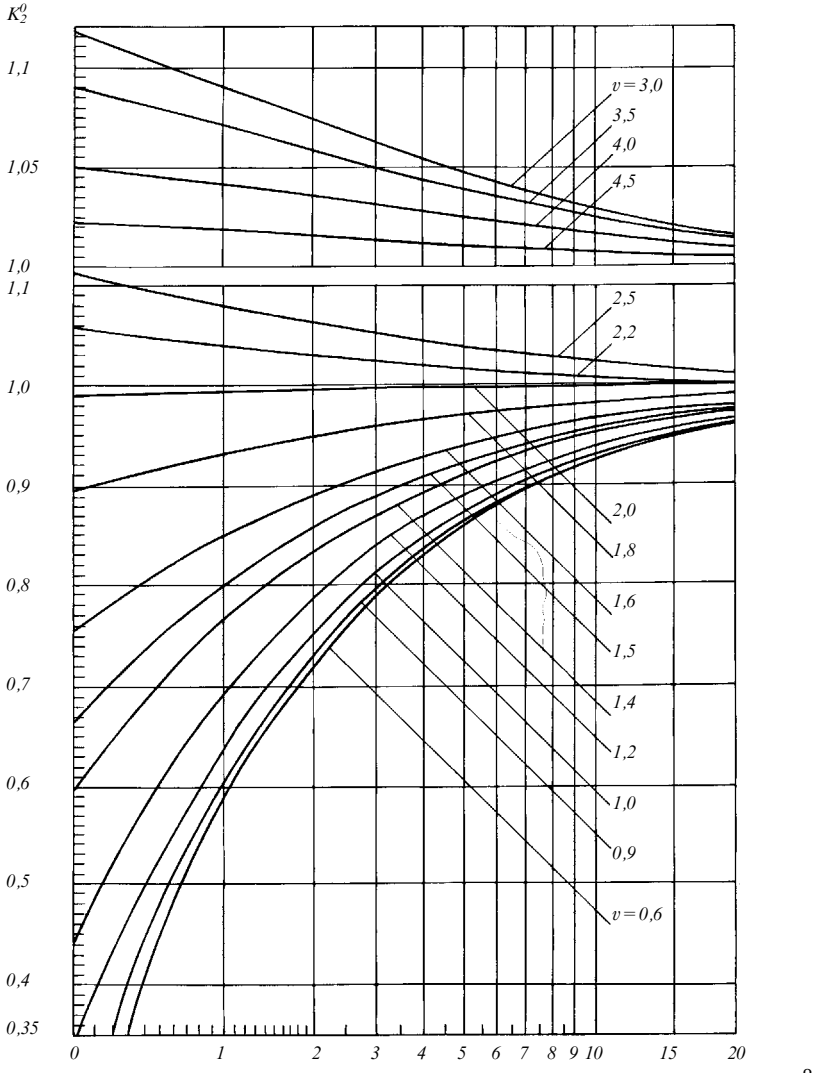
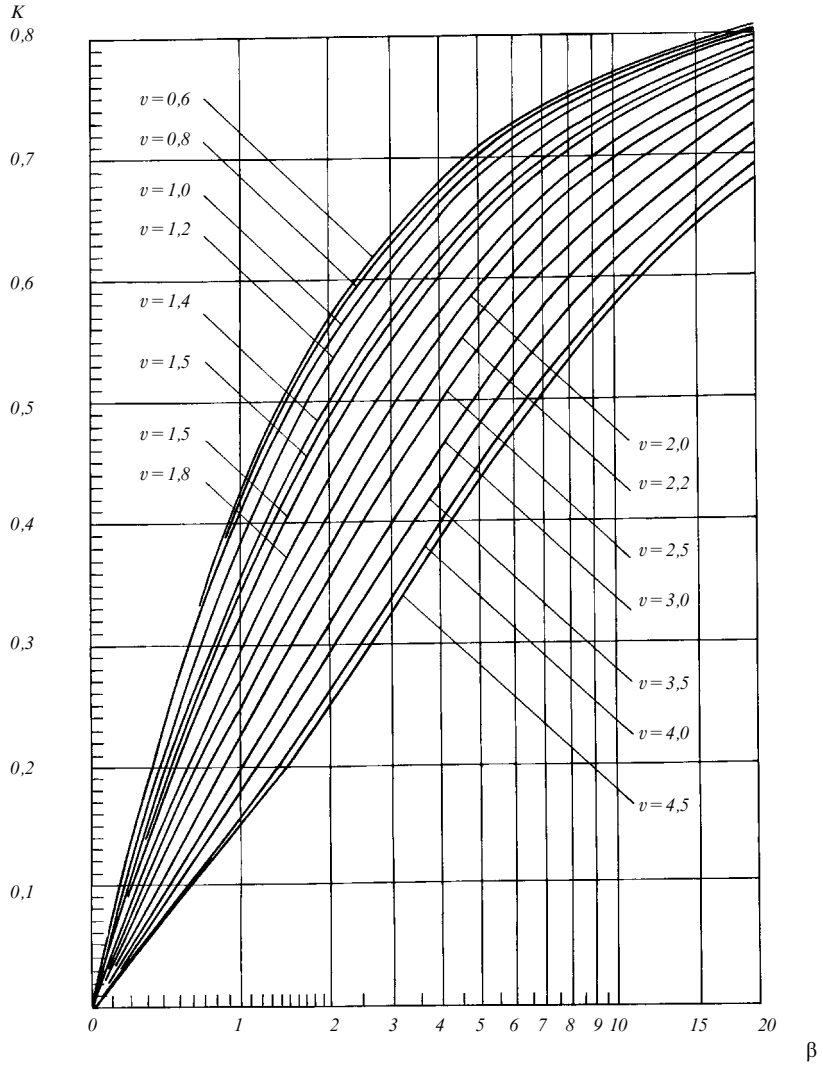

K_2^0
1,1
1,05
1,0
1,1
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,35
v = 3,0
3,5
4,0
4,5
2,5
2,2
2,0
1,8
1,6
1,5
1,4
1,2
1,0
0,9
v = 0,6
0
1
2
3
4
5
6
7
8
9
10
15
20
β

Fig. 1


K
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
v = 0,6
v = 0,8
v = 1,0
v = 1,2
v = 1,4
v = 1,5
v = 1,5
v = 1,8
v = 2,0
v = 2,2
v = 2,5
v = 3,0
v = 3,5
v = 4,0
v = 4,5
0
1
2
3
4
5
6
7
8
9
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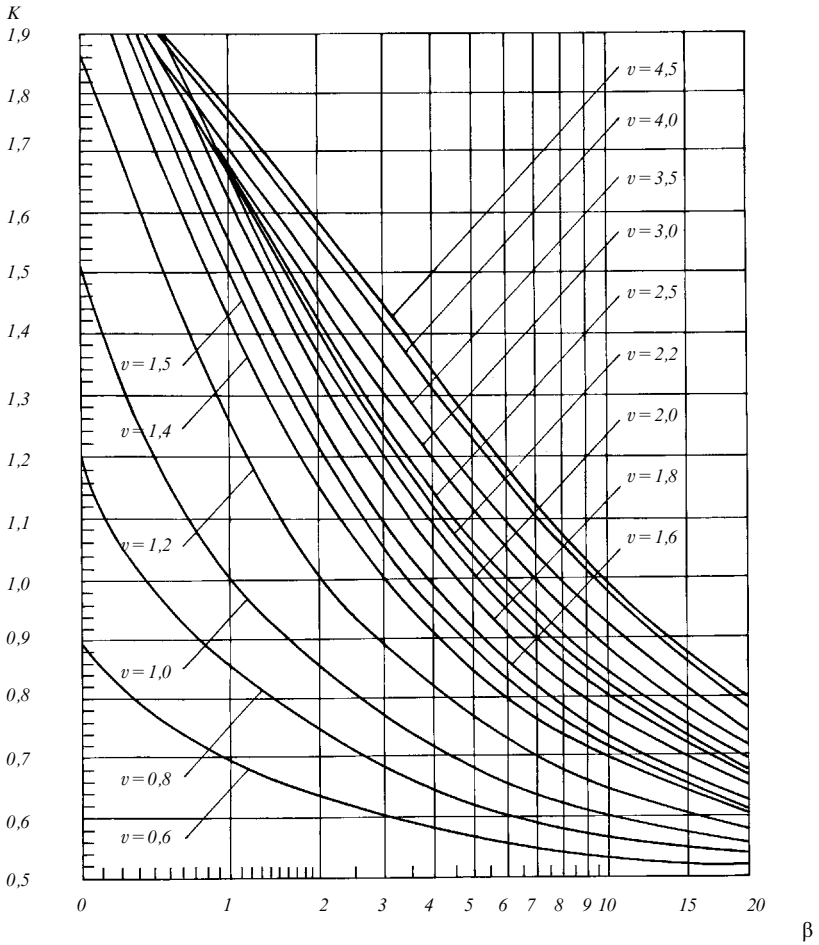
15
20
β

Fig. 2


K
1,9
1,8
1,7
1,6
1,5
1,4
1,3
1,2
1,1
1,0
0,9
0,8
0,7
0,6
0,5
v = 4,5
v = 4,0
v = 3,5
v = 3,0
v = 2,5
v = 2,2
v = 2,0
v = 1,8
v = 1,6
v = 1,5
v = 1,4
v = 1,2
v = 1,0
v = 0,8
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β

Fig. 3

APPENDIX 3

PHYSICAL AND MECHANICAL PROPERTIES OF GLASS-REINFORCED PLASTICS

Physical and mechanical properties of glass-reinforced plastics depending on the reinforcement schemes given in Appendix 1 shall comply with the values given in Tables 1—3.

Table 1

Physical and mechanical properties of glass-reinforced plastics with glass fabric of satin weave and parallel orientation, and a polyester binder (type I). Tested in dry condition at 20 °C

Nos.	Type	Glass content by mass, per cent	Average density, t/m^3	Young's modulus, MPa	Shear modulus in laminate, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate, MPa
1	I_1	49	1,65	$\frac{1{,}80 \times 10^4}{1{,}20 \times 10^4}$	$0{,}30 \times 10^4$	$\frac{0{,}15}{0{,}10}$	$\frac{300}{180}$	$\frac{270}{180}$	90
2	I_2	52	1,70	$\frac{1{,}90 \times 10^4}{1{,}30 \times 10^4}$	$0{,}32 \times 10^4$	$\frac{0{,}15}{0{,}10}$	$\frac{320}{190}$	$\frac{290}{180}$	100
3	I_3	55	1,75	$\frac{2{,}00 \times 10^4}{1{,}35 \times 10^4}$	$0{,}33 \times 10^4$	$\frac{0{,}15}{0{,}10}$	$\frac{350}{210}$	$\frac{330}{210}$	100

Notes: 1. Young's modulus is given for tension-and-compression.
2. Shown in the numerator are the values for the warp direction and in the denominator, for the weft direction.
3. For the glass fabric the ratio of breaking strength in the warp and weft direction is 2:1.

Table 2

Physical and mechanical properties of glass-reinforced plastics with glass fabric of satin weave and cross weave and cross orientation, and a polyester binder (type II). Tested in dry condition at 20 °C

Nos.	Type	Glass content by mass, per cent	Average density, t/m^3	Young's modulus, MPa	Shear modulus in laminate, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate, MPa
1	II_1	49	1,65	$1,50 \times 10^4$	$0,30 \times 10^4$	0,15	240	220	90
2	II_2	52	1,70	$1,60 \times 10^4$	$0,32 \times 10^4$	0,15	250	240	100
3	II_3	55	1,75	$1,70 \times 10^4$	$0,33 \times 10^4$	0,15	280	270	100

Notes: 1. Young's modulus is given for tension-and-compression.
2. For the glass fabric the ratio of breaking strength in the warp and weft direction is 2:1.

Table 3

Physical and mechanical properties of glass-reinforced plastics with glass fabric of satin weave and cross weave and parallel-and-diagonal reinforcement, and a polyester binder (types III and IV). Tested in dry condition at 20 °C

Nos.	Type	Glass content by mass, per cent	Average density, t/m^3	Young's modulus, MPa	Shear modulus in laminate, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate, MPa
1	III_1 IV_1	49	1,65	$\frac{1,40 \times 10^4}{1,10 \times 10^4}$	$0,47 \times 10^4$	$\frac{0,30}{0,24}$	$\frac{240}{160}$	$\frac{220}{170}$	115
2	III_2 IV_2	52	1,70	$\frac{1,60 \times 10^4}{1,20 \times 10^4}$	$0,52 \times 10^4$	$\frac{0,30}{0,24}$	$\frac{250}{170}$	$\frac{240}{180}$	125
3	III_3 IV_3	55	1,75	$\frac{1,70 \times 10^4}{1,30 \times 10^4}$	$0,57 \times 10^4$	$\frac{0,30}{0,24}$	$\frac{270}{180}$	$\frac{260}{190}$	135

Notes: 1. Young's modulus is given for tension-and-compression.
2. Shown in the numerator are the values for the warp direction and in the denominator, for the weft direction.
3. For the glass fabric the ratio of breaking strength in the warp and weft direction is 2:1.

APPENDIX 4

GUIDELINES FOR STRENGTH CALCULATIONS

1 GENERAL REQUIREMENTS

1.1 The external hull of the manned submersible shall provide resistance to loads acting while in service:

in submerged condition;

when sailing in high sea;

when the submersible is recovered aboard the support ship under specified conditions;

when the submersible is carried on board the support ship,

when the submersible strikes against the support ship side and in case of other obstacles.

1.1.1 When the submersible sails in submerged position, as well as in high sea, the values of the maximum bending moments and shear forces are determined proceeding from the displacement and principal particulars of the submersible, in accordance with the general methods of structural mechanics.

1.1.2 When the submersible is recovered aboard the support ship, the values of the maximum bending moments and shear forces shall be determined with due regard to the water masses filling the permeable volumes, as well as for the dynamic overloads due to jerks associated with lifting. The dynamic factor is determined proceeding from the high sea conditions, parameters of the support ship motions and parameters of the lifting gear. Where these parameters are unknown or are not specially stated, the external hull structures involved in general bending shall be calculated proceeding from the requirements of 3.2, Part II "Hull" of the Rules without regard to the added water masses.

1.1.3 The maximum bending moments and shear forces in case when the submersible is carried on board the support ship shall be determined with due regard to the inertia forces proceeding from the parameters of the support ship motions under specified conditions.

1.2 In strength calculations, the greatest load of the listed ones shall be assumed as the design load. When loads of different categories are simultaneously acting on the structures, calculation shall be carried out for such combination of these loads, which results in the greatest stresses and strains arising in the structural members.

1.3 The intensity of the design load for ballast tanks is determined by the formula

$$P_d = kP_t \tag{1.3-1}$$

where P_t = test pressure determined according to 4.2;
k = coefficient determined by the formula

$$k = \max\begin{Bmatrix} 1{,}1(1+0{,}01H/P_t) \\ 1{,}25 \end{Bmatrix} \tag{1.3-2}$$

where H = tank height, m.

1.4 The allowable stresses in the hull structural members shall not exceed the values determined by the formulae:

$$[\sigma] = R_m/n_b\ ; \tag{1.4-1}$$

$$[\tau] = \tau_m/n_b \tag{1.4-2}$$

where R_m, t_m = the ultimate compression (tensile) or shear strength in dry condition, respectively, at t = 20 °C, MPa;
n_b = safety factor determined from Table 1.4.

Table 1.4

Structure type	Nature of the load involved		
	Instantaneous loads	Statically variable loads	Permanent loads
Structures contributing to general and local strength	1,8	2,3	3,2
Structures contributing to local strength	1,6	2,0	2,8
Non-essential structures	1,3	1,7	2,4

Notes: 1. The values of the safety factor are given at the temperature of the structures being not higher than 30 °C; in cases where the structures are heated to 60 °C, the safety factors shall be increased by 1,4 times. The values of the safety factors for intermediate temperatures shall be determined by linear interpolation.

2. In case where the structure is exposed to intense solar radiation, the safety factors shall be increased by 1,1 times.

1.5 The design values of the Young's and shear moduli are taken equal to:

$$E_d = n_m E; \tag{1.5-1}$$

$$G_d = n_m G \tag{1.5-2}$$

where E and G = values of the Young's and shear moduli determined for dry material at 20 °C, MPa;
n_m = coefficient accounting for the change in the moduli due to expose to the external effects: at instantaneous load n_m = 0,9; at permanent load n_m = 0,6.

1.6 The stability factor for the hull structural members shall not be less than 1,5. In case of general bending, for the shell stiffened by framing, buckling of the external hull plates may be permitted.

1.7 The allowable deflection values calculated with due account of shear are taken to be 1/50 of span for the framing members. The deflections of the shell and ends, if these are considered as cantilever structures, can be neglected.

2 RECOMMENDATIONS FOR STRENGTH CALCULATIONS

2.1 Flat ballast tank plates, bulkhead laminates (glass reinforced plastics of types III and IV) are calculated as flat plates rigidly fixed on the supporting contour under the action of evenly distributed load, according to the procedure for calculation of appropriate isotropic plates.

The load value is determined in accordance with 1.3. In doing so, it is necessary to refer to the average values of the Young's modulus and Poisson's ratio.

At $|\lg V_1| > 2{,}42$ the plate is considered to be an absolutely rigid plate, at $|\lg V_1| < 2{,}42$ – as ultimately rigid plate.

The value of V_1 is determined by the formula

$$V_1 = (1600/\sqrt{K})(S_0/b)^4(\overline{E}_{1d}/P_d) \qquad (2.1)$$

where $K = F/(F + S_0)$ = bracing coefficient that defines the possibility for the greater sides of the supporting contour to approach each other;

F = sectional area of the structural members (bracing members) keeping the sides concerned of the supporting contour from approaching each other, and referenced to the supporting contour length, cm;

b = length of the smaller side of the supporting contour, cm;

S_0 = plate thickness, cm;

P_d = design pressure, MPa;

$\overline{E}_{1d} = E_m/(1 - \nu_m^2)$ = reduced design Young's modulus of the material, MPa;

$E_m = (E_{1d} + E_{2d})/2$ = average design Young's modulus of the material, MPa;

$\nu_m = (\nu_1 + \nu_2)/2$ = average Poisson's ratio;

E_{1d}, E_{2d} = design Young's moduli in warp direction and parallel portion weft direction, respectively, MPa;

ν_1, ν_2 = Poisson's ratios in warp and weft direction, respectively.

2.2 Bending strains and stresses of the absolutely rigid plates made of glass reinforced plastic shall be calculated proceeding from their fixation along the contour in accordance with Fig. 2.2.

Deflection at the plate center is determined by the formula

$$\omega = k_1 P_d b^4/(E_d S^3) \qquad (2.2\text{-}1)$$

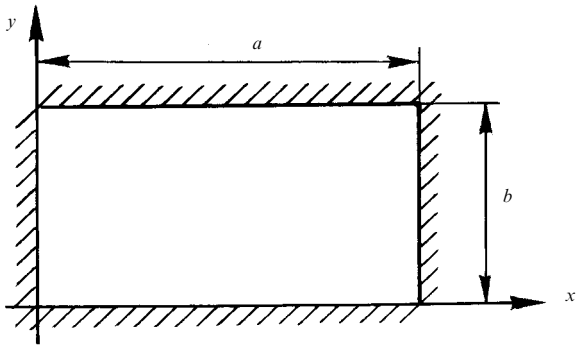

Fig. 2.2

where E_d = design Young's modulus of the material equal to the modulus in warp direction (smaller side).

Bending moment at the plate center, at the section parallel to y-axis (see Fig. 2.2) shall be determined by the formula

$$M_1 = k_2 P_d b^2. \tag{2.2-2}$$

Bending moment at the plate center, at the section parallel to x-axis (see Fig. 2.2) shall be determined by the formula

$$M_2 = k_3 P_d b^2. \tag{2.2-3}$$

Bending moment at the middle of the greater side of the supporting contour, at the section parallel to x-axis (see Fig. 2.2) shall be determined by the formula

$$M_2' = k_5 P_d b^2. \tag{2.2-4}$$

The values of coefficient k are given in Table 2.2 for isotropic plates, as well as for orthotropic plates with the ratio between the elastic moduli in the smaller and greater plate side direction being equal to 1,0 (as applied to the glass-reinforced plastic of type II) and 1,5 (as applied to the glass-reinforced plastic of type I with the warp orientation along the smaller side).

In case where the plates are made of the glass-reinforced plastic of types III and IV, they are considered as isotropic plates.

Where other types of plate fixation on the supporting contour are used, the plates may be calculated by the formulae for isotropic plates, and the average values of the elastic characteristics shall be taken as the design ones.

Table 2.2

k	Plate	a/b							
		1,00	1,25	1,50	1,75	2,00	2,50	3,00	
k_1	Isotropic	0,0138	0,0200	0,0241	0,0263	0,0276	0,0278	0,0279	0,0284
	Orthotropic (type II)	0,0153	0,0210	0,0255	0,0275	0,0290	0,0307	0,0312	0,0320
	Orthotropic (type I)	0,0168	0,0227	0,0266	0,0283	0,0299	0,0299	0,0309	0,0320
k_2	Isotropic	0,0229	0,0228	0,0201	—	—	—	—	—
	Orthotropic (type II)	0,0210	0,0235	0,0210	—	—	—	—	—
	Orthotropic (type I)	0,0213	0,0196	0,0174	—	—	—	—	—
k_3	Isotropic	0,0229	0,0315	0,0386	0,0383	0,0399	0,0404	0,0405	0,0417
	Orthotropic (type II)	0,0240	0,0330	0,0375	0,0395	0,0408	0,0415	0,0418	0,0425
	Orthotropic (type I)	0,0259	0,0344	0,0384	0,0400	0,0410	0,0415	0,0419	0,0425
k_5	Isotropic	0,0517	0,0640	0,0753	0,0814	0,0829	0,0880	0,0832	0,0833
	Orthotropic (type II)	0,0540	0,0670	0,0783	0,0820	0,0830	0,0833	0,0838	0,0850
	Orthotropic (type I)	0,0580	0,0698	0,0794	0,0825	0,0832	0,0835	0,0840	0,0850

Note. The Table gives the coefficients for orthotropic plates, the warp of which is oriented along the smaller side.

2.3 Calculation of strains and stresses of a flat cylindrical panel under the action of internal pressure[1].

Deflection at the middle of the panel is determined by the following formula:

$$\omega(o) = +(P_d R^2 / E_{2d} S) k_0. \tag{2.3-1}$$

Stress at the middle of the panel is determined by the following formulae:
at longitudinal section:

$$\sigma_2(o) = (P_d R / S) \overline{k}_1; \tag{2.3-2}$$

[1] Where the ratio of the generatrix length to the directrix length $\geqslant 0{,}7$.

in transverse section:

$$\sigma_2(o) = (P_d R/S)(\overline{k}_4 + \nu_2 \overline{k}_1). \tag{2.3-3}$$

Stress on the supporting contour is calculated by the following formulae: at longitudinal section (at the mid-point of the rectilinear edge):

$$\sigma_2(\beta) = (P_d R/S)\overline{k}_2; \tag{2.3-4}$$

at transverse section (at the mid-point of the curvilinear edge):

$$\sigma_1^{(1)} = (P_d R/S)\overline{k}_3 \tag{2.3-5}$$

where P_d = design internal pressure, MPa;
R = median radius of curvature of the panel, cm;
S = thickness of the panel plating, cm;
$\overline{E}_{2d} = E_{2d}/(1-\nu_1\nu_2)$ = reduced design Young's modulus of the panel material along the directrix, MPa;
ν_1, ν_2 = Poisson's ratios along the generatrix and along the directrix, respectively;
$\overline{k}_0$, $\overline{k}_1$, $\overline{k}_2$, $\overline{k}_3$, $\overline{k}_4$ = coefficients determined by the formulae:

$$\overline{k}_1 = 1 + (S\sin\beta/2R\text{æ}_4)[S/6R \pm (1-\text{æ}_5)]; \tag{2.3-6}$$

$$\overline{k}_2 = 1 + (S\sin\beta/2R\text{æ}_4)[S\cos\beta/6R \pm 1]; \tag{2.3-7}$$

$$\overline{k}_3 = (F_{tb}/h_{bp}R) \pm 3\overline{K}/SRd^2; \tag{2.3-8}$$

$$\overline{k}_4 = (F_{tb}/h_{bp}R) \pm (6\overline{K}/SRd^2)l^{-4}(2\sin u + \cos u); \tag{2.3-9}$$

$$\overline{k}_0 = 1 + \text{æ}_6 - (\text{æ}_5/\text{æ}_4)\sin\beta. \tag{2.3-10}$$

where $\text{æ}_5 = \sin\beta/\beta$; (2.3-11)

$$\text{æ}_4 = (\sin^2\beta/\beta) - \frac{1+\rho}{2}(\beta + \cos\beta\sin\beta); \tag{2.3-12}$$

$$\text{æ}_6 = (\sin^2\beta/\text{æ}_4) - [\cos\beta/\beta + \frac{1+\rho}{2}\sin\beta]\cos\beta; \tag{2.3-13}$$

$$\rho = S^2/12R^2; \tag{2.3-14}$$

$$\alpha = \sqrt[4]{\overline{E}_{2d}3/\overline{E}_{1d}R^2S^2} = \sqrt{(E_{2d}/E_{1d})(3/R^2S^2)}; \tag{2.3-15}$$

$u = (l/2)d$;

where β = half angle of the cylindrical panel development, deg;
F_{tb} = transverse bulkhead area, cm^2;
h_{bp} = transverse bulkhead perimeter, cm;
l = panel length, cm.

In Formulae (2.3-6) and (2.3-9) the sign "+" refers to the outer and the sign "–" to the inner surface of the sheathing, while in Formulae (2.3-7)

and (2.3-8) the sign "+" refers to the inner and the sign "–" to the outer surface of the sheathing.

2.4 Determination of strains and stresses in the cylindrical panel stiffened by frames under the action of internal pressure.

Deflection in the mid-point of the spacing is determined by the following formula:

$$w_0 = (P_d R^2 / E_{2d} S) F_1. \tag{2.4-1}$$

Stress in the sheathing at the longitudinal section at the mid-point of the spacing is determined by the formula

$$\sigma_2 = (P_d R / S) F_2. \tag{2.4-2}$$

Stress in the sheathing at the transverse section in way of the frame is determined by the formula

$$\sigma_1 = (P_d R / S) F_3. \tag{2.4-3}$$

The greatest shear force is determined by the formula

$$N_1 = (P_d l_d / 2) F_4. \tag{2.4-4}$$

Auxiliary functions of F are determined by the following formulae:

$$F_1 = 1 - [4uR^2(chu\sin u + shu\cos u)] / [2uR^2(sh2u + \sin 2u + AE_{2d}S(ch2u - \cos 2u)]; \tag{2.4-5}$$

$$F_2 = F_1 + \nu_2\{\pm 3l_d^2 R(chu\sin u - chu\cos u) /$$

$$/(Su[2R^2u(sh2u + \sin 2u) + E_{2d}Sl_dA(ch2u - \cos 2u)]) + F_{tb}/(h_{bp}R)\}; \tag{2.4-6}$$

$$F_3 = \pm(3/2)(l_d^2 R / Su)(sh2u - \sin 2u) /$$

$$/[2R^2u(sh2u + \sin 2u) + AE_{2d}Sl_d(ch2u - \cos 2u)] + F_{tb}/(h_{bp}R); \tag{2.4-7}$$

$$F_4 = 2R^2(ch2u - \cos 2u) / [2uR^2(sh2u + \sin 2u) + AE_{2d}l_dS(ch2u - \cos 2u)]. \tag{2.4-8}$$

Compliance of the frame A is determined by the formula

$$A = (2R_{fr}^2 / E_{frd}F_{fr})[1 + æ_6 - æ_5/æ_4)\sin\beta]\{1 + l_{1u}(sh2u + \sin 2u) / [l_d(ch2u - \cos 2u)]\} \times$$

$$\times \{1/[(R_{fr}/R)^2(E_{2d}/E_{frd})(Sl_1/F_{fr}) + 1]\} \tag{2.4-9}$$

where $u = (l_d/2)\sqrt[4]{3E_{2d}(1 - \nu_1\nu_2)/(E_{1d}R^2S^2)}$. (2.4-10)

Here E_{2d} = design Young's modulus of the sheathing material along the directrix, MPa;
E_{1d} = design Young's modulus of the sheathing material along the generatrix, MPa;
ν_1, ν_2 = Poisson's ratios;
R = radius of the median sheathing surface, cm;
S = sheathing thickness, cm;
$l_d = l - l_1$ = design spacing length, cm

where l = spacing, determined by the formula

$$l_1 = S_f + (1/2)b_m; \tag{2.4-11}$$

S_f = frame web thickness, cm;
b_m = mating-in angle flange width, cm;
F_{f2d} = design Young's modulus of the frame material assumed as the basic one, MPa;
R_{fr} = radius of the frame neutral axis (see Fig. 2.4), cm;

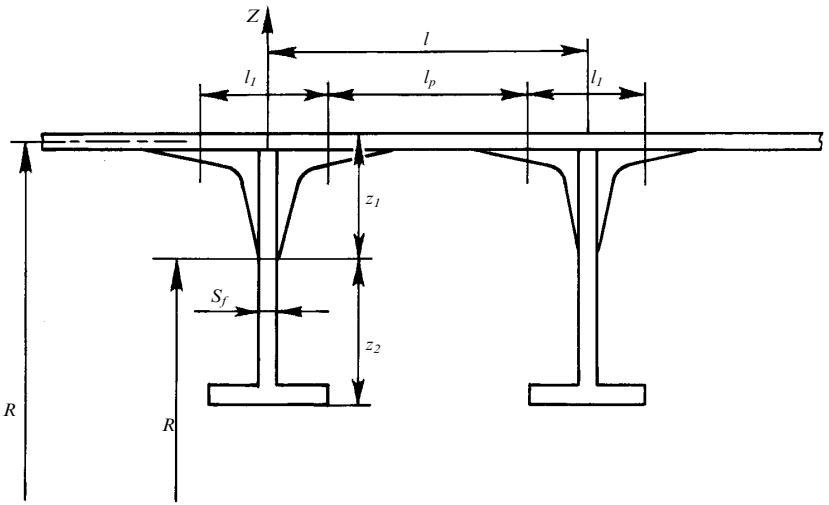

Fig. 2.4

F_{fr} = area of the frame with effective flange, cm^2;
$æ_4$, $æ_5$, $æ_6$ are determined by Formulae (2.3-11)—(2.3-13)

where $\rho = J_{fr}/F_{fr}R_{fr}^2$; (2.4-12)
J_{fr} = moment of inertia of the frame section with effective flange equal to l_1, cm^4.

Stress of the frame at fixation is determined by the formula

$$\sigma_{fr} = (P_d R_{fr}/F_{fr})[1 + \rho \sin\beta \cos\beta/æ_4 + [(Z_i \sin\beta/R_{eH} æ_4)](\cos\beta - \sin\beta/\beta)]\varphi_i \tag{2.4-13}$$

where $æ_4$ is determined by Formula (2.3-12);
β = half angle of frame development, deg;

Z_i = distance from the frame neutral axis to extreme fibres, cm;
$\varphi_i = E_{id}/E_{frd}$ = reduction factor;
E_{id} = design Young's modulus of the frame structure material, MPa.

In determination of the geometric parameters of the frame section (area, moment of inertia, etc.) account shall be taken of the difference between the elastic moduli of the structural member components that results from both the different reinforcement patterns applied and the different extent, to which the material properties change under the effect of the environmental conditions.

The design Young's modulus of the frame material E_{frd} is assumed as a reference modulus.

PART III. EQUIPMENT, ARRANGEMENTS AND OUTFIT

1 GENERAL

1.1 APPLICATION

The requirements of the present Part of the Rules apply to equipment, arrangements and outfit of the manned submersibles, passenger submersibles, ship's diving systems, evacuation compression chambers.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to the general terminology of the Rules are given in the General Regulations and in Part I "Classification" of the Rules for the Classification and Construction of Sea-Going Ships.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions on survey of equipment, arrangements and outfit of the manned submersibles, ship's diving systems and passenger submersibles are given in the General Regulations and in Part I "Classification".

1.3.2 Subject to survey by the Register during manufacture, installation and testing of the manned submersibles, passenger submersibles, ship's diving systems and compression chambers are equipment and products being part thereof, which are listed in Appendix 1 to Part I "Classification".

1.3.3 For equipment and products listed in Appendix 1 to Part I "Classification", technical documentation specified in 5.1.4 of the indicated Part shall be submitted to the Register.

2 ARRANGEMENT AND CLOSING DEVICES OF OPENINGS IN PRESSURE HULL AND PRESSURE BULKHEADS OF MANNED SUBMERSIBLES, PASSENGER SUBMERSIBLES, DIVING BELLS AND COMPRESSION CHAMBERS

2.1 GENERAL

2.1.1 The number and arrangement of access and transfer hatches and view ports of the manned submersibles, diving bells and compression chambers are decided on at the design stage depending on the purpose and operating conditions of the submersibles, diving bells and compression chambers.

2.1.2 The number and arrangement of access and transfer hatches of the passenger submersibles is subject to special consideration by the Register in each case with due account of the length of the submersible, length of its pressure hull, number of passengers, operation conditions and availability of life-saving appliances.

2.1.3 When determining the number, dimensions and arrangement of hatches in the passenger submersible, consideration shall be given to the following circumstances;

.1 access and transfer hatches are of great importance for evacuation of passenger and crew in case of emergency;

.2 hatches shall be constructed with due regard to all the appropriate risks such as fire, smoke, hydrostatic stability under the conditions of passengers' movement, possibility of flooding due to rough sea, etc.;

.3 the number of hatches shall not exceed the safe minimum.

2.1.4 The number of penetrators for electric cables and hoses, as well as rods for various purposes in the pressure hull of the manned submersibles, passenger submersibles, diving bells and compression chambers shall be minimal.

2.1.5 Electric cables and hoses, as well as rods for various purposes shall penetrate the pressure hull through gas- and watertight seals and connectors of a type approved by the Register, which are capable of withstanding hydrostatic pressure equal to the test pressure of the pressure hull of the manned submersibles, passenger submersibles and diving bells.

2.2 GENERAL REQUIREMENTS FOR HATCHES OF MANNED SUBMERSIBLES, PASSENGER SUBMERSIBLES, DIVING BELLS AND COMPRESSION CHAMBERS

2.2.1 Hatch covers of the manned submersibles, passenger submersibles, diving bells and compression chambers shall be hinged.

2.2.2 Hatch covers of the compression chambers, diving bells and diving compartment of the lock-out submersibles shall be provided with devices for their opening (closing) by an effort not in excess of 118 N with no pressure difference between the inner and outer sides of the cover. Hatch covers of the manned submersibles shall be provided with devices for their opening (closing) by an effort not in excess of 245 N. Devices for opening (closing) hatch covers of the passenger submersibles shall be capable of being operated by a single person under all expected conditions.

2.2.3 Covers of access hatches and hatches for transfer from one compartment to another shall be so strong as the appropriate hull portions of the manned submersibles, passenger submersibles, diving bells and compression chambers, in which they are fitted. Their strength shall be determined using calculation procedures approved by the Register.

2.2.4 Hatch covers having an arrangement for opening from two sides shall have neither internal nor external one-side locking means.

2.2.5 Hatch covers designed for two-sided barometric pressure shall have a safety device preventing the hatch cover from opening until the pressures on both sides are equalized. Covers of such hatches shall have inner and outer drives for securing.

2.2.6 Covers of hatches in the pressure hull and pressure bulkheads of the manned submersibles, passenger submersibles, diving bells and compression chambers shall have an arrangement for efficient holding them in the end open position.

2.3 HATCHES OF MANNED SUBMERSIBLES, PASSENGER SUBMERSIBLES AND DIVING BELLS

2.3.1 Access hatches of the manned submersibles and passenger submersibles shall be of round configuration with a clear diameter not less than 450 mm or of an oval shape having size not less than 450×350 mm.

Access hatches of diving bells shall have diameter not less than 650 mm.

2.3.2 Access hatch covers shall have a securing device, which makes it possible to operate the covers from both sides.

2.3.3 Hatch covers shall be interlocked with the submergence and surfacing system to preclude the likelihood of submerging of the manned submersibles and passenger submersibles with open covers.

2.3.4 Hatch covers and their sealings shall provide tightness of the manned submersibles, passenger submersibles and diving bells in underwater and surface positions.

If gas medium with an excessive pressure is used inside the manned submersibles and diving bells, the tightness of hatches shall be ensured at the excessive pressure of this medium from 0,01961 MPa to the test one.

2.3.5 To be marked by an indelible paint (or in other approved way) clearly visible on the cover background is two-ended arrow and letters "O" and "C" indicating the direction of cover control rotation when the cover is being opened and closed.

2.3.6 Hatches with covers arranged on both sides of the hatch coaming shall be provided in the passenger submersibles. In well-grounded cases, hatches with one cover may be provided.

2.3.7 The construction of the sealing arrangement of covers and supporting flanges of hatches and locks of the manned submersibles, passenger submersibles and diving bells shall preclude cutting and pressing out rubber gaskets by the maximum pressure corresponding to the test depth and affecting the cover or support flange.

2.3.8 The construction of the sealing arrangement of hatch covers sealed by an external pressure shall provide their free opening on relieving the pressure.

2.3.9 Access hatches of self-sustained manned submersibles and passenger submersibles, as a rule, shall be faired by housings or other structures to prevent flooding of the manned submersible hatches when in the surface position at sea states that permit operation of these submersibles.

2.4 HATCHES AND AIR LOCKS OF COMPRESSION CHAMBERS

2.4.1 Hatch covers of compression chambers and their sealings shall ensure tightness of the compression chambers at a gas medium pressure from 0,01961 MPa to the test one.

2.4.2 External access hatches of the compression chambers and hatches arranged in their interior bulkheads shall have round configuration with a diameter not less than 600 mm or an elliptical form not less than 500×600 mm in size. The large axis of elliptical hatches shall be horizontal.

2.4.3 Covers of external hatches shall be generally closed from the inside and pressed by internal pressure.

2.4.4 In interior bulkheads of the compression chambers designed for various working pressure, provision shall be made for hatches with double covers closed from either side of the bulkhead and fitted with an arrangement, which enables the pressure between the covers to be equalized with the pressure of the appropriate compartment of the compression chamber.

2.4.5 For initial sealing of the hatch covers of the compression chamber use may be made of clamping devices to be released after compression of the sealing arrangement at a pressure up to 0,01961 MPa; along with that provision shall be made for releasing the clamping device from the adjacent compartment.

2.4.6 Rubber sealing gaskets of hatch and lock covers of the compression chambers shall be protected from cutting and pressing out by test pressure in the compression chamber, acting on the covers.

Use may be made of stops limiting the deformation of the sealing gaskets when the cover is being pressed against the hatch by an internal pressure.

2.4.7 Hatches designed for two-sided barometric load may be permitted inside the compression chambers.

2.4.8 Air locks of the compression chambers for food, medicine and other supplies shall have inner and outer covers and an arrangement enabling the pressure inside the air lock to be equalized with the pressure inside the compartment and outer atmospheric pressure.

2.4.9 Air lock covers and their securing devices shall be as strong as the compression chamber hull, which shall be supported by calculations made using the procedures approved by the Register.

2.4.10 The inner cover of the air lock shall be closed from the inside of the chamber and pressed by internal pressure.

For initial compression of the cover sealing a clamping device shall be provided.

2.4.11 Securing devices of the air lock outer cover shall be designed for taking up the load due to working pressure of the compression chamber acting on the cover.

Structural measures shall be taken to prevent simultaneous opening of the inner and outer covers, as well as opening of the outer cover until the pressure in the air lock becomes equal to the atmospheric one.

2.4.12 The design and material of the hatch and air lock covers hinges of the compression chambers shall prevent spark formation.

2.5 VIEWPORTS

2.5.1 Viewports with acrylic glasses shall be designed, manufactured and maintained in accordance with the requirements of Section 2 "Viewports" and Section 3 "Window Fabricators" of the last edition of the ASME Safety Standard for Pressure Vessels for Human Occupancy[1]. Other standards and materials may be also accepted by the Register, provided that they ensure the equivalent level of safety as regards designing, manufacturing and maintaining of the viewports.

2.5.2 Arrangements shall be made to prevent mechanical damage of the viewports.

2.5.3 The viewports of the compression chambers of the diving bells and diving compartment of the lock-out submersibles shall be fitted with strong and tight protective covers to be closed from the inside in case of the viewport damage.

3 MANOEUVRING AND DIRECTIONAL STABILITY FACILITIES OF MANNED SUBMERSIBLES

3.1 Each self-sustained and tethered (self-propelled or towed) manned submersible shall be provided with efficient manoeuvring and directional stability facilities. Such facilities may be steerable propellers or nozzles, propellers in fixed and steering nozzles, Voith-Schneider propellers, thrusters of different types, as well as vertical and horizontal rudders, stabilizers and diving planes.

3.2 The choice of main particulars, number and location of the manoeuvring and directional stability facilities of self-sustained and tethered manned submersibles is made at the discretion of the Designer and Owner, having regard to providing proper manoeuvrability of the manned submersible consistent with its intended application and operating conditions.

3.3 The parameters and strength characteristics of manoeuvring and directional stability facilities of the manned submersible shall be submitted to the Register with appropriate supporting calculations and results of model

[1] See Collection of the IMO Resolutions Relating to the RS Activities, No. 4, Part 5.

experiments and/or full-scale trials. They are subject to special consideration by the Register in each particular case.

4 EMERGENCY RELEASE DEVICES FOR JETTISONABLE BALLAST AND OTHER EQUIPMENT EXTERNAL TO THE PRESSURE HULL

4.1 To ensure positive buoyancy in emergency situations the manned submersibles, passenger submersibles and diving bells shall have an emergency release device for jettisonable ballast and/or other equipment (manipulators, containers with accumulator batteries, guide rope anchor, side thrusters) located external to the pressure hull.

4.2 The release device shall be operated from the inside of the pressure hull. Duplication of the release device actuator is recommended.

4.3 In the passenger submersibles to actuate the release device at least two manual operations shall be required. The release device actuator shall be independent of electric power supply.

4.4 Arrangements shall be made to prevent spontaneous or accidental operation of the release device actuator.

4.5 The release device actuator shall have marking showing the direction of rotation or movement of the control.

4.6 Control panels of electromagnetic or pyrotechnic actuator of the release device shall be protected by sealed covers or other safety arrangements. The emergency release controls shall have inscriptions indicating the type of the releasable equipment.

4.7 Effort at the manual control of the device shall not exceed 245 N.

4.8 Safety margin of each load-bearing structure of the emergency release device for ballast weight and/or other equipment when the maximum load likely to occur under operating conditions is acting on the device shall be equal to at least 3 in relation to the minimum ultimate strength of the material, from which the structural member is manufactured.

5 MATING SYSTEM FOR CONNECTION OF LOCK-OUT SUBMERSIBLES, DIVING BELLS TO COMPRESSION CHAMBERS AND COMPRESSION CHAMBERS TO ONE ANOTHER

5.1 Lock-out submersibles, diving bells and compression chambers shall have arrangements, which provide tight and efficient connection of the lock-out submersible and diving bell to the compression chambers and the compression chambers to one another.

5.2 Connecting flanges, hatches, sealing and closing devices of the lock-out submersibles, diving bells and compression chambers shall be designed for the maximum force arising in the process of connection of the lock-out submersible, diving bell to the compression chamber and the compression chambers to one another at the operating pressure.

Account shall be taken, among other things, of additional inertia forces arising in the mating system and arrangements for fixing the diving bells and lock-out submersibles to the deck in rolling, pitching and heaving of the support ship.

5.3 The mating system of the compression chambers shall be so designed that uniform compression of the sealing arrangements around the entire flange circumference when connected to the lock-out submersible, diving bell is provided.

5.4 The mating system of the lock-out submersibles, diving bells and compression chambers shall incorporate an interlocking device.

5.5 The interlocking device shall preclude a possibility of actuating the closing device at increased pressure in the transfer lock.

The interlocking device shall also prevent the movement of the trolley of the diving bell, lock-out submersible, evacuation compression chamber and hyperboat as well as operation of the main lifting, winch until the closing device lock of the mating system is released.

5.6 Where a power mating system is used, provision shall be made for a stand-by power mating system or an appropriate arrangement for connection of the lock-out submersible and diving bell to the compression chamber in case of failure of the main power system.

6 EMERGENCY RELEASE DEVICE OF THE SUPPORT WIRE ROPE AND UMBILICAL

6.1 Diving bells arranged for emergency ascent by free surfacing shall have emergency release devices for the support wire rope(s) and umbilical.

6.2 The emergency release devices for the support wire rope(s) and umbilical shall comply with the requirements of 4.2—4.6.

7 LIFTING LUGS AND LIFTING GEAR OF MANNED SUBMERSIBLES AND DIVING BELLS

7.1 The structural strength of lifting lugs and lifting gear of the manned submersibles and diving bells shall be determined basing on the action of the design load, which shall not be less than threefold rated weight of the manned submersible, diving bell in air.

7.2 When the design load referred to in 7.1 is acted on the lifting lugs, the maximum normal stresses therein shall not exceed 0,7 of the upper yield point of their material.

7.3 The strength calculation procedures for the lifting lugs and lifting gear of the manned submersibles and diving bells shall be agreed with the Register.

7.4 The diving bells shall have an additional lug for emergency lifting, meeting the requirements of this Section.

8 LIFE-SAVING APPLIANCES, SIGNAL AND EMERGENCY SIGNAL MEANS

8.1 In the compartments of the passenger submersibles life jackets shall be provided. Preference shall be given to inflatable life jackets.

The number of life jackets in each compartment of the manned submersibles shall correspond to the number of crew members and passengers staying in that compartment plus one spare jacket.

8.2 The passenger submersibles shall be equipped with lifebuoys or equivalent means stored at the places of embarkation (disembarkation) of passengers.

The number of lifebuoys or equivalent means is subject to special consideration by the Register in each particular case.

8.3 The passenger submersibles shall be equipped with the first-aid outfit.

8.4 The list of signal means used by passenger submersibles when in surface position shall comply with the requirements of Part III "Signal Means" of the Rules for the Equipment of Sea-Going Ships.

The passenger submersibles need not be provided with signal shapes.

8.5 The need for equipping the passenger submersibles, manned submersibles and diving bells with an ascending emergency signal means enabling them to be located when under water in case of emergency is subject to special consideration by the Register in each particular case.

8.6 The ascending emergency signal means shall be installed on the hull of the passenger submersible, manned submersible and diving bell and shall be fastened thereto by a rope.

8.7 Location and construction of the ascending emergency signal means and its attachments to the hull shall enable its release and ascending to the surface at limiting heel and trim angles, which are likely to occur in operation of the passenger submersibles, manned submersibles and diving bells.

8.8 The release control of the ascending emergency signal means shall not depend on electric power, may be manual or hydraulic with manual actuation and shall comply with the requirements of 4.2—4.8.

8.9 The length of rope of the ascending emergency signal means shall be by 10—15 per cent greater than the operating depth of the passenger submersible, manned submersible and diving bell. The float size and rope length shall be such that the expected currents do not interfere with ascent of the emergency signal means to the surface.

8.10 The ascending emergency signal means shall be fitted with a white flashing light providing not less than 60 flashes per minute and a visibility range not less than 6 miles in dark time at an atmosphere transmission coefficient 0,8 and with a radio beacon operating within the frequency range covered by a special search system of the passenger submersibles, manned submersibles and diving bells on the water surface. The flashing light and radio beacon shall have an independent power source capable of providing their continuous operation during 24 hours.

8.11 The manned submersibles (including diving bells arranged for emergency ascent by free surfacing) shall carry means enabling them to be located when afloat, including a white flashing light with not less than 60 flashes per minute and a visibility range not less than 6 miles in dark time at the atmosphere transmission coefficient 0,8.

8.12 The lock-out submersibles and diving bells shall be provided with a flashing light enabling them to be located under water, which shall start operating from the moment of submergence of the lock-out submersible and diving bell.

Use of the flashing light referred to in 8.11 is permitted.

9 EVACUATION COMPRESSION CHAMBER

Where the diving system includes an evacuation compression chamber, it shall have sufficient capacity to provide evacuation of all divers under pressure, if need arises to leave the support ship. The compression chamber shall comply with the requirements of the Rules.

10 LAUNCHING APPLIANCE FOR EVACUATION COMPRESSION CHAMBER

10.1 Appliances shall be provided for safe lowering and lifting the evacuation compression chamber. Where such appliance is actuated by the main source of electrical power, provision shall be made for auxiliary launching appliances actuated by an independent source of power.

10.2 In the event of failure of the electrical power supply to the launching appliance during lifting and lowering of the evacuation compression chamber, a braking system shall be automatically engaged. A manual release of the brake shall be provided in the braking system.

10.3 The launching appliance shall be designed so as to ensure easy connection and disconnection of the evacuation compression chamber to/from the deck compression chamber, as well as its transportation and lowering into the water against the same angles of heel and trim as for other survival craft.

10.4 In case when for connection or disconnection of the evacuation compression chamber and the deck compression chamber use is made of an actuator dependent on a source of power in its operation, provision shall be made also for arrangements to actuate connection and disconnection either manually or from the stored mechanical source of power, independent of the ship's power supply.

10.5 Methods provided for disengaging the running ends or hoisting wire rope, once the chamber is put into the water, shall provide easy disconnection; particular attention shall be given to evacuation compression chambers without attending personnel.

10.6 For the cases when the evacuation compression chamber is lifted from the sea or transported from one ship to another in open sea, particular attention shall be given to the safe performance of these operations, that is provision shall be made for an appropriate equipment to allow for the added water mass effect, presence of bilge water, dynamic loads due to motions in seaway and other factors arising in the process of transportation of the evacuation compression chamber to the ship. Clearly visible instructions for proper lifting the evacuation compression chamber with indication of its mass shall be displayed nearby the launching appliance.

11 ACCESS AND PROTECTIVE MEANS IN PASSENGER SUBMERSIBLES

11.1 For protection of passengers and crew of the passenger submersibles, provision shall be made for appropriate means, such as handrails, non-skid coatings, etc., having regard to all operating conditions likely to occur.

11.2 Provision shall be made in the passenger submersible for safe facilities for embarkation of passengers with due account of the relative heights of the passenger submersibles and embarkation place, effect of waves, protection of appendages of the passenger submersible as well as delivery ship, if applicable.

PART IV. BUOYANCY, STABILITY AND UNSINKABILITY

1 GENERAL

1.1 APPLICATION

The requirements of the present Part of the Rules apply to self-sustained and tethered manned submersibles and diving bells.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to this Part of the Rules and concerning the general terminology are given in Part IV "Stability" of the Rules for the Classification and Construction of Sea-Going Ships and in the General Regulations.

1.2.2 In addition, the following definitions have been adopted.

Attending personnel means the crew of the support ship carrying out technical maintenance of the manned submersible during the time intervals between submergences (except the manned submersible crew members) and performing handling operations.

Experimental determination of the manned submersible stability means an operation to be performed in order to determine the initial metacentric height.

Pressure container means a structure taking up and balancing the water pressure and intended to accommodate various apparatus and devices and to protect them from that pressure.

Pressure tank means a structure taking up and balancing the water pressure and intended to carry liquid cargoes and to protect them from that pressure.

Reballasting of the manned submersible means an operation to be performed in order to bring the residual buoyancy, trim and heel to the specified (rated) values.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions on the classification, surveys during construction and classification surveys, as well as the requirements for technical documentation to be submitted to the Register for consideration and approval are set out in the General Regulations and in Part I "Classification".

1.3.2 For the manned submersibles and diving bells being part of the ship's diving systems, the Register carries out:

.1 prior to construction of the manned submersibles and diving bells: review of technical documentation pertaining to buoyancy, stability and subdivision of the submersibles and bells;

.2 during construction and testing of the manned submersibles and diving bells: supervision of reballasting and experimental determination of stability, as well as review and approval of the Information on Buoyancy, Stability and Unsinkability and the report (record) on reballasting and experimental determination of stability;

.3 surveys to reveal changes in the manned submersible and diving bell load after reballasting, conversion, major repair, as well as after any other change in the load in order to decide on the further suitability of the Information on Buoyancy, Stability and Unsinkability.

2 BUOYANCY AND UNSINKABILITY

2.1 BUOYANCY IN SURFACE POSITION

2.1.1 The reserve of buoyancy of the manned submersible when in surface position shall be positive and ensure compliance with the conditions of 2.1.3 and 3.1.2.

2.1.2 The value of buoyancy reserve of the diving bell with the solid ballast jettisoned shall not be less than 3 per cent of the displacement.

2.1.3 Requirements for the height of the access hatch fencing (edges) above the waterline in still water:

.1 the upper edges of the access hatch coamings of the self-sustained and tethered manned submersibles, the operating conditions of which provide for opening of the hatch cover while afloat at the sea state that is maximum permissible for the submersible concerned, shall prevent flooding of the hatches; otherwise, the access hatches shall be guarded by a housing or other

structures preventing flooding of the hatches under the same operating conditions;

.2 for the manned submersibles having length equal to or less than 19 m, the minimum permissible height F_1 of the access hatch fencing (edges), in m, above the waterline in still water in case of the manned submersibles referred to in 2.1.3.1 shall be determined by the formula

$$F_1 \geqslant (1{,}4 - 2{,}8 h_{3\%\max}/L) h_{3\%\max} \qquad (2.1.3.2)$$

where $h_{3\%\max}$ = the maximum specified height with 3 per cent of probability of exceeding level at the limiting sea state permitted, proceeding from the operating conditions of the manned submersible, m;

L = submersible length, m, to be taken equal to the maximum of a series of values calculated for all $h_{3\%} \leqslant h_{3\%\max}$ beginning from $h_{3\%} = 0{,}75$ m.

The value F_1 shall not be taken less than 0,75 m.

For the manned submersibles of more than 19 m in length the calculation using Formula (2.1.3.2) shall be made only for $h_{3\%\max}$.

When determining the value of F_1 for the manned submersible having a length equal to or less than 19 m, account shall be taken of the fact that the maximum value of $h_{3\%}$ does not necessarily correspond to the maximum value of F_1;

.3 if there are clear grounds, the Register may permit the value of F_1 reduced as compared with that given in 2.1.3.2. Operating experience of the manned submersible concerned (when the problem regarding increase of the permitted sea state is dealt with), model test results or special calculations may be used as the clear grounds;

.4 the height of the access hatch fencing (edges) above the waterline in still water for the self-sustained and tethered manned submersibles, the operating conditions of which provide for opening of the hatch cover while afloat when maintenance is performed in smooth sea (up to Beaufort 1), shall not be less than 0,5 m;

.5 for self-sustained and tethered manned submersibles, the operating conditions of which provide for opening of the hatch cover only on board the support ship, the height of hatch fencing (edges), from the standpoint of flooding prevention, is not specified;

.6 when some other pressure hull structures (e.g. hinged semispherical bulkheads in the manned submersibles of “Mantis” type, etc.) are used as access hatch in the self-sustained and tethered manned submersibles referred to in 2.1.3.5, the height of the hull upper edge above the waterline in still water is specified for reasons of ease of performing handling operations.

2.1.4 Requirements for heel and trim angles:

.1 movement of the crew inside and the attending personnel outside the manned submersible when in surface position shall not cause trim or heel in excess of $\pm 15^{\circ}$ and $\pm 10^{\circ}$, respectively;

.2 draft scales shall be marked on the external hull of the manned submersibles to enable determination of trim when in still water.

2.2 BUOYANCY IN SUBMERGED POSITION

2.2.1 The emergency reserve of buoyancy of the manned submersible, dependent on the mass of jettisonable ballast and equipment shall ensure emergency surfacing under conditions stated in 2.3.

2.2.2 Self-propelled manned submersibles shall be equipped with facilities for trimming them in submergence and for compensating the changes in load and buoyancy.

2.2.3 Self-propelled manned submersibles shall be capable of maintaining zero buoyancy at any depth over the entire range of water density and temperature changes, within which operation of the submersible is envisaged, under all operating and loading conditions.

2.3 UNSINKABILITY OF MANNED SUBMERSIBLES

The manned submersible shall be capable of surfacing from any depth down to the operating one when it is impossible to remove water from the pressure tanks or in case of flooding of one pressure tank or one pressure container.

3 STABILITY

3.1 REQUIREMENTS FOR INITIAL STABILITY IN SURFACE AND SUBMERGED POSITIONS

3.1.1 Stability of the manned submersible shall remain positive under all envisaged operating conditions including surfacing in case of emergency jettisoning of solid ballast and/or any equipment with ballast tanks on one or both sides flooded.

3.1.2 Angle of dynamic heel (trim) of the manned submersible when in surface position in case of flooding of one ballast tank shall be taken equal to

twice the angle of static heel (trim) of the submersible in case of flooding of the same tank and shall not be in excess of the flooding angle, at which the hatch fence edge immerses.

3.1.3 The minimum permissible value of the initial transverse metacentric height of the manned submersible when in surface position, m, shall be determined by the formula

$$h_{\min}^{perm} \geqslant 0{,}05 + 0{,}9 \times 10^{-3} D \qquad (3.1.3)$$

where D = submersible displacement.

3.1.4 The minimum permissible value of the initial transverse metacentric height of the manned submersible when in submerged position, m, shall be determined by the formula

$$h_{\min}^{perm} \geqslant 0{,}065 + 0{,}75 \times 10^{-3} D. \qquad (3.1.4)$$

3.1.5 For towed manned submersibles having constant positive buoyancy and displacement less than 10 t, the value of the initial metacentric height when in surface and submerged positions may be reduced down to 0,05 m.

3.1.6 The initial metacentric height of the diving bell shall be positive.

3.2 REQUIREMENTS FOR TRANSITION STABILITY

3.2.1 Stability of the manned submersible shall remain positive during submergence or surfacing and when submergence or surfacing is interrupted in any instant.

3.2.2 The initial metacentric height in case of interrupted submergence or surfacing of the diving bell shall be positive.

4 REQUIREMENTS FOR THE INFORMATION (SERVICE DOCUMENTATION) ON STABILITY, BUOYANCY AND UNSINKABILITY

4.1 Information (Service Documentation) on Stability, Buoyancy and Unsinkability approved by the Register and complied in accordance with the instructions given in Appendix 3 shall be issued to each submersible.

The requirements for the Information that are specific for each manned submersible are subject to special consideration by the Register in each particular case.

5 ADDITIONAL REQUIREMENTS FOR BUOYANCY, STABILITY AND EMERGENCY SURFACING OF PASSENGER SUBMERSIBLES

5.1 The passenger submersible shall surface/submerge safely and under control within the entire range of operating depths.

5.2 The passenger submersible shall retain satisfactory trim and stability during surfacing, submergence and under water and on surface.

5.3 The passenger submersible shall remain on surface without flooding under all normal design weather conditions and all operating loading conditions.

5.4 For the passenger submersible, provision shall be made for two independent facilities for ascending to the surface in stabilized condition, without heel and trim. One such facility shall ensure surfacing without use of electric power.

5.5 In addition to the requirement set forth in 5.4, provision shall be made for emergency surfacing through jettisoning cargo of such mass that in case of flooding of the largest watertight hull volume, apart from compartment where people stay, the surfacing speed is equal to the operating surfacing speed. The jettisonable cargo may consist of the jettisonable solid ballast, separable parts of the manned submersible or combination thereof. As an alternative, if the passenger compartment has positive buoyancy, it may be provided with means to separate it from all other parts of the submersible, including separable parts.

5.6 Separation of the parts of the manned submersible shall be provided for at the design stage. For this purpose the special design measures, operating and emergency arrangements and/or jettisoning facilities may be required.

5.7 If required in the process of implementation of emergency arrangements, provision shall be made for jettisoning lifting cables and hoses.

5.8 Cargo jettisoning systems, if provided, shall be actuated manually, be independent of electric power and come into action after at least two operations.

5.9 The passenger submersible, at any combinations of cargo jettisoning shall have positive stability in order to ensure safe evacuation of passengers in accordance with the contingency plan.

5.10 Provision shall be made for external devices for lifting the submersible to surface.

5.11 The passenger submersible shall be capable of emergency surfacing in case where drainage of pressure and ballast tanks is impossible.

5.12 Movement of passengers and crew over the submersible (including that during embarkation and disembarkation) possible in operation shall not cause trim or heel exceeding:

in surface condition – an angle equal to one half the flooding angle, at which the access hatch guard edge immerses;

in submerged position – maximum angles, at which normal (non-emergency) operation is possible.

In any case, the trim and heel shall not exceed 15° and 10°, respectively.

5.13 Experimental determination of stability of the passenger submersible shall be performed both in surface and submerged positions.

APPENDIX 1

INSTRUCTIONS FOR REBALLASTING OF MANNED SUBMERSIBLE

1 GENERAL

1.1 Reballasting (after construction, modification or repair) is an operation to be performed in order to bring the manned submersible to the design values of residual buoyancy, trim and heel. The purpose of reballasting shall determine the quantity of solid ballast and light-weight filler in order to bring the submersible buoyancy and load characteristics in balance.

1.2 Reballasting shall be carried out in the presence of the Surveyor to the Register in compliance with these Instructions.

1.3 Guidelines for reballasting process are elaborated by the Designer for each submersible design having regard to the specific conditions of construction and shall reflect the loading condition, that is whether there are or not the crew, accumulator battery, light-weight filler, special and permanent solid ballast and the peculiarities of reballasting for the submersible concerned. The guidelines shall be agreed with the Register.

2 HYDROMETEOROLOGICAL CONDITIONS AND POSITIONS OF MANNED SUBMERSIBLE DURING REBALLASTING

2.1 Reballasting of the submersible shall be performed in calm weather, in smooth water and with no current. The value of the specific weight of the water in the area of reballasting shall be determined experimentally.

2.2 Reballasting of the manned submersible is performed in protected and specially equipped water area or basin. The special equipment includes primarily facilities for handling the submersible, marking water depth, ensuring ease of performing reballasting operations.

2.3 The depth of water under the submersible keel during reballasting shall not excess the operating depth of the manned submersible concerned and shall be not less than 1/3 of its length.

2.4 If reballasting is performed in a specially equipped basin, its overall dimensions shall be large enough to exclude the possibility that the submersible appendages hit against and catch on the walls and equipment during free submergence.

3 PREPARATION OF MANNED SUBMERSIBLE FOR REBALLASTING

3.1 Prior to reballasting:

tests of the manned submersible, its machinery and systems shall be carried out to full extent to confirm readiness of the submersible;

arrangements ensuring fulfillment of all the requirements concerning trial submergence shall be performed;

load condition and design trimming of the manned submersible shall be checked with the aim to determine the quantity and distribution of the trimming weights, which have to be placed in the submersible to ensure the required values of buoyancy, heel and trim.

3.2 During the design trimming, as-built overweight or underweight of the manned submersible shall be estimated and taken into account.

3.3 After design trimming, the estimation of the transverse metacentic height value in submerged position during reballasting shall be made. The value of the initial transverse metacentric height shall be determined by the formula

$$h = h_0 + \Delta h$$

where h_0 = value of the transverse metacentric height in submerged position, based on the calculations of buoyancy and initial stability, m;

Δh = change in the initial transverse metacentric height as compared with the design one, m, determined by the formula

$$\Delta h = (M_{z0} - M_{zd})/D$$

where M_{z0} = total vertical moment from the load calculation, tm;

M_{zd} = total vertical moment at design trimming, tm;

D = displacement of the manned submersible corresponding to design load, t.

4 PERFORMANCE OF REBALLASTING

4.1 If necessary, immediately prior to reballasting, the load condition shall be revised with the aim to adjust the design load and eventually the quantity of weight to be taken in for reballasting.

4.2 The manned submersible dives in accordance with recommendations and instructions to be worked out for each specific submersible design.

4.3 The ballast tanks during reballasting shall be fully filled.

4.4 Measures shall be taken to prevent formation of air pockets in the external hull structures.

4.5 No touch to the basin walls, its equipment, ground, as well as no tension of mooring ropes during reballasting is permitted.

4.6 The reballasting is considered to be completed when the manned submersible attains a stable submerged position with the required values of heel and trim and some minor reserve of buoyancy.

INSTRUCTIONS FOR EXPERIMENTAL DETERMINATION OF MANNED SUBMERSIBLE STABILITY

1 GENERAL

1.1 The purpose of experimental determination of the manned submersible stability (hereinafter referred to as "the experiment") shall determine the initial metacentric height corresponding to a particular displacement.

1.2 The experiment is conducted by the action of a specified moment on the submersible reballasted.

1.3 To produce heeling (trimming) moments for experimental stability determination use is made of solid ballast consisting of ballast pigs. Mass shall be marked on each ballast pig.

1.4 The mass of individual ballast pigs and their total number shall be determined separately for each submersible design.

1.5 The ballast is divided into two groups of equal mass. Each group is specially marked and intended for placing on one side of the manned submersible (forward or aft) in a position, which ensures, where possible, the greatest ballast transfer arm.

1.6 To determine angles of inclination during the experiment plumb lines or inclinometers shall be employed. The number and location of these facilities shall be stated separately for each manned submersible's design.

1.7 Measurements of deviation of the plumb line during the experiment shall be made with the use of a special rod graduated with a millimetric scale.

1.8 To reduce swinging of the plumb line its bottom end shall be lowered into a water or oil vessel.

2 PREPARATION FOR THE EXPERIMENT

2.1 Preparation for the experiment is made simultaneously with preparation for reballasting and consists in installation in the submersible of special ballast and facilities for measuring inclination angles.

2.2 Mass of the special ballast and facilities for measuring inclination angles shall be allowed for in the design trimming.

2.3 The experiment is carried out in submerged position immediately after reballasting and, as a rule, without surfacing.

3 CONDUCT OF THE EXPERIMENT

3.1 Prior to movements of the ballast, initial position of the plumb lines shall be noted.

3.2 Movement of ballast to produce heeling (trimming) moments shall be effected alternately from one side to another with return to its original position.

3.3 After each movement, deviation of the plumb line shall be recorded.

3.4 The number of ballast movements from side to side (series) is dictated by the required accuracy of the experiment but shall not be less than 3.

3.5 The value of the initial transverse metacentric height of the submersible during the experiment shall be determined for each series by the formula

$$h = pl_p/(D\Delta\theta)$$

where p = mass of the ballast transferred at one time, t;
l_p = ballast transfer arm, m;
D = submersible displacement, t;
$\Delta\theta$ = increment of the inclination angle, in radians, corresponding to the moment involved determined by formula

$$\Delta\theta = d/l = [\bar{x}_1 - \bar{x}_3 - (\bar{x}_0 - \bar{x}_4)/2]/l$$

where d = deviation of the plumb line when ballast is transferred to one side, mm. The extreme positions of the plumb line during swinging are noted in accordance with Table 3.5;
l = plumb line length, mm.

Table 3.5

Plumb line length, mm _____ Observer _____
(full name)

Number of fixed positions of plumb line, K		Number of observations and symbols					Difference		Squared sums of pairwise successive numbers	
		0	1	2	3	4				
To the left	To the right	x'_{0k}	x'_{1k}	x'_{2k}	x'_{3k}	x'_{4k}	$\delta_{1k} = x'_{1k} - \bar{x}_1$	$\delta_{3k} = x'_{3k} - \bar{x}_3$	$[\delta_{1k} + \delta_{1(k+1)}]^2$	$[\delta_{3k} + \delta_{3(k+1)}]^2$
1	2									
3	4									
5	6									
7	8									
9	10									
11	12									
13	14									
15	16									
17	18									
19	20									
Sum										
Arithm. mean	$\bar{x}$	$\bar{x}_0$	$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_3$	$\bar{x}_4$				

3.6 The inclination angle shall be within the range from 1° to 3° (to one side or from side to side).

3.7 The experiment in each series is considered to be satisfactory, provided:

.1 the values of changes in the inclination angles, when the ballast is transferred to one side, calculated for each plumb line differ from one another by not more than 2 per cent (5 per cent when stability of the passenger submersible is determined experimentally in surface position);

.2 the error for the mid-position of the long plumb line does not exceed that determined by the formula

$$\delta = \sqrt{[(\overline{x}_0 - x)^2 + (\overline{x}_2 - x)^2 + (\overline{x}_4 - x)^2]/3} \leqslant 0{,}03d - 1{,}5$$

where $x = 1/3(\overline{x}_0 + \overline{x}_2 + \overline{x}_4)$; $d = \overline{x}_1 - \overline{x}_3 - (\overline{x}_0 - \overline{x}_4)/2$;

.3 the relative (in relation to the long plumb line deviation) root-mean-square error of the experiment does not exceed that determined by the formula

$$\varepsilon_h = \sqrt{\delta_i^2 + \delta_3^2 + \delta^2}/d \leqslant 0{,}03$$

where $\delta_i = 1/\left[4(n-1)(n-2)\right]; \sum_{k=1}^{k=n-1} [\delta_{ik} + \delta_{i(k+1)}]^2 \geqslant 1;$

$i = 1; 3;$

$i =$ number of observation;

$k =$ ordinal number of the plumb line deviation measurement;

$n =$ number of measurements for one reading.

The values of δ_{ik} are determined from Table 3.5.

3.8 Where the inclination angles are measured by means of inclinometers the quality of the experiment performance shall be checked in accordance with methods approved by the Register.

3.9 For calculation of the stability characteristics, the minimum value of the metacentric height shall be chosen out of all series.

3.10 The experiment shall be documented by a record signed by the chairman and members of the commission for reballasting and experimental determination of the manned submersible stability, as well as by the Surveyor to the Register.

APPENDIX 3

INSTRUCTIONS FOR DRAWING UP INFORMATION (SERVICE DOCUMENTATION) ON STABILITY, BUOYANCY AND UNSINKABILITY

1. The present Instructions contain only general provisions as to the purpose and contents of the Information on Stability, Buoyancy and Unsinkability, because the contents, scope and form of the Information for various types and missions of the manned submersibles, operating area, qualification of seafarers shall be chosen in each case in the best way and agreed upon with the Register.

2. Each manned submersible shall be provided with the Information in order to assist the Master and control authorities in maintaining adequate stability of the submersible in service in compliance with the requirements of these Rules. Formal observance of the provisions contained in the Information does not relieve the Master of the responsibility for the stability of the submersible.

3. The Information shall be complied with regard to the experimental stability determination data. Furthermore, the Information shall contain references to documents, on the basis of which it was drawn up.

4. It is recommended that the Information includes the particulars of the manned submersible, such as:

type and purpose of the manned submersible;

service area;

main dimensions;

displacement and other additional data deemed necessary by the Designer.

5. A provision is recommended to be made in the Information for a form to make notes by the Surveyors to the Register on extension of the validity of the Information or on the need for its updating.

6. A provision shall be made in the Information for a form of a signature to be made by the Master who has just entered upon his duties to the effect that he became familiar with the contents of the Information and is ready to observe it.

7. The Information shall specify the ultimate sea state, at which safe recovery of the manned submersible aboard the support ship may be possible.

PART V. FIRE PROTECTION

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to structural fire protection, fire fighting and fire-detection and alarm systems, as well as to fire-extinguishing equipment and outfit of the diving bells, compartments of the manned submersibles and compression chambers and those spaces of the support ships, which are intended for control, communication and siting of the manned submersibles and ship's diving systems and placement of the manned submersible ancillary gear.

1.1.2 Besides the requirements of this Part of the Rules, all applicable requirements given in Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships shall be applied to fire protection of the spaces mentioned in 1.1.1, unless expressly provided otherwise in this Part.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to the general terminology of the Rules are given in the General Regulations and in Part I "Classification".

1.2.2 Definitions and explanations relating to fire protection are given in Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships.

1.2.3 For the purpose of this Part the following definition is adopted.

Limiting oxygen concentration (C_{loc}) of the material means the minimum volumetric oxygen concentration in the artificial gas medium of the compartments of the compression chamber, diving bell, diving compartment of the lock-out submersible, at which independent combustion of the material being locally ignited is impossible.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions pertaining to the procedure of classification, survey during fabrication, construction, as well as the requirements for the technical documentation to be submitted to the Register for consideration and approval are contained in the General Regulations and in Part I "Classification".

1.3.2 In the process of construction of the manned submersible, ship's diving system and support ship the scope of surveys carried out by the Register is established in compliance with 1.3.2, Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships and this Part.

2 STRUCTURAL FIRE PROTECTION

2.1 Structural fire protection of the support ship spaces intended for control, communication and siting of the manned submersibles and ship's diving systems, as well as for placement of the manned submersible ancillary gear shall comply with the requirements of Section 2, Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships, imposed on the ship control stations depending on their purpose.

General arrangement of the manned submersible shall be such as to reduce fire and smoke hazard.

2.2 Structural members and equipment in the manned submersible compartments kept under normal atmospheric pressure shall be generally constructed of non-combustible materials.

Combustible materials shall be tested in accordance with the International Fire Test Procedures Code, as adopted by the IMO Maritime Safety Committee by resolution MSC.61(67).

2.3 Non-metallic materials used for construction of the structural members and equipment located inside the diving bell, diving compartment of the lock-out submersibles and compression chambers shall have the value of the limiting oxygen concentration (C_{loc}) meeting the following condition:

$$C_{loc} \geqslant 1{,}05 C_{vc}$$

where C_{vc} = the maximum volumetric oxygen concentration over the entire range of working pressures of the artificial gas medium in the compartments of the compression chamber, diving bell, diving compartment of the lock-out submersible.

The value of C_{loc} of material is established experimentally based on the results of fire tests in compliance with the procedure for determination of the limiting oxygen content of material in artificial gas media at elevated pressures.

2.4 Synthetic-based materials shall not be generally used for the internal equipment of the diving bells, diving compartment of the lock-out submersibles and compression chambers. The specific electrical resistance of the materials used, which shall be less than 108 Ohm·m, is considered to be suitable for avoiding building-up of static electricity.

2.5 All internal metallic equipment of the diving bells, diving compartment of the lock-out submersibles and compression chambers (bunks, seats, flooring, etc) shall be efficiently secured and adequately protected to prevent spark formation.

3 FIRE FIGHTING EQUIPMENT AND SYSTEMS

3.1 Compartments of the compression chamber shall be protected by a pressure water-spraying or gas smothering system, which comes into action within not more than 1 s, capable of being actuated from both the inside and outside of the compression chambers and of meeting the following requirements:

.1 the pressure water-spraying system shall provide the water discharge rate not less than 0,5 l/s per 1 m^2 of the largest horizontal cross-sectional area of the interior surface of the compression chamber compartment to be protected at a pressure therein being up to 1,0 MPa, functioning without interruption during not less than 1 min;

.2 the gas smothering system shall employ inert gas used to produce a breathing mixture in the compression chamber. The amount of inert gas shall be determined by the formula

$$V_c = 5V_\delta \qquad (3.1.2)$$

where V_δ = interior volume of the compression chamber compartments, m^3.

The inert gas delivery rate shall be such as to ensure the pressure building-up rate in compliance with Table 3.1.2.

Supply of inert gas to the compression chamber shall be continued also after opening of the safety valve.

Table 3.1.2

Pressure range in the compression chamber, MPa	Pressure building-up rate in the compression chamber, MPa/min	Ultimate permissible value of pressure building-up during fire extinction, MPa
0—0,3	$0,5 \geqslant \Delta P/t \geqslant 0,3$	0,5
0,3—0,6	$0,7 \geqslant \Delta P/t \geqslant 0,5$	1,0
0,6—1,0	$1,0 \geqslant \Delta P/t \geqslant 0,7$	1,5

Special group of bottles shall be provided for smothering. Use of inert gas from these bottles for other purposes shall be subject to special consideration by the Register in each particular case.

3.2 The fire fighting system of the support ship spaces intended for control, communication and siting of the manned submersibles and ship's diving systems, as well as for placement of the manned submersible ancillary gear shall be arranged with due regard to the following requirements:

.1 in addition to the water fire main system, the above spaces shall be provided with a fixed fire extinguishing system specified in Table 3.1.2.1, Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships for the control stations referred to in 1.5.1.2 of the above-mentioned Part. For control and communication spaces of the manned submersibles and ship's diving systems only a pressure water-spraying system may be used;

.2 in areas where the diving bell, diving compartment of the lock-out submersible, compression chambers or pressurized gas storage containers are located, a local pressure water-spraying system with a delivery rate not less than 10 l/min per 1 m^2 of vertical projected area and supplied with water from the ship's water main system shall be additionally provided.

4 FIRE DETECTION AND ALARM SYSTEM

4.1 The spaces referred to in 3.2, shall be provided with an automatic fire detection and alarm system in compliance with the applicable requirements of 4.1, Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships.

4.2 Manned submersibles consisting of two or more compartments shall be provided with automatic fire detection and alarm system with detectors fitted in each compartment.

Such fire detection and alarm system shall produce audible and visible signals to be transmitted to the submersible control station.

5 FIRE FIGHTING OUTFIT

5.1 For the spaces intended for communication and control of the manned submersible and ship's diving system provision shall be made on the support ship for self-contained breathing apparatus capable of functioning not less than 30 min. The number of such apparatus shall correspond to the number of the attending personnel members in these spaces.

5.2 In the manned submersible compartments, other than the diving compartments, an emergency fixed breathing system or self-contained breathing apparatus or self-breathing apparatus capable of functioning for a period required for emergency surfacing of the manned submersible from the operating diving depth and retrieval thereof aboard the support ship shall be provided.

The number of the apparatus in each pressure compartment shall correspond to that of the specified crew members of the manned submersible plus one spare apparatus.

5.3 In each compartment of the manned submersible, as well as in the diving bell and compression chamber compartments, at least one portable fire extinguisher capable of extinguishing fire on electrical equipment shall be located; the fire extinguishing medium of such fire extinguisher shall have no harmful effect in an enclosed space on the human health.

Fire extinguishers stowed in high pressure compartments shall be arranged for operation under high-pressure conditions.

5.4 In spaces referred to in 3.2 portable fire extinguishers shall be provided in conformity with Table 5.1.2, Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships as applied to control stations.

6 ADDITIONAL REQUIREMENTS FOR PASSENGER SUBMERSIBLES

6.1 Each passenger cabin shall be provided with an emergency breathing system or self-contained breathing apparatus or self-breathing apparatus capable of functioning during a period of time required for emergency surfacing from the operating diving depth and for evacuation of the passengers. The number of self-contained breathing apparatus or self-breathing

apparatus in each passenger cabin shall correspond to the number of passenger seats plus one spare apparatus.

6.2 Each service space and each passenger cabin diving shall be provided with appropriate fire fighting means. Such means may be fixed fire fighting systems and/or portable fire extinguishers. When selecting the system construction and the fire extinguishing medium, consideration shall be given to the type and position of the potential fire sources, threat posed by the fire extinguishing media to human health and building-up of pressure. Carbon dioxide and sea water shall not be generally used for fire extinction.

6.3 Calculation of the amount of extinguishing medium required for the space to be protected shall be submitted to the Register for consideration.

PART VI. MACHINERY INSTALLATIONS, MECHANICAL EQUIPMENT AND SYSTEMS

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to machinery installations, engines, propelling devices, machinery, pressure vessels and heat exchangers, systems, piping and other mechanical equipment of the manned submersibles and ship's diving systems ensuring operability of same, safety of personnel therein, recovery and launching of the manned submersibles and ship's diving systems, as well as their safety at sea and submergence.

1.1.2 Mechanical equipment and machinery of the manned submersibles and ship's diving systems are subject, in addition to the requirements of the Rules, to all applicable requirements of Parts VII–X, XII and XV of the Rules for the Classification and Construction of Sea-Going Ships, as well as of the Rules for the Cargo Handling Gear of Sea-Going Ships, unless provided otherwise in these Rules.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to the general terminology of the Rules are given in the General Regulations. Definitions and explanations relating to machinery installation are given in Part VII "Machinery Installations" of the Rules for the Classification and Construction of Sea-Going Ships.

1.2.2 For the purpose of this Part of the Rules, the following definitions have been adopted.

B o t t l e means a pressure vessel having one or two manholes with openings for mounting fittings (such as valves, plugs).

B r e a t h i n g g a s (b r e a t h i n g m i x t u r e) means all gases and gas mixtures used for breathing during diving operations.

C o n d i t i o n i n g s y s t e m means a system maintaining the specified parameters of gas mixture temperature and relative humidity.

L i f e s u p p o r t s y s t e m means a combination of systems, equipment, monitoring and safety devices ensuring normal vital activity of divers in the

deck compression chamber and crew of the manned submersibles and diving bells over the whole range of pressures and conditions they can be exposed to during diving operations.

O x y g e n s y s t e m means a piping system for gases, the oxygen content in which exceeds 25 per cent.

R e c o v e r y s y s t e m means a system ensuring collection and purification of breathing mixture for re-use.

R e g e n e r a t i o n s y s t e m means a system ensuring specified parameters of breathing gas composition, oxygen and detrimental impurities content not in excess of the ultimate permissible concentrations over the whole range of pressures.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions relating to the classification procedure, surveys during manufacture and construction, as well as the requirements for the technical documentation to be submitted to the Register for consideration and approval are stated in the General Regulations and in Part I “Classification”.

1.3.2 Items of survey during manufacture, installation and testing of manned submersibles and ship's diving systems are given in Appendix 1 to Part I "Classification".

2 MACHINERY INSTALLATIONS AND MECHANICAL EQUIPMENT

2.1 GENERAL REQUIREMENTS

2.1.1 Mechanical equipment, fittings and devices used in the manned submersibles and ship’s diving systems shall be of the type approved by the Register.

2.1.2 Mechanical equipment and systems of the manned submersibles and diving bells shall remain operable under any critical operating conditions, except machinery and equipment, the operability of which is specially specified as a function of their position in space.

2.1.3 Materials used in manufacture and repair of mechanical equipment and systems shall be compatible with the environment, in which they will be operated, with regard to the requirements of 2.5 of the General Regulations.

2.1.4 Essential components and systems exposed to the environment shall be suitable for operation at temperatures from – 30 ºC up to +50 ºC unless otherwise specified.

2.1.5 The equipment external to the pressure hull of the manned submersibles and diving bells shall be designed for operation in hyperbaric conditions corresponding to the test diving depth of the manned submersibles and diving bells and have an adequate corrosion margin or corrosion protection means.

2.1.6 Design and arrangement of starting and control devices of machinery and systems of the manned submersibles and diving bells shall provide for the possibility of start-up and control by one person.

2.1.7 Moving parts, equipment external to the pressure hull of the manned submersibles and diving bells shall be protected against mechanical damages, which may be caused to them when they come up against obstacles and against jamming due to invasion of foreign objects.

2.1.8 During submergence and surfacing of the manned submersibles and diving bells, the working fluid pressure in the hydraulic system shall not be less than the outside water pressure including that at the test diving depth of the manned submersibles and diving bells.

2.1.9 Design of control devices shall prevent the possibility of spontaneous changes in set points. Direction of movement of the control levers and handwheels shall be indicated by arrows or inscriptions.

2.1.10 Compression chambers and other components of the ship's diving systems shall be generally sited on support ship in enclosed heated spaces.

Siting of the ship's diving system components on open decks is subject to the special consideration by the Register in each particular case.

2.1.11 Siting of the ship's diving system on the support ship shall allow easy servicing and checking of safety devices and fittings.

2.1.12 Portable equipment and working tools shall be secured on the manned submersibles and diving bells so as to enable them to remain in place in extreme positions, at maximum accelerations and shocks against the hull of support ship possible during handling operations and submergence of the manned submersibles and diving bells.

2.1.13 Spaces for reception and delivery of gases shall have direct access to the open deck.

2.1.14 Booster oxygen compressor room, oxygen bottle storage room and helium-oxygen mixture preparation room shall be adjacent and have independent accesses to the deck.

2.1.15 Communication of the spaces referred to in 2.1.14 with the ship's spaces of common purpose is generally prohibited.

Possibility of intercommunication between the above spaces is subject to special consideration by the Register in each particular case.

2.1.16 The height of the gas bottle storage room and the width of passages therein shall be sufficient for normal servicing of bottles, for installation and dismounting of pipes and devices. The width of the passages shall not be less than 0,6 m.

2.1.17 For monitoring of the oxygen content in spaces wherein increased oxygen content may be possible, gas analyzers shall be installed with alarms being actuated when the oxygen concentration in these spaces reaches 23 per cent.

2.2 MACHINERY AND MECHANICAL EQUIPMENT

2.2.1 Machinery and propulsion installations of the manned submersibles and diving bells shall comprise a minimum number of rotating and moving parts and have noise characteristics and vibration levels not in excess of those established by national standards.

2.2.2 All moving and rotating mechanical parts shall be efficiently protected by enclosures or casings to prevent injures to attending personnel or divers, as well as to protect machinery from damages due to contact with ground and other objects or from engagements by sea weeds and ropes that may be encountered at sea bottom.

It is recommended to equip propellers with nozzles or guards.

2.2.3 The design of slave members of manipulators of the manned submersibles and diving bells shall provide generally for forced detachment of end working parts in an emergency situation.

2.3 CONTROL STATIONS AND MEANS OF COMMUNICATION

2.3.1 Indicators showing open/closed positions of valves, cocks, sluice valves and other closing fittings shall be provided in the control panels of the systems.

2.3.2 Control stations of the manned submersibles shall be provided with indicators showing amount of water in compensating tanks.

2.3.3 Visible and audible alarm devices shall be generally provided in the control panels of systems to indicate malfunctions in the systems.

2.3.4 The main controls shall be readily accessible, have marking and identification painting.

For life support system control panels, it is recommended to use mimic diagrams operating jointly with the controls and permitting control of the entire system equipment and closing fittings.

For panels with a large number of controls, it is recommended to use levers, tumbler switches and handwheels of various shape.

2.3.5 Control stations of the propulsion/steering system of the manned submersibles shall be equipped with tachometers and instruments showing the sense of rotation of propelling devices.

2.3.6 Control station of the compression chamber and diving bell life support system, as well as control station for launching/recovery of the manned submersibles and diving bells shall have telephone communication with the compression chamber. These control stations shall have loudspeaking communication and, as an emergency one, telephone communication between them.

2.3.7 The life support system control panels shall provide for the possibility of separate regulation of breathing gas mixture supply to the diving bells, compression chambers, living compartment of the lock-out submersibles.

Breathing gas mixtures shall be supplied to control panels via two independent mains or cable-hoses.

2.3.8 Control stations for handling of the manned submersibles and diving bells shall have access to the launching area of the manned submersibles and diving bells and to the area of mating the submersibles and diving bells to the ingress/egress compartment of the compression chamber. A clear view of these areas shall be provided from control station.

2.3.9 Control stations for handling of the manned submersibles and diving bells shall be located in safe areas of the support ship and have independent exit to the open deck.

2.3.10 Control stations for the life support system, handling systems of the manned submersibles, diving bells and evacuation compression chambers (hyperboats) shall have telephone and loudspeaking communication with the central control station of support ship and with the navigating bridge, while the control station of the diving bell shall have, in addition, communication with the control station for the dynamic positioning system and shipboard cargo crane, if any.

2.3.11 The stations for mating the lock-out submersible with the compression chambers of ship's diving system shall have loudspeaking communication with the control station for life support system and control station for handling operations.

2.4 MACHINERY OF THE HANDLING SYSTEM

2.4.1 The handling system machinery are subject to the requirements of Part IX "Machinery" of the Rules for the Classification and Construction of Sea-Going Ships and of the Rules for the Cargo Handling Gear of Sea-Going Ships, unless otherwise provided in this Part.

2.4.2 The following requirements shall be taken into account in the design of the handling system machinery:

.1 design loads of lifting gear shall be determined with due regard to the loads of handling system and conditions of force determination in structural members (see Part X "Shipboard Handling Systems of Manned Submersibles and Ship's Diving Systems");

.2 safety margins of the machinery parts shall not be less than those of metal structures of the handling system (see Part X "Shipboard Handling Systems of Manned Submersibles and Ship's Diving Systems");

.3 allowable stresses in the dynamic load calculation shall be taken not in excess of 0,8 times the yield stress of the material.

2.4.3 If one of the items of handling system machinery fails, another means shall be provided to ensure recovery of the lock-out submersible and diving bell aboard the support ship and mating with the compression chamber.

When the power mating facility is used for mating operations, a spare power mating facility or an appropriate means shall be provided to ensure connection of the manned submersible or diving bell to the compression chamber in the event of failure of the main power system.

2.4.4 Synchronous operation of the handling system machinery shall be provided. The driving arrangements of winches and reels shall make it possible to generate and change slack in the breathing gas mixture supply hoses and cables.

2.4.5 When the rope is wound in one layer, the drums shall be provided with helical grooves of a depth not less than one-half the diameter of the rope wound.

2.4.6 When the rope is wound in several layers, smooth drums may be used. In such cases, the winch shall be provided with a fairlead.

2.5 COMPRESSOR PLANTS

2.5.1 The compressor plant intended to ensure diving shall include, as a minimum, the following equipment: compressors with their drives, gas bottles, filters, piping with fittings and air distribution panels.

2.5.2 Air and gas compressors shall comply with the requirements of 5.1, Part IX "Machinery" of the Rules for the Classification and Construction of Sea-Going Ships.

2.5.3 The number of the compressors and bottles shall be determined proceeding from the required capacity. The capacity of the compressors shall exceed by 10—15 per cent the capacity needed to supply all the consumers having regard to the use of the reserves of air or breathing mixture. As a rule, the number of compressors shall be not less than two.

2.5.4 Use may be made of the compressors, the discharge pressure of which exceeds pressure, for which the system is designed, by up to 15 per cent.

2.5.5 The purifying and drying device shall be fitted on the discharge line of the system, at the compressor outlet, before the bottle.

3 HEAT EXCHANGERS AND PRESSURE VESSELS

3.1 GENERAL

3.1.1 Heat exchangers, pressure vessels, and fixed surface compression chambers are subject to the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification and Construction of Sea-Going Ships, unless otherwise provided in this Part.

3.1.2 Pressure vessels on open deck shall be protected from mechanical damages and solar radiation.

3.1.3 Pressure vessels shall be installed at a distance not less than 1 m from heat emission sources.

3.1.4 Bottles shall be so secured as to preclude displacement thereof at any admissible heels and trims.

3.1.5 Each bottle or group of bottles (except for the cases specified in 6.4.5.4, Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification and Construction of Sea-Going Ships") shall be equipped with safety valves fitted directly on the bottle or on filling pipeline.

No bursting disks or fusible plugs shall be installed.

3.1.6 Bottles for the storage of gases, gas mixtures or their heads shall be painted in colours given in Table 3.1.6. Moreover, each bottle shall bear on its cylindrical portion the name and chemical formula of gas stored therein.

Table 3.1.6

Gas (gas mixture)	Chemical symbol	Colour of bottles (or heads) and pipelines
Oxygen	O_2	White
Helium	He	Brown
Air	—	White and black
Nitrogen	N_2	Black
Helium-oxygen mixture	$(He + O_2)$	White and brown
Carbon dioxide	CO_2	Grey

3.1.7 Colour of bottles and marking of gases stored therein shall be clearly distinguishable from the position of shut-off valve.

3.1.8 Bottles with oxygen shall be stowed in upright position in a special enclosed room. This room shall be located outside the machinery spaces, at a distance of at least 2 m from accommodation spaces and control stations, and at least 4 m from spaces where readily ignitable materials are stored or essential shipboard equipment is installed.

Bottles with oxygen shall be stored separately from bottles with other single-component gases or gas mixtures.

3.1.9 Use of the same bottles for alternate storage of different single-component gases is not permitted. As an exception, bottles intended for storage of helium may be used for storage of helium-oxygen mixture and vice versa.

3.1.10 For storage of different breathing gas mixtures separate groups of bottles shall be provided.

3.2 PRESSURE VESSELS

3.2.1 All pressure vessels installed in the manned submersibles and diving bells are subject to the requirements of 3.1 of the present Part and 6.4.5, Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification and Construction of Sea-Going Ships.

3.2.2 Bottles and pressure vessels external to the pressure hull shall be designed for external pressure equal to the pressure at the design diving depth.

They shall be hydraulically tested in empty condition by an external pressure equal to 1,5 times the pressure at maximum operating depth.

3.2.3 Capacity of bottles or group of bottles installed inside the pressure hull shall be such that any leakage of gas therefrom does not result in rise of the pressure within the compartment by more than 0,1 MPa, and the oxygen content in this case being not in excess of 25 per cent by volume.

3.2.4 If the oxygen bottles are located externally to the pressure hull of the manned submersible, they shall be divided at least in two groups having separate inlets into the submersible.

3.3 HEAT EXCHANGERS

3.3.1 Breathing mixture heaters shall have devices for the discharge of gas mixture and draining arrangements.

3.3.2 Breathing mixture heaters shall be equipped with safety devices with a design discharge capacity preventing building-up of a pressure exceeding the operating pressure by more than 10 per cent.

Fitting of shut-off valves between the heat exchanger and the safety device is not permitted.

3.4 FITTINGS AND SAFETY DEVICES

3.4.1 Shut-off, regulating and safety fittings shall be tested by a pressure not lower than 1,5 P_{op}.

3.4.2 Compartments of the compression chambers, diving bells and living compartment of the lock-out submersibles shall be provided with alarms to be actuated when the operating pressure is exceeded, or with safety valves, the number and discharge capacity of which shall prevent building-up of pressure exceeding the operating pressure by more than 10 per cent.

After actuation, the safety valves shall cut off completely discharge of gas upon pressure drop to a level in excess of that of the first decompression stage when descending to the maximum diving depth.

3.4.3 The safety valve of diving bells and living compartment of the lock-out submersibles shall be isolated from their inner space by a readily accessible quick-closing valve.

This valve shall be fitted inside the diving bell and living compartment of the lock-out submersible and be constantly open and sealed. The safety valve shall be protected from mechanical damage and catching.

3.4.4 The safety valves of the compression chambers shall have manually operated quick-closing valves fitted on both sides of the pressure hull. The valves shall be constantly open and sealed.

3.4.5 Fittings, pipes and devices installed on the diving bells and inside the compression chamber shall be tested by an external pressure equal to 1,5 times the pressure at the operating diving depth.

3.4.6 After assembly, the fittings shall be tested for tightness of closing by a pressure equal to the design pressure for gases and gas mixtures and to 1,25 P_{op} for liquid media.

3.4.7 All pipes entering into the compression chamber and living compartment of the lock-out submersible shall be equipped with manually operated shut-off valves fitted directly on the pressure hull, on both sides thereof.

One of these valves shall be generally a non-return valve and be automatically closed when the pressure in the system is reduced. The external breathing gas mixture conditioning and purification system shall be provided with a quick-closing valve, which comes into action automatically upon pressure drop to a level not in excess of the last decompression stage.

Installation of closing fittings on one side only is subject to special consideration by the Register in each particular case.

3.4.8 Any pipeline running through the pressure hull of the manned submersible shall be provided with manually operated shut-off valve fitted on the inner side of the pressure hull. If this is impracticable, use may be made of short side branch pipes fitted between the hull and the valve and capable of withstanding the expected mechanical loads and loads due to pressure.

3.4.9 Valves installed on the outside of the diving bell hull and intended for reduction of pressure, drainage, connection of pressure gauge shall be protected against mechanical damages. Flooding valve shall be installed also inside the diving bell.

3.4.10 Valves and cocks shall be provided with indicators to show open/closed position. If use of the indicators is impracticable, other means of valve position indication may be admitted.

3.4.11 The pipelines of the manned submersibles, which are exposed to sea water and run through the manned spaces of the pressure hull shall be provided, in addition to the valve mentioned in 3.4.8, also with a non-return or shut-off valve.

3.4.12 Use of tapered cocks (plugs) is not permitted.

3.5 SPECIAL REQUIREMENTS FOR THE FIXED SURFACE COMPRESSION CHAMBERS

3.5.1 The diving system intended to ensure operations at depths more than 12 m shall, as a minimum, include either one surface compression chamber with two separate compartments, or two interconnected separate chambers so designed as to permit the personnel to enter and leave the compression chamber while one compartment or chamber remains pressurized. All doors shall be designed so that locking mechanisms can be operated from both sides.

3.5.2 Where the compression chamber is used under the circumstance when a person is intended to remain under pressure for a period of more than 12 hours, it shall be so arranged as to allow most divers to stand upright and stretch out comfortably on their bunks. The smaller of two compartments shall be large enough for at least two persons. One of these compartments shall be a living compartment.

3.5.3 The living compartment and other compartments intended to be used for decompression shall have a lock through which food, medicine and equipment may be passed into the chamber while the persons inside remain under pressure.

3.5.4 Locks shall be designed to prevent accidental opening under pressure and, where necessary, interlocks shall be provided for this purpose.

3.5.5 Each pressure compartment shall have view ports to allow observation of all the persons in the compression chamber from the outside.

3.5.6 The surface compression chamber shall provide a suitable environment and facilities for the persons who use it, having regard to the type and duration of the diving operation. Where the chamber is intended to be occupied for more than 12 hours, toilet facilities shall be also provided. Toilet facilities capable of discharging the waste outside shall be fitted with suitable interlocks.

3.5.7 The diving system shall be capable to provide the safe transfer of the persons under pressure from the diving bell to the surface compression chamber (and vice versa).

4 SYSTEMS AND PIPING

4.1 GENERAL

4.1.1 Materials used in the manufacture of pipelines and fittings, as well as testing thereof shall comply with the requirements of Part VIII "Systems and Piping" of the Rules for the Classification and Construction of Sea-Going Ships.

4.1.2 It is recommended to use pipes made of copper, titanium alloys and stainless steel, as well as bimetallic pipes. The pipelines with fittings shall ensure passage of sufficient amount of gas having specified parameters at the design diving depth.

4.1.3 Systems, joints and equipment exposed to internal or external pressure or to their combined effect shall correspond to this purpose. All pipes, which may be exposed to sea water under pressure, shall be as strong as the pressure hull.

4.1.4 Pipes located in places where they can be subject to mechanical damage shall be safely protected.

4.1.5 Materials used in oxygen systems shall be compatible with oxygen at operating pressures and temperatures. Pipes and fittings made of stainless steel shall not be used in oxygen systems.

4.1.6 The high-pressure oxygen pipeline section (between the bottle and reducing device) shall be of the minimum length.

4.1.7 Pipelines for single-component gases, gas mixture and oxygen under high pressure shall be safely protected against mechanical damages. They shall not be located inside accommodation and machinery spaces.

4.1.8 Pipelines and heaters of water and steam heating systems installed inside the manned submersibles, compression chambers and diving bells shall be manufactured of seamless corrosion-resistant pipes.

4.1.9 Pipelines passing through the spaces inaccessible for maintenance shall consist of one-piece pipe section along the full length.

4.1.10 Pipelines located on open decks shall be covered by casings. The strength of the pipelines and fittings shall be such that the destructive pressure exceeds the operating one by not less than four times.

4.1.11 On air or gas outlets inside the compression chamber, protective devices shall be fitted to prevent sticking of objects and people present in the chamber upon pressure drop (e.g. convex gratings).

4.1.12 Indication of external pressure acting upon the manned submersibles and diving bells shall be provided inside thereof.

4.1.13 In order to monitor the gas medium composition in the compression chambers, living compartment of the lock-out submersibles and hyperboat, gas analyzers continually determining oxygen and carbon dioxide content shall be fitted. Moreover, for the manned submersibles under atmospheric pressure express-analyzers shall be also provided.

4.1.14 Air or gas discharge from the compression chambers shall be arranged at the bottom of the compartment. Compression chamber compartments shall be free of stagnant, non-ventilated pockets.

4.1.15 Gases vented from the ship's diving systems shall be discharged into open air in locations remote from the personnel, ignition sources or any area where presence of gas may be hazardous.

4.1.16 The systems providing the operation of the ship's diving systems shall be generally separated from other systems of the support ship.

Necessity of interconnection of these systems is subject to special consideration by the Register in each particular case.

4.1.17 Pipelines for oxygen shall not be laid close to the pipelines and equipment containing fuel or oil, and to the hot surfaces.

4.1.18 Shut-off valves of the oxygen systems under the pressure in excess of 0,17 MPa, except for the isolating valves fitted directly on the pressure hull shall be so constructed as to be opened in slowed-down manner.

4.1.19 In order to protect the hydraulic systems against overpressure, a safety valve shall be fitted on discharge pipeline. Upon operation of this valve, the fluid shall return to the system.

4.2 SUBMERGENCE AND SURFACING SYSTEMS

4.2.1 The vent valves of ballast tanks in the manned submersibles shall be closed automatically in the event of failure of their actuators.

4.2.2 The amount of high pressure air for use in submergence and surfacing systems of the manned submersibles shall be such as to ensure full three-time blowout of ballast tanks at a depth not less than 10 m.

4.2.3 The compensating tanks shall be equipped with water level gauges.

4.2.4 The high-pressure air valves of the ballast tank blowout system shall be interlocked in closed position when the vent valves open and also when both the vent valves and sea valves open simultaneously.

4.2.5 The equipment for blowout of the ballast tanks in the manned submersibles shall be such that the possibility of their damaging by overpressure is eliminated completely.

4.3 LIFE SUPPORT SYSTEMS

4.3.1 The control stations for the life support systems of the compression chambers, diving bells and manned submersibles shall ensure:

.1 switch-over from one gas storage bottle to another;

.2 control of pressure in each compartment independently of the pressure in adjacent compartments;

.3 independent decompression of divers of each compartment;

.4 control of oxygen supply to compartments and of breathing mixture supply to masks;

.5 switch-over from operational gas mixture supply to emergency gas mixture supply in not more than 1 min;

.6 simultaneous supply of gas mixture to not less than two divers and the diving bell operator into that bell and the living compartment of the lock-out submersible;

.7 adjustment of operational parameters of single-component gases and gas mixtures delivered to distribution panels and alarm to indicate exceeding of the allowable limits of same;

.8 maintenance of the required pressure inside the chambers and bell;

.9 maintenance of the necessary content of oxygen and carbon dioxide inside the chambers and diving bell.

4.3.2 Prior to installation, the pipelines and heaters of water or steam heating system shall be hydraulically tested for strength by a test pressure equal to twice the operating pressure. In any case, stresses arising during hydraulic test shall not exceed 0,9 times the yield stress of the material at the test temperature.

As the operating pressure for the pipelines, fittings and heaters located inside the compression chamber and diving bell, the higher of the external or internal pressure shall be assumed, while for the pipelines and fittings located outside the compression chamber – it is the appropriate pressure of the working medium.

4.3.3 The sections of pipelines shall be tested upon installation by hydraulic pressure equal to 1,5 times the operating pressure.

4.3.4 Once installed on board ship, the life support system shall be tested for tightness by a pressure equal to the maximum operating pressure. Testing shall be carried out with the use of that gas, for which the system is intended or with a gas equivalent thereto in the leakage rate. Pressure drop of the gas shall

not exceed 1 per cent of the operating one per day when testing the life support system with a hyperbaric compartment.

4.3.5 Pipelines of the gas systems shall be coloured according to Table 3.1.6.

4.3.6 Where flexible removable pipelines are used for gas and breathing gas mixture supply, an isolating valve and pressure gauges shall be fitted at the connections of the removable pipelines, and in case of gas and breathing gas mixture supply to the bottles of the manned submersibles and diving bells, valves for pressure relief in the removable pipeline shall be fitted as well.

For each gas and breathing gas mixture a separate removable pipeline with its own connection sizes shall be provided.

4.3.7 For the transfer of gases and breathing mixtures gas booster compressors shall be used.

Oxygen compressors shall not be used for the transfer of breathing mixtures or air.

4.3.8 A non-return or stop-check valve shall be fitted on the delivery pipeline of each booster compressor.

4.3.9 The equipment of the regeneration system may be installed outside the compression chamber and connected thereto by pipelines. The system pipelines shall be designed for the operation pressure adopted for the compression chamber. The regeneration system shall be independent for each compartment of the compression chamber and be duplicated.

4.3.10 The regeneration system inlets to the compartment shall be fitted with shut-off valves, which make it possible to disconnect the system from the compression chamber, and with quick-closing automatic devices cutting the regenerating system off the compression chamber in the event of failure and pressure drop.

4.3.11 In the system for regeneration of air medium under atmospheric pressure in the manned submersible compartments, it is allowed to use solid regenerative chemicals placed in the regeneration units, the covers of which shall be tightly closed by a quick-acting locking devices.

4.3.12 In the manned submersibles under atmospheric pressure, the life support system shall maintain an oxygen content in the air for breathing in the range from 18—23 per cent by volume, and CO_2 content below 0,5 per cent by volume under normal conditions and below 1 per cent by volume under emergency conditions.

4.3.13 When calculating the necessary capacity of the main and emergency life support system in the manned submersibles, the oxygen consumption shall be assumed to be equal to 28,3 l/hr per person, and the rate of CO_2 formation – equal to 0,0523 kg/hr per person.

4.3.14 The control stations of the life support system shall be provided with indication of:

.1 oxygen and carbon dioxide content;

.2 pressure in each compartment;

.3 gas medium temperature in each compartment;

.4 pressure in gas bottles connected and at the outlet of pressure regulator;

.5 oxygen pressure in mains to supply it to compartments and masks.

4.3.15 The helium storage space is recommended to contain a gas analyzer, which operates at the oxygen content below 20 per cent by volume.

4.3.16 Additional requirements for the life support systems of evacuation compression chambers:

.1 in addition to the controls intended for supplying breathing mixtures and maintaining necessary parameters, fitted externally, provision shall be made for the controls fitted inside the pressure hull;

.2 oxygen supply to the evacuation compression chambers shall be controlled from the control panels and effected through two independent distribution systems;

.3 compression chambers used for evacuation with decompression being carried out simultaneously shall be provided with necessary life support systems including a therapeutic mixture supply system;

.4 evacuation compression chambers shall be equipped with connections for supply of hot and cold water, as well as of therapeutic breathing mixture, arranged on the outside, in a readily accessible place.

The connection sizes shall be as follows:

3/4 inch (seat): cold and hot water;

1/4 inch (seat): breathing mixture.

The connections shall be clearly marked and properly protected;

.5 breathing gas bottles, pipelines of systems and equipment of the evacuation compression chambers intended for use in the event of fire shall be suitably insulated. Thermal insulation shall not be toxic.

4.4 EMERGENCY LIFE SUPPORT SYSTEM

4.4.1 For diving bells and tethered manned submersibles, an emergency life support system shall be provided to enable persons to remain therein for a period not less than 24 hours.

4.4.2 In each manned submersible, diving bell and diving compartment of the lock-out submersibles, provision shall be made for emergency breathing

masks supplied with breathing mixture, one for each person present therein plus one spare mask.

4.4.3 For self-sustained manned submersibles and evacuation compression chamber, an emergency life support system shall be provided to enable person remain therein for a period not less than 72 hours.

For the lock-out submersibles, a reduction in the minimum operating period of the emergency life support system to 24 hours is permitted.

4.4.4 In the compression chamber, an internal emergency life support system shall be provided, the operating time and capacity of which is determined by the Designer on agreement with the Customer and the Ministry of Health.

4.5 VENTILATION AND AIR CONDITIONING

4.5.1 Spaces referred to in 2.1.13, 2.1.14 and 2.1.16 shall be generally equipped with forced supply-exhaust ventilation capable of providing at least 10 air changes per hour.

4.5.2 In general, air shall be exhausted from these spaces in the following way:

.1 2/3 from the lower part and 1/3 from the upper part of the spaces intended for oxygen bottles, oxygen booster compressors, helium-oxygen mixture preparation and the compressor room;

.2 2/3 from the upper part and 1/3 from the lower part of the spaces intended for helium bottles and helium booster compressors;

.3 1/2 from the upper as well as from the lower part of the spaces for bottles containing compressed air, air-helium and recovered mixtures.

4.5.3 In the spaces for oxygen bottles, oxygen booster compressors and helium-oxygen mixture preparation the exhaust flow rate shall exceed the supply flow rate. The ventilators shall be generally installed outside the spaces listed.

4.5.4 The outlets of exhaust ventilation ducts shall be provided with flame-arresting fittings.

4.5.5 All closures of the ventilation ducts shall preclude spark formation.

4.5.6 The design of ventilators shall comply with the requirements of 5.3.3, Part IX “Machinery” of the Rules for the Classification and Construction of Sea-Going Ships.

4.5.7 The machinery of air conditioning system shall comply with the requirements of Part IX “Machinery”, Part X “Boilers, Heat Exchangers and Pressure Vessels” and Part XII “Refrigerating Plants” of the Rules for the Classification and Construction of Sea-Going Ships.

4.6 FITTINGS AND SAFETY DEVICES

4.6.1 Fittings used in the systems of the manned submersibles and ship's diving systems shall have position indicators: "open" and "closed".

4.6.2 Air supply pipelines for blowing out compensating tanks in the manned submersibles shall have not less than two isolating valves.

4.6.3 If the compression chamber has more than one steam or water heater, each of them shall have shut-off valves.

4.6.4 Where reducing valves are used on the low-pressure side, a safety valve and a pressure gauge shall be fitted. The discharge capacity of the reducing valve (valves) shall be not less than:

.1 compressor capacity when the pipeline is fed from a compressor;

.2 maximum gas or gas mixture flow rate required for the consumer operation when the pipeline is fed from bottles.

4.6.5 On the pipelines for supplying gases and gas mixtures to the panels of compression chambers and to the panels for gas supply to diving bells and to gas distribution panels, there shall be not less than two reducing valves (one of which is a standby one) installed in parallel. The discharge capacity of each reducing valve shall provide the highest flow rate that could be possibly required by the consumer.

4.6.6 The casings of the fittings with covers of the gas systems shall be tested for strength by a pressure equal to 1,5 P_{op}. The assembled fittings shall be tested for tightness of closing by a pressure equal to the design one.

4.6.7 The fittings shall ensure passage of an adequate amount of gas having specified parameters at the maximum submergence depth.

4.6.8 The number and discharge capacity of safety valve shall be calculated so that the pressure in the pipeline does not exceed the operating one by more than 10 per cent.

4.6.9 The discharge capacity of the safety valve shall be calculated according to the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification and Construction of Sea-Going Ships.

4.6.10 The design of the safety valve shall provide for its adjustment and functional checkout.

4.6.11 When the compression chambers are located on open decks, safety valves shall be weathertight.

4.6.12 In oxygen systems, ball valves shall not be generally fitted, but such is not the case for the emergency shut-off valves to be fitted directly on the hull.

4.7 DIVING HOSES

4.7.1 Diving hoses shall comply with the following requirements:

.1 to enable their use in sea water at temperatures from −2 to +50 ºC and at ambient air temperature from −55 to +55 ºC;

.2 the outer hose layer shall be resistant to the attack of gasoline, kerosene and lubricating oils;

.3 tightness shall be ensured at the gas medium pressure not less than 1,5 P_{op};

.4 safety margin of hoses in assembly with hose couplings with respect to destructive loads shall be:

not less than 2 – for external pressure disturbing the hose stability;

not less than 3 – for internal pressure with the longitudinal loads being taken into account;

.5 longitudinal strength of the assembled hoses and hose couplings shall ensure reliable operation of diving bells at the operating depths and shall be confirmed by the calculation;

.6 deformation of the external diameter shall not be in excess of 15 per cent of the initial value, when compressed by a load of 1500 N evenly distributed along a length of 150 mm;

.7 no permanent elongation shall exist at longitudinal tension with a force not less than 1800 N.

4.7.2 The design of detachable and non-detachable connections intended for connecting the hoses shall ensure tightness of the connection and prevent any spontaneous disconnection and damage of hoses.

4.8 INSTRUMENTATION

4.8.1 The manned submersibles and ship's diving systems shall have instrumentation for monitoring the parameters of the systems and equipment installed.

4.8.2 On the scales of pressure and depth gauges, the pressure corresponding to the maximum operating pressure and limiting operating depth shall be marked by a red line.

4.8.3 Pressure gauges in diving boards, panels and other means of supplying gas medium to the compression chambers, diving bells and directly to a diver shall be of accuracy class 1.

4.8.4 Checking and sealing (branding) of pressure gauges shall be done not less than once per year by the competent bodies recognized by the Register.

4.8.5 In the control panel for the systems of compression chambers or in the vicinity thereof, pressure gauges showing the pressure in the delivery mains shall be installed. The pressure gauges shall be installed so that their readings can be clearly seen by the attending personnel.

4.8.6 Pressure and depth gauges installed in the systems of the manned submersibles and ship's diving systems shall have arrangements for their cut-off and connection of checking devices.

4.8.7 Pressure gauges in control panels shall have a device to ensure automatic disconnection thereof as soon as the allowable pressure is exceeded.

4.8.8 The pressure and depth gauges shall comply with the requirements of Section 2, Part XV "Automation" of the Rules for the Classification and Construction of Sea-Going Ships.

PART VII. ELECTRICAL EQUIPMENT

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to electrical equipment of the manned submersibles and ship's diving systems and supplements the requirements stated in Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships.

1.1.2 The automation equipment of systems, machinery and devices providing the safety of the manned submersibles and ship's diving systems and personnel therein shall comply with the requirements of Sections 1, 2 and 3, Part XV "Automation" of the Rules for the Classification and Construction of Sea-Going Ships.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to the general terminology of the Rules are given in the General Regulations for the Classification and Other Activity and in Part I "Classification" of the Rules for the Classification and Construction of Sea-Going Ships, and those relating to electrical equipment are given in Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships.

1.3 SCOPE OF SURVEYS

1.3.1 Subject to survey in the manned submersibles and ship's diving systems is the electric equipment associated with the operation of systems, devices and machinery indispensable for the safety of the manned submersibles and ship's diving systems and of personnel therein.

1.3.2 General provisions relating to the classification procedure, survey of the electrical equipment under construction and during manufacture, as well as the requirements for technical documentation on the electrical equipment of the manned submersibles and ship's diving systems to be submitted to the Register for consideration and approval are stated in the General Regulations and in Part I "Classification".

1.3.3 In addition to 1.3.2.1, Part XI "Electrical Equipment" of the Rules

for the Classification and Construction of Sea-Going Ships, the following equipment is considered to be essential for the manned submersibles and ship's diving systems:

.1 electric drives of the machinery used in propulsion, submerging and surfacing, adjusting and compensating and trimming systems of the manned submersibles;

.2 electric drives of handling system machinery;

.3 electric drives of pumps, compressors, fans and electrical equipment of other devices in the life support system;

.4 electric drives of the arrangements for emergency release of ballast and outboard equipment to be jettisoned in case of emergency;

.5 electric systems for monitoring and alarm (actual and limiting values) for submergence depth, overpressure in the diving bell and compression chambers, pressure and other parameters of breathing gas mixture, position of remote-controlled valves in submerging, surfacing and trimming systems, ingress of water into the pressure hull of the manned submersibles, discharge of accumulator batteries, insulation resistance of electrical circuits, fire detection and alarm system, overloading of electric motors installed inside the pressure hull of the manned submersibles, diving bells and compression chambers;

.6 deep-water electric plug-and-socket joints, connectors and cable penetrators;

.7 fixed external lighting.

1.3.4 Survey in the manned submersibles and ship's diving systems of the electrical equipment of systems, devices and machinery intended for process operations and not mentioned in 1.3.3 shall be carried out in accordance with 1.3.2.2, Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships.

1.3.5 In addition to the electrical equipment listed in 1.3.3.1, Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships, the electrical equipment listed in 1.3.3 is subject to survey during fabrication at the manufacturer.

2 ELECTRICAL INSTALLATION

2.1 ELECTRICAL POWER SOURCES OF TETHERED MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS

2.1.1 The main generators of the support ship shall be used as a main source of electrical power for tethered manned submersibles and ship's diving systems. Power output of the ship's electrical power plant shall be such that in addition to the requirements of 3.1.2, Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships, uninterrupted power supply of essential services of the manned submersibles, diving bells, compression chambers and handling systems is ensured.

2.1.2 When an independent electrical power plant is used for power supply of the consumers in tethered manned submersibles and ship's diving systems, the number and power output of electrical power sources and converters shall be such that in the event of failure of any one power source or converter the remainder would ensure power supply of essential services of the tethered manned submersibles and ship's diving systems, or it would be possible to supply such services from the support ship's electric power plant.

The independent electric power plant shall be located outside the room with equipment of the tethered manned submersibles and ship's diving systems.

2.1.3 The emergency source of electrical power for the tethered manned submersibles and ship's diving systems may be either the support ship's emergency power source or an independent power source complying with the requirements of Section 9, Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships. The capacity of the emergency source shall be sufficient to supply uninterruptedly, along with the ship's emergency load (when the ship's emergency power source is used), for a period necessary to complete a diving operation (retrieval of the tethered manned submersible aboard the support ship), the following equipment of the tethered manned submersibles and ship's diving systems:

.1 emergency lighting;

.2 electric drives of the life support system machinery;

.3 emergency communication means;

.4 alarm systems mentioned in 1.3.3.5;

.5 heating systems of the compression chamber and diving bell compartments;

.6 electric drives of the handling systems.

2.1.4 In addition to the emergency power source referred to in 2.1.3, tethered manned submersible and ship's diving system shall be provided with an emergency accumulator battery installed directly on the manned submersible and ship's diving system, of a capacity sufficient for power supply, without reduction of voltage at its terminals lower than 0,9 times the rated voltage of electrical consumers of the life support system, emergency communication means and emergency lighting for a period necessary to maintain vital activity of the crew within 24 hours.

2.2 ELECTRICAL POWER SOURCES OF SELF-SUSTAINED MANNED SUBMERSIBLES

2.2.1 The main source of electrical power for the self-sustained manned submersibles may be accumulator batteries or electrochemical generators.

The use of other types of electrical power sources is subject to special consideration by the Register in each particular case.

2.2.2 The emergency source of electrical power for the self-sustained manned submersibles shall be an independent accumulator battery of a capacity sufficient for power supply, without reduction of voltage at its terminals lower than 0,9 times the rated voltage of electrical consumers of the life support system, emergency communication and emergency lighting for a period necessary for maintaining vital activity of the crew within 72 hours.

For the self-sustained manned submersible with a diving compartment, it is permitted to reduce the rated operating time of emergency consumers, but it shall not be less than that specified in 2.1.4.

2.2.3 The arrangement of emergency source of electrical power, emergency distribution board and distribution board of emergency lighting shall be such that a fire or another damage in the space of the main source of electrical power would not break the supply, control and distribution of electrical power from the emergency source.

2.3 ELECTRICAL POWER DISTRIBUTION AND ALLOWABLE VOLTAGE

2.3.1 Only isolated systems of electrical power distribution are allowed in the installations of the manned submersibles and ship's diving systems.

The use of other systems of electrical power distribution is subject to special consideration by the Register in each particular case.

2.3.2 Each isolated system of electrical power distribution shall have devices for monitoring and alarm to indicate an inadmissible reduction of the insulation resistance.

2.3.3 The rated voltage at the terminals of power sources and consumers in the manned submersibles and ship's diving systems shall not exceed the following values:

.1 30 V d. c. — at the terminals of the emergency accumulator batteries in the manned submersibles and ship's diving systems, as well as of the consumers in the diving bells, diving compartments of the lock-out submersibles and compression chambers;

.2 250 V d. c. — at the terminals of the main power sources of self-sustained submersibles, submersible transformer (if used), stationary power consumers, lighting and heaters of the manned submersibles.

The use of higher voltages is subject to special consideration by the Register in each particular case.

2.3.4 The hulls of diving bells, manned submersibles and compression chambers shall have devices for reliable earthing by connection to the support ship hull when staying at the port. The cross-sectional area of the earthing cable core shall be not less than 16 mm^2.

2.4 POWER SUPPLY OF ESSENTIAL SERVICES

2.4.1 The following consumers of the tethered manned submersibles and ship's diving systems shall be supplied by separate feeders from the main switchboard bus bars via emergency switchboard installed on the support ship:

.1 switchboard of the handling system machinery electric drives;

.2 electric power reception and distribution switchboards of the diving bell, tethered manned submersible and compression chambers.

2.4.2 In addition to the requirements of 4.3.1, Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships, the following consumers shall be supplied by separate feeders from the main switchboard of the self-sustained manned submersible:

.1 electric drives of the life support system pumps and compressors;

.2 electric drives of the carbon dioxide removal fans of the life support system;

.3 sonar communication means and navigational equipment;

.4 alarm systems listed in 1.3.3.5;

.5 electric drives of the submerging and surfacing system machinery;

.6 electric drives of the adjusting and compensating and trimming system machinery;

.7 fixed external lighting system.

2.5 DISTRIBUTION UNITS

Circuit breakers shall be used for protection of electrical equipment.

The use of fuses is allowed only in circuits supplied from the accumulator batteries and in control, monitoring and alarm circuits.

No control and protective units shall be installed inside the compression chambers.

2.6 ELECTRIC DRIVES OF MACHINERY AND EQUIPMENT

Electric drives of machinery and equipment of the manned submersibles and ship's diving systems shall have means for centralized emergency switch-off. For the ship's diving systems, such means shall be located in permanently attended control station.

No collector-type electric motors shall be installed in the compression chambers, the oxygen content in which at operating pressure exceeds 5 per cent.

2.7 LIGHTING

2.7.1 If necessary, lighting fixtures in spaces and compartments of the manned submersibles and ship's diving systems shall have devices providing efficient protection against mechanical damages.

The design of the lighting fixtures shall allow the replacement of electric light bulbs under pressure.

The circuits of external deep-water lighting fixtures shall include protective relays to switch-off the voltage in the event of cable break or bulb damage.

2.7.2 Locations where the controls and instruments of the life support system, communication means, submergence depth indicators, etc., which ensure the safety of the manned submersibles and ship's diving systems and personnel therein are installed, shall be provided with emergency lighting to be switched on automatically when the main lighting is switched off.

It is allowed to have combined lighting fixtures of the main and emergency lighting.

No switches of the lighting fixtures shall be installed in the compression chambers.

2.7.3 Socket outlets for portable lighting and other portable electrical equipment shall have switches to preclude application of voltage to the socket when the consumer is disconnected.

2.8 SERVICE TELEPHONE COMMUNICATION

2.8.1 The diving operation control station of the support ship shall have an independent telephone communication with:

.1 diver in the water;

.2 diving bell;

.3 compression chamber spaces;

.4 control stations of handling system, life support system and support ship;

.5 main control station of support ship;

.6 control station of dynamic positioning system.

2.8.2 The main control station of the self-sustained manned submersible shall have an independent telephone communication with the diving compartment and other habitable spaces of the manned submersible, as well as with an extension control station of the rudder propeller of the manned submersible if such station is provided for surface sailing of the manned submersible.

2.8.3 To maintain the communication with the diving bell, compartment or compression chamber intended for operation with the use of helium gas mixture, not less than two speech unscramblers shall be installed, one of which being located at the diving operation control station on board the support ship.

2.9 CABLING

2.9.1 Use shall be made of non-combustible and flame-retarding cables and conductors with copper cores manufactured in accordance with the requirements of Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships or current standards approved by the Register.

2.9.2 The umbilical, by means of which the electrical power is supplied to the tethered manned submersible and diving bell, shall have an adequate strength to prevent cable from breaking due to tensioning and jerks in a seaway (see also 6.2.8 and 6.2.9, Part X "Shipboard Handling Systems of Manned Submersibles and Ship Diving Systems").

2.9.3 Cables laid external to the pressure hull of the manned submersible or diving bell shall be made radially and longitudinally tight and protected against mechanical damages.

Cables without longitudinal tightness may be allowed if the longitudinal tightness is ensured by the cable penetrator design or if there is no need for them to penetrate the pressure hull.

2.9.4 Where devices external to the pressure hull are supplied via two separate cables, the latter shall be laid through different sealed penetrators spaced as far as possible apart.

2.10 CABLE PENETRATIONS IN THE PRESSURE HULL

2.10.1 Cable penetrators, plug-and-socket joints and connectors shall be made tight (i.e. to withstand the pressure at the test submergence depth and to prevent leakage of gas medium) under normal operating condition and when the parts of the manned submersible and diving bell are disconnected.

2.10.2 Electrical cable penetrations in the pressure hull shall be designed, manufactured and tested in compliance with the requirements of the national or international standards agreed with the Register.

2.10.3 Cable penetrators shall ensure watertightness of the pressure hull in case of the cable break or other damage.

2.10.4 Electrical conductors in the cable penetrations shall be manufactured of monolithic (non-multicore) material.

2.10.5 Positive and negative conductors from the electrical power source shall not be introduced into the pressure hull through the same penetrator.

Exceptions may be accepted in case that:

there is no probability of a short circuit or tracking between the conductors and the parameters (values) of the voltages and currents are such that in case of a break-down or damage of the conductor insulation the watertightness of the penetration is retained.

2.10.6 The cable penetrations shall not be used for leading any pipelines but this does not preclude use of common plates to lead in both the cables and the pipelines.

2.11 ACCUMULATOR BATTERIES

2.11.1 Accumulator batteries, which in the process of operation give off explosive substances or substances harmful for human health, shall be located outside the submersible pressure hull.

Other locations of the accumulator batteries are subject to special consideration by the Register in each particular case.

2.11.2 The design of the exhaust gas system, when submersible accumulators are used, shall be such as to preclude the discharge of compensating liquid to the environment.

2.11.3 The batteries shall be interconnected by flexible straps.

2.12 DESIGN OF ELECTRICAL EQUIPMENT

2.12.1 All electrical and electronic equipment shall be designed having regard to the environmental conditions, in which it is intended to operate so as to minimize the risk of fire, explosion, electric shock and emission of toxic gases and to remain operative under any critical operating conditions: instantaneous list up to 45º and trim up to 30º, continuous list up to 30º and trim up to 15º.

2.12.2 The electrical equipment shall be capable of trouble-free performance in gas-air medium at a temperature from –2 ºC to +45 ºC and relative humidity up to 98 per cent at +35 ºC.

2.12.3 Submerged electrical equipment, as well as the equipment of diving compartments shall be designed for operation in overpressure conditions corresponding to the test submergence depth of the manned submersibles and diving bells, as well as in open air to carry out maintenance, inspections or reception of media.

It is allowed to have electrical equipment in tight capsules or filled with compensating liquids. Compensating liquids shall have good dielectric and corrosion-proof properties and shall not generate toxic or aggressive compounds in the process of operation.

The design of compensating devices is subject to special consideration by the Register in each particular case.

3 ADDITIONAL REQUIREMENTS FOR THE PASSENGER SUBMERSIBLES

3.1 MAIN SOURCE OF ELECTRICAL POWER

3.1.1 The main source of electrical power shall have the power (capacity) sufficient to supply all the necessary equipment during the period of normal voyage and in addition thereto, it shall have the power reserve to provide

supply of electrical power, for a time period consistent with the emergency rescue plan but not less than 24 hours, to the following consumers:

.1 emergency lighting;

.2 communication equipment;

.3 life support system;

.4 environmental monitoring equipment;

.5 main control systems;

.6 other necessary equipment for life support;

.7 alarm device to indicate submergence to design depth (if its operation depends on the electrical power).

3.1.2 The emergency source of electrical power of the passenger submersibles shall be a separate accumulator battery of a capacity sufficient to supply the electrical consumers listed in 3.1.1,without reduction of voltage below 0,9 times the rated voltage of the consumers, for a period exceeding 1,5 times the time of emergency surfacing, but not less than during 1 hour.

3.1.3 The control station of the passenger submersible shall be provided with indication of the voltage, current and residual capacitance of each electrical power source, as well as with a device for measuring and indicating the insulation resistance of each insulated electrical power distribution system.

3.1.4 In order to monitor the hydrogen content in the battery room, gas analyzers with visual and audible alarm actuated before the lower explosive concentration of the hydrogen-air mixture is attained shall be installed.

3.1.5 The central control station of the self-sustained passenger submersible shall be provided with an independent telephone communication with the passenger spaces of the passenger submersible, with the extension control station of the rudder propeller of the passenger submersible if such station is provided for surface sailing of the passenger submersible, and a provision shall be made for communication between different passenger compartments.

PART VIII. RADIO AND SONAR EQUIPMENT

1 GENERAL

1.1 APPLICATION

The requirements of the present Part of the Rules apply to radio and sonar equipment of the manned submersibles and diving bells and their support ships.

The radio and sonar equipment shall comply with the requirements of Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships unless provided otherwise in this Part.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to the radio equipment are given in Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships and those relating to general terminology of the Rules — in the General Regulations and in Part I "Classification".

1.3 SCOPE OF SURVEYS

1.3.1 General provisions for the procedure of survey of the radio equipment are given in the General Regulations for the Classification and Other Activity and in Part I "Survey Regulations" and Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships.

1.3.2 Subject to survey by the Register during manufacture, installation and in operation are:

.1 communications sonar systems;

.2 VHF radio installations;

.3 emergency sonar beacons with a fixed frequency of 37,5 kHz;

.4 emergency receivers of sonar signals at a fixed frequency of 37,5 kHz.

1.3.3 Technical requirements for radio and sonar equipment, its location and installation in the manned submersibles and diving bells, which are not mentioned in this Part, as well as the scope of survey of this equipment are subject to special consideration by the Register in each particular case.

1.4 TECHNICAL DOCUMENTATION

The list of technical documents on the radio and sonar equipment, to be submitted for consideration as a part of the design documentation of the manned submersibles and diving bells is given in Section 5, Part I "Classification".

2 LIST OF RADIO AND SONAR EQUIPMENT

2.1 GENERAL REQUIREMENTS

2.1.1 For the purpose of defining the standard list of radio and sonar equipment, the manned submersibles and diving bells are divided into the following groups:

.1 tethered manned submersibles and diving bells;

.2 self-sustained manned submersibles.

2.1.2 The radio and sonar equipment of the manned submersibles shall provide communication with the support ship in the surface and submerged positions.

2.1.3 All manned submersibles and diving bells shall be equipped with emergency sonar beacons with the frequencies as given in Table 2.1.5 for monitoring the position of the manned submersible, diving bell in an emergency situation from the support ship. To perform such monitoring, an emergency receiver of sonar signals shall be installed on board the support ship.

2.1.4 The tethered manned submersible and diving bell shall maintain telephone and sonar communications with the support ship, sonar communication being the emergency one.

2.1.5 Depending on the group, radio and sonar equipment shall be installed in the manned submersible, diving bell and support ships in accordance with Table 2.1.5.

Table 2.1.5

No.	Radio and sonar equipment	Tethered manned submersibles and diving bells	Self-sustained manned submersibles	Support ship
1	Communication sonar system	1[1]	1	1
2	VHF radio installation	—	1	1
3	Emergency sonar beacon with a fixed frequency of 37,5 kHz	1	1[2]	—
4	Emergency receiver of sonar signal at a fixed frequency of 37,5 kHz	—	—	1[2]
5	Emergency position-indicating radio beacon of COSPAS-SARSAT system	1[3]	1[3]	—
6	Radio beacon	1[4]	1[4]	—
7	Radar transponder	1[5]	1[5]	—

[1] To be installed as an emergency one.

[2] For manned submersibles with operating submergence depth in excess of 500 m and for their support ships, in well-grounded cases the emergency frequency of 37,5 kHz may be replaced by a frequency within the range from 8 to 18 kHz.

[3] Equipment recommended for installation.

[4] Provisions for fitting equipment are specified in Part III "Arrangements, Equipment and Outfit".

[5] Required under conditions of unclear visibility of the manned submersible and diving bell on the radar screen.

2.2 SOURCES OF POWER SUPPLY TO RADIO AND SONAR EQUIPMENT

The sources of power supply to the radio and sonar equipment listed in Table 2.1.5 shall comply with the requirements of 2.3, Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships.

The radio and sonar equipment shall be supplied from the main and emergency sources of electrical power as required in Section 2, Part VII "Electrical Equipment".

3 DESIGN OF RADIO AND SONAR EQUIPMENT

3.1 COMMUNICATIONS SONAR SYSTEM

The communications sonar system shall provide, in the single-band telephony mode, communication between the manned submersible, diving bell and the support ship at a distance that exceeds twice the operating submergence depth.

It is recommended that between the communication sessions the sonar system should provide automatic signal transmission to enable the support ship to monitor the underwater position of the manned submersible or diving bell.

3.2 VHF RADIO STATION

The VHF radio station shall provide stable communication between the manned submersible, diving bell in surface position and the support ship and comply with the requirements of 6.1, Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships.

3.3 EMERGENCY SONAR BEACON WITH A FIXED FREQUENCY OF 37,5 kHZ

The emergency sonar beacon is intended for transmitting sonar signal from the manned submersible, diving bell at a fixed frequency of 37,5 kHz to the support ship in order to observe bearing in an emergency.

Its basic performance parameters shall not be lower than those given in Table 3.3.

Table 3.3

Basic performance parameters	Value
Common emergency answering frequency, kHz	37,5 ± 0,05
Individual calling frequencies, kHz:	
channel A	38,5 ± 0,05
channel B	39,5 ± 0,05
Minimum output	85dB/1 mbar at a distance of 1 m
Minimum operating time of a primary battery for operation with a signal at 85dB level	5 days

3.4 EMERGENCY RECEIVER OF SONAR SIGNALS AT A FIXED FREQUENCY OF 37,5 kHZ

The emergency receiver of sonar signals at a fixed frequency of 37,5 kHz installed on board the support ship shall provide reception of sonar signals from the emergency sonar beacon of the manned submersibles and diving bells and determine direction to an object in emergency.

4 LOCATION OF RADIO AND SONAR EQUIPMENT

4.1 Controls and indicators of the radio and sonar equipment listed in Table 2.1.5 shall be located in control stations of the manned submersibles, diving bells and support ship.

Deviations from this requirement due to specific features of the manned submersible, diving bell are subject to special consideration by the Register in each particular case.

PART IX. NAVIGATIONAL EQUIPMENT

1 GENERAL

1.1 APPLICATION

The requirements of the present Part of the Rules apply to navigational equipment of the manned submersibles and diving bells.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to general terminology of the Rules are given in the General Regulations and in Part I “Classification” of the Rules, and Part I "Classification" of the Rules for the Classification and Construction of Sea-Going Ships.

1.2.2 Definitions and explanations relating to the navigational equipment are given in Part V “Navigational Equipment” of the Rules for the Equipment of Sea-Going Ships.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions concerning the procedure of survey of the navigational equipment are stated in the General Regulations and in Part I “Survey Regulations” and Part V “Navigational Equipment” of the Rules for the Equipment of Sea-Going Ships.

1.3.2 The following equipment is subject to survey by the Register during manufacture, installation and in operation:

.1 course indicators;

.2 logs;

.3 echo sounders;

.4 depth indicators;

.5 sonars;

.6 automated navigational systems.

1.3.3 Technical requirements for the navigation instruments and devices, their location and installation in the manned submersibles and diving bells, which are not specified in this Part, as well as the scope of surveys of these instruments and devices are subject to special consideration by the Register in

each particular case.

1.3.4 The navigational instruments and devices listed in items 5—8 of Table 2.2.1 are subject to survey of the Register only in the form of checking their availability in the manned submersibles and diving bells.

1.4 TECHNICAL DOCUMENTATION

The list of technical documents on the navigational equipment to be submitted to the Register for consideration as part of the design documentation of the manned submersible or ship's diving system is given in Section 5, Part I "Classification".

2 LIST OF NAVIGATIONAL EQUIPMENT OF MANNED SUBMERSIBLE, DIVING BELL AND SUPPORT SHIP

2.1 GENERAL REQUIREMENTS

2.1.1 The manned submersibles and ship's diving systems shall be provided with the navigational equipment capable of ensuring their operational safety under all design conditions.

2.1.2 For surface sailing, the manned submersibles shall be provided with means and/or procedures capable of ensuring their maritime safety. The self-sustained submersibles shall be provided with means capable of ensuring such visibility that enables them to sail safely.

2.1.3 Provision shall be made for means enabling other ships to catch quickly sight of the manned submersible when in surface position.

2.1.4 The navigational equipment of the self-sustained manned submersible shall be capable of determining depth and elements of movement of the manned submersible in surface and submerged positions, as well as observing the surrounding conditions in the underwater position.

2.1.5 The navigational equipment of the support ship shall be capable of fixing the submerged and surface positions of the manned submersible and diving bell.

2.2 LIST OF NAVIGATIONAL EQUIPMENT OF TETHERED AND SELF-SUSTAINED MANNED SUBMERSIBLES AND DIVING BELLS

2.2.1 Tethered and self-sustained manned submersibles shall have navigational equipment listed in Table 2.2.1.

Table 2.2.1

No.	Navigational equipment	Tethered manned submersible and diving bell	Self-sustained manned submersible
1	Course indicator	—	1
2	Log	—	1
3	Depth indicator	1[1]	1[1]
4	Echo sounder	—	1
5	Clock	1	1
6	Stopwatch	—	1
7	Inclinometer and trim indicator	1	1
8	Current speed indicator	1	—
9	Sonar	—	1

[1] Passenger submersibles shall have two independent instruments to record the submergence depth. At least one of these instruments shall be a pressure gauge, which is also capable of operating in an emergency situation. If both instruments are pressure gauges they shall not have a common inlet.

2.2.2 It is not necessary for the manned submersible to have an automated navigational system; however, where such system is installed the requirements of 3.3 shall be met.

3 DESIGN OF NAVIGATIONAL INSTRUMENTS AND DEVICES

3.1 DEPTH INDICATOR

3.1.1 Depth indicator shall provide:

.1 continuous measurement of submergence depth with accuracy not less than ± 1 per cent of operating depth;

.2 continuous delivery of information for automated navigational system (if any);

.3 audible and visible alarm to indicate approaching the operational depth at 50 and 10 m (and more, considering the requirement of 3.1.1) before it, as well as information on reaching it.

3.2 SONAR

3.2.1 The sonar shall provide:

.1 review of navigational situation and detection of obstacles in the direction of movement over a distance exceeding the stopping distance of the manned submersible after the propelling devices have been stopped at normal speed;

.2 adjustment of operating range and angular field of view depending on size, reflectivity and distance to underwater objects.

3.2.2 It is recommended to use scanning sonars.

3.3 AUTOMATED NAVIGATIONAL SYSTEM

3.3.1 The automated navigational system of the manned submersibles shall provide:

.1 measurement and processing of navigational information for the purpose of steering and maritime safety of the manned submersibles;

.2 possibility of change-over to manual control.

4 LOCATION OF NAVIGATIONAL EQUIPMENT

4.1 Controls and indicators of the navigational equipment listed in Table 2.2.1 and in 2.2.2 shall be located in the control station. Any deviations from this requirement due to specific feature of the manned submersible or diving bell are subject to special consideration by the Register in each particular case.

PART X. SHIPBOARD HANDLING SYSTEMS OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to the handling system of the manned submersibles and diving bells of ship's diving systems intended for launching the manned submersibles or diving bells from the support ship to the water surface or to the required depth, for towing (in case of towed manned submersibles), for recovery aboard the support ship, as well for emergency recovery aboard the support ship.

1.1.2 The present Part supplements the Rules for the Cargo Handling Gear of Sea-Going Ships.

All the requirements of the Rules for the Cargo Handling Gear of Sea-Going Ships apply to the handling system, unless other requirements are specified in these Rules.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to general terminology of the Rules and to cargo handling gear are given in the General Regulations and in 1.2 of the Rules for the Cargo Handling Gear of Sea-Going Ships, respectively.

1.2.2 For the purpose of the present Part, the following definitions have been adopted.

S a f e w o r k i n g l o a d o f h a n d l i n g s y s t e m means the greatest allowable mass of the manned submersible or diving bell to be lifted out of water with its regular crew and outfit, with allowance made for instantaneous values of the mass of water remained in permeable parts.

D e s i g n s e a s t a t e means the sea state increased by 1 as against the design one.

T r a c k i n g means hoisting of the manned submersible or diving bell from the water surface aboard the support ship in a seaway by means of the handling system equipped with a device for tracking the manned submersible or diving bell during its movement in the seaway.

1.3 SCOPE OF SURVEYS

1.3.1 The scope of surveys is determined by the requirements of 1.3 of the Rules for the Cargo Handling Gear of Sea-Going Ships. Besides, subject to the survey by the Register are:

.1 counterbalance platforms (for tightening the guide wire ropes);

.2 anti-sway appliances (during the transfer of the manned submersible or diving bell upon emergence from water and until mating and boarding on the support ship deck);

.3 handling system trolleys;

.4 dynamic load dampers in the carrying and guide wire rope systems;

.5 other mechanical and electrical equipment recognized by the Register as essential for safe operation of the handling system;

.6 devices for gripping and suspending the manned submersibles or diving bells.

1.4 TECHNICAL DOCUMENTATION

The scope of technical documentation to be submitted to the Register for consideration and approval shall not be less than that specified in 1.4 of the Rules for the Cargo Handling Gear of Sea-Going Ships.

2 GENERAL TECHNICAL REQUIREMENTS

2.1 Machinery and control devices of the handling system shall be located so that the attending personnel have sufficient view of the work site and can continuously see the movement of trusses (girders) of the handling system, manned submersible, diving bell and their suspension members.

2.2 The control of launching the manned submersible or diving bell under normal conditions shall be effected by means of the winch drive and not by means of mechanical brakes.

2.3 Handling system machinery or groups of synchronously operating machinery having a. c. drives shall be switched off upon loss of any of three phases.

2.4 In the event of failure of the handling winch, each handling system shall allow hoisting of the manned submersible or diving bell onto the support ship by handling wire ropes with the use of mooring or other deck machinery; in doing so, efficient stopping of handling wire ropes shall be provided during changeover from the handling winch to deck machinery.

The design may provide for emergency recovery of the manned submersible or diving bell onto the deck by the emergency and guide ropes.

For self-sustained and tethered manned submersibles, the handling system, in emergency situations, shall allow their hoisting to the water surface and retaining in that position in order to make it possible to open the access hatch of the manned submersible for the exit of the crew.

2.5 The design of the handling system shall provide uniform tension of all wire ropes or their branches (see also 5.1.2).

Support wire ropes shall not twist or rub each other or other hoses and cables when objects are under water.

2.6 The length of the umbilical if it is separated from the lifting rope shall be such as to allow lowering of a non-propelled submersible to a test diving depth plus 5 per cent.

2.7 At bending points of the umbilical, guide rollers or rounded pieces of appropriate diameter shall be installed to prevent hoses and cables from fracture.

2.8 Reliable communication shall be maintained between the handling system machinery operator and the supervisor of launching/recovery operations. Control of handling machinery shall be effected from one station.

2.9 In order to avoid dangerous sway of the manned submersible or diving bell striking against the support ship side in a seaway, the handling system shall have a device approved by the Register to restrict swaying of the manned submersible or diving bell from the moment of emergence until boarding on the support ship deck.

2.10 The area of launching/recovery of the manned submersibles or diving bells including the overboard area surface in way of launching/ recovery area and the handling system control station shall have stationary lighting supplied from the main and emergency power sources.

2.11 For safe servicing of the handling system, ladders or platforms providing easy access to the machinery, as well as guard rails (if required) shall be arranged.

Where luffing trusses are used, ladders and platforms shall ensure operation in any position of the truss.

2.12 For lifting and lowering the manned submersibles or diving bells, the handling system shall ensure launching and recovery operations at the support ship's static list of not less than 10º either side and at static trim of 5º. Outreach of the handling system shall provide launching and recovery of the manned submersible or diving bell without touching the support ship's side at the summer draft.

2.13 The handling system shall have a slinging and unslinging device corresponding to the type of the manned submersible, for which the handling system concerned is intended.

2.14 The launching and recovery gear and the guide wire rope gear of the handling system shall have a device for tracking the object in a seaway in order to take up the slack in wire ropes, with a tracking range up to 5 m.

2.15 A possibility shall be provided for a diving bell to be placed on a trolley and transported horizontally for mating with a compression chamber when the counterbalance platform is lowered and the guide wire ropes tightened.

2.16 The handling system control cabins or consoles shall be equipped with screen wipers or other effective devices.

3 DESIGN STANDARDS

3.1 GENERAL REQUIREMENTS

Methods of calculating forces in the cargo handling gear components are not specified by the Rules, however, in specific cases, the Register may require the use of calculation procedures it has approved.

3.2 DESIGN LOADS AND STRESSES

3.2.1 In determination of the design loads, the requirements of the Rules for the Cargo Handling Gear of Sea-Going Ships shall be taken as a guide, as far as it is reasonable and applicable to the handling system.

3.2.2 In addition to the requirements of the Rules for the Cargo Handling Gear of Sea-Going Ships, the design loads shall also account for jerks in handling system ropes during operation at design sea state (with regard to the

entrained masses of water, current and action of the damper), as well as for the braking inertia forces of the machinery operating at full speed.

3.3 ALLOWABLE STRESSES, SAFETY AND STABILITY MARGINS

3.3.1 Strength calculations of metal structures, machinery and loose gear of the handling system shall be made for static and dynamic loads. Allowable stresses in the calculation for static load are assumed equal to 0,4 R_{eH}, and for dynamic load it is 0,8R_{eH} (R_{eH} means the yield stress of the material).

3.3.2 If the handling system is designed for operation with different submersibles, calculations shall be made for the submersible having the greatest mass.

3.4 CALCULATION OF MACHINERY

In calculations the handling system machinery, account shall be taken of the requirements of 3.2 and 3.3 of this Part, as well as 1.5.2 of the Rules for the Cargo Handling Gear of Sea-Going Ships.

4 METAL STRUCTURES

4.1 General requirements for the metal structures of the handling system are specified depending on the type of structure by the provisions of Sections 4—7 of the Rules for the Cargo Handling Gear of Sea-Going Ships, having regard to the requirements of this Section.

4.2 To reduce dynamic forces in wire ropes and metal structures when the handling system is in operation during the support ship motions (particularly when the submersible rises off the wave) and to gain the required safety margins as related to dynamic loads, efficient dampers (compensators) shall be provided, if necessary.

4.3 The design of retractable bridges and luffing trusses (girders) of the handling system and their drives shall:

.1 eliminate spontaneous movement of trolleys or retractable telescopic trusses during motions;

.2 secure the handling system in extreme positions (operational and luffed) by efficient stopping devices (ties, slings, stops);

.3 provide stopping of a trolley or a truss in any position when the drive is stopped;

.4 eliminate jamming when the truss moves on rails.

4.4 Trolleys for the submersibles and retractable trusses of the handling systems shall have appliances preventing them from derailment and guard boards preventing foreign objects from being entrapped under the wheels. Clearance between the guard boards and rails shall not exceed 10 mm.

4.5 Railways of the handling system and load trolleys shall be designed so as to ensure safe operation of the handling system at the design sea state and shall be suitably reinforced.

5 MACHINERY

5.1 GENERAL REQUIREMENTS

5.1.1 When designing the handling system, the requirements of this Section shall be taken into account in addition to the general requirements for machinery stated in Section 2.

5.1.2 The design of the handling system shall provide for synchronous operation of handling machinery, which ensure jointly appropriate positions of the manned submersible or diving bell during launching and recovery or luffing of the handling system (see also 2.7) with the possibility of their separate starting.

5.1.3 Reels for hoses and cables shall have slip devices or breakdown torque clutches, which operate at loads not in excess of elastic strain loads in cables and hoses.

5.1.4 If lifting of the diving bell up to the water surface is provided by means of umbilical, the slip device or breakdown torque clutch is not required to be fitted. The same requirement applies to the umbilical reels, as well.

5.1.5 The handling system machinery shall provide smooth movement of the manned submersible or diving bell without any jerks or delays, at speeds required for their safe launching, recovery or towing.

5.1.6 It is not allowed to use friction or claw clutches for starting the winches intended for launching and recovery of the diving bells referred to in 1.1.1.

5.1.7 In well-grounded cases, the handling system may be manually operated; in such cases, manually driven winches shall have an automatic hoist brake consisting of a handle, a ratchet and a brake.

5.1.8 The handling system luffing gear, winches, reels and load trolleys traveling gear with electric or electrohydraulic drive shall have closed-band automatic brakes with a safety factor of braking as related to the work load not less than 1,75 and duplicating manual brakes with a safety factor of braking not less than 1,25. Where two independent brakes are available, manual brakes are not required.

5.1.9 Duplicating manual brakes shall have worm gear. The effort on the brake handle (flywheel) shall not exceed 80 N.

5.1.10 The machinery brakes shall be of closed-band type and shall be automatically locked in the following cases:

.1 upon actuation of safety devices and electrical protection;

.2 upon disconnection of the drive by control devices;

.3 when power supply is interrupted or when the pressure in the hydraulic system is lower than the permissible value.

5.1.11 The brake pulleys shall be of steel. Use of cast iron for brake pulleys and levers is not allowed.

5.1.12 The stops of the handling system shall be provided with buffers.

5.1.13 The rope capacity of the winch (reel) drums shall be sufficient for launching tethered manned submersibles and diving bells to the test depth and self-sustained submersibles to the water surface so that not less than four dead turns of wire rope (cable or hose) remain on the winch (reel) drum, apart from those under the clamp; then:

.1 diameter of the drum shall be not less than 20 diameters of the wire rope;

.2 flanges of the drums shall extend not less than 1,5 wire rope diameters above the upper layer of the wire rope.

5.2 SAFETY DEVICES

5.2.1 The handling system control stations shall have indicators of extreme truss positions (operational and luffed).

5.2.2 Handling systems (except for manually driven systems) shall have limit switches for automatic stopping of the following gear in their extreme positions:

.1 launching and recovery;

.2 truss (girder) luffing;

.3 traveling of bridge-type truss or load trolley.

Where piston-type hydraulic drives are installed in the gear for luffing trusses/girders at their transition to extreme positions, limit switches may be omitted.

5.2.3 Winches and reels of handling systems of the tethered manned submersibles and diving bells shall have counters of paid-out length of wire ropes, hoses and cables. Similar counters shall be fitted at the handling system control stations.

6 INTERCHANGEABLE COMPONENTS, STEEL WIRE ROPES AND CHAINS

6.1 INTERCHANGEABLE COMPONENTS

6.1.1 Interchangeable components shall comply with the requirements of 9.3 of the Rules for the Cargo Handling Gear of Sea-Going Ships with regard to the requirements of this Section.

6.1.2 Safety margins of the interchangeable components of the handling system shall not be less than those specified for the main structures of the handling system.

6.1.3 The diameter of pulleys for steel wire ropes measured at the groove bottom shall not be less than 18 wire rope diameters.

6.2 STEEL WIRE ROPES

6.2.1 Steel wire ropes shall comply with the requirements of 9.5 of the Rules for the Cargo Handling Gear of Sea-Going Ships with regard to the provisions of this Section.

6.2.2 Handling ropes shall be made of galvanized steel wire, with a diameter of the wire in external strands of not less than 0,6 mm, and shall have a test certificate issued by the Register.

6.2.3 Wire ropes used for the handling system shall be of non-spinning type.

6.2.4 Upon agreement with the Register, State standards or other standards may be applied to the wire ropes.

6.2.5 Each wire rope of the handling system shall be tested for the breaking strength as a whole.

6.2.6 If the submersible is suspended by two wire ropes and one of them shall be replaced, the other one shall be replaced too.

6.2.7 Steel wire ropes shall be calculated for strength using formula $P/S \geqslant K$ where P is the breaking strength of the wire rope as a whole (according to the Register certificate), in N; S is the maximum tension in the

wire rope branch under a load equal to the safe working load of the handling system, in N; K is the safety factor of the wire rope as related to breaking strength, assumed according to Table 6.2.7.

Table 6.2.7

No.	Wire ropes	K not less than
1	For launching diving bells, as well as other tethered manned submersibles with negative buoyancy not equipped for emergency surfacing	10
2	For emergency recovery of the objects specified under item 1 by a single wire rope	5
3	Guides used for emergency recovery of the objects specified under item 1	6
4	For recovery of the tethered manned submersibles and diving bells with negative buoyancy, equipped with an emergency surfacing arrangement and of the self-sustained manned submersibles	6
5	For emergency recovery of the objects specified under item 4	3
6	For all handling systems when checked for dynamic loads arising at allowable sea state (with regard to automation)	2,5

6.2.8 If the design provides for emergency lifting of the tethered manned submersibles and diving bells up to the water surface by means of umbilical, its strength shall be sufficient to withstand twice the loads specified by 3.2.2.

6.2.9 If the umbilical is used as a load support line, its safety factor shall not be less than 6.

6.2.10 The highest tension in the wire rope branch under a load equal to the safe working load of the handling system shall be determined by formula $S = Q/n\eta$ where Q is the allowable working load corresponding to the safe working load of the handling system, in N; n is the number of wire rope branches; η is the efficiency of blocks.

6.3 CHAINS

6.3.1 Chains used in the handling systems shall have certificates of the Register. Safety factor as related to breaking load shall not be less than that given in Table 6.3.1 depending on the type and purpose of chains.

Table 6.3.1

No.	Chains	Knot less than
1	Loading, welded, working on a smooth drum	6
2	Loading, welded, working on a sprocket wheel	8
3	Loading, flat link	6
4	Loading, welded, and loading, flat link, used in components of mating devices	8

6.3.2 Chains used in the handling systems shall be short-linked (calibrated chains, when used on a sprocket wheel) with terminal links for attachment.

7 MATERIALS AND WELD INSPECTION

7.1 MATERIALS

Materials used in manufacturing and mounting of metal structures of the handling system and weld quality shall comply with the requirements of Section 3 of the Rules for the Cargo Handling Gear of sea-Going Ships and standard specifications of the Register depending on specific features of the handling system operation.

7.2 WELD INSPECTION

7.2.1 The total amount of weld inspection is specified by the Rules for the Cargo Handling Gear of Sea-Going Ships.

7.2.2 All essential butt welds shall be subjected to non-destructive testing or any other inspection approved by the Register.

Each transverse butt weld shall be examined by radiography throughout its length. Other welds shall be examined by radiography for not less than 25 per cent of length; crossings of welds shall be obligatory subjected to radiography.

Where intolerable defects are found in the welds, not less than 25 per cent of their length shall be additionally subjected to radiography.

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Russian Maritime Register of Shipping
Rules for the Classification and Construction of Manned Submersibles, Ship's Diving Systems and Passenger Submersibles

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