

# **RULES**

## **FOR THE CLASSIFICATION AND CONSTRUCTION OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS**

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## **RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS**

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Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems have been approved in accordance with the established approval procedure and come into force on 1 July 2022.

The Rules establish specific requirements for the manned submersibles, including the passenger submersibles and ship's diving systems, 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, as well as the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships.

With this in view, all the applicable requirements of the above Rules cover the manned submersibles and ship's diving systems, unless other requirements are contained in these Rules. Where the above Rules are applied to the manned submersibles and ship's diving systems, the term "ship" shall also mean the manned submersible and ship's diving system.

**REVISION HISTORY**

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

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

## **GENERAL REGULATIONS FOR THE CLASSIFICATION AND OTHER ACTIVITY RELATING TO MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS**

### **1 TERMS AND DEFINITIONS**

The following definitions have been adopted in the Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems<sup>1</sup> of the Russian Maritime Register of Shipping<sup>2</sup>:

**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 on the manned submersible or diving bell design.

**Emergency (standby) life-support system** means a life support system ensuring vital activity of the manned submersible and ship's diving system crews in the tight compartments of the manned submersible and diving bell or in the compression chamber in emergency situations related to failure of main life support system or in case of deterioration of compartment atmosphere composition which endangers life or health of crew.

**Self-sustained manned submersible** means a manned submersible not mechanically linked to an attendant ship (offshore installation) which it is submerged from.

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

**Manned submersible displacement** means displacement corresponding to the buoyancy volume of the manned submersible.

**Diving compression chamber** means a pressure vessel intended for habitation and vital activity of divers in it under conditions of gas medium overpressure during diving operations and therapeutic recompression and equipped for this purpose with special systems and arrangements.

**Bounce diving compression chamber** means a diving compression chamber in the bounce diving system equipped with special systems and arrangements and intended for life support of divers in it at high gas medium pressure conditions during decompression or therapeutic recompression.

**Saturation diving compression chamber** means a diving compression chamber in a saturation diving system equipped with special systems and arrangements and intended for life support of divers in it at high gas medium pressure conditions for more than 8 h during saturation diving operations and therapeutic recompression of divers.

**Diving compression system** means several diving compression chambers in the ship's diving system which are structurally connected to each other by transfer hatches with strong and tight protective covers.

**Diving stage** means a structure intended for accommodation and transportation of divers into water and their surfacing with decompression in water by means of the support ship handling system.

**Diving bell** means a suspended manned submersible in the diving system equipped with special systems and arrangements and intended for transportation of divers to the underwater work location, life-support of divers in diving outfit during work, surfacing and decompression in water or high pressure gas medium.

**Dry diving bell** means a diving bell designed as a strong tight pressure vessel equipped with an access hatch with a tight cover, intended for transportation of divers into water at atmospheric or high gas medium pressure, life support in gas medium and, during

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<sup>1</sup> Hereinafter referred to as "the Rules".

<sup>2</sup> Hereinafter referred to as "the Register, RS".

underwater operations in diving outfit, recovery aboard the support ship for connection with the compression chamber to transfer divers into this chamber at high gas medium pressure, for rest or decompression.

**Wet diving bell (half-bell)** means a diving bell designed as a structure with a watertight dome and open lower part which maintains gas cushion inside during diving and recovery, making it habitable for divers under pressure without underwater breathing apparatus and equipped with systems and arrangements for life support during decompression in water during surfacing.

**Saturation diving system** means a complex of functionally integrated technical means, systems and arrangements intended for ensuring diving operations from high gas medium pressure conditions with complete saturation of body with indifferent gases (saturation dives).

**Bounce diving system** means a complex of functionally integrated technical means, systems and arrangements intended for ensuring diving operations from atmospheric pressure conditions (from surface) with non-complete saturation of diver's body with indifferent gases.

**Diving submersible** means a manned submersible equipped with a lock chamber (a hyperbaric compartment) intended for transportation of divers to a place of underwater operations and ensuring diving operations.

**Diver's ladder** means a ladder, usually removable one, intended for independent descent of diver into water and ascent of diver from water.

**Divers** means ship's diving system personnel (crew members) which are exposed to high pressure of gas and water during diving operations.

**Gas container** means a structurally connected group of gas bottles connected with pipelines with valves and instrumentation intended for preparation, transportation and consumption of diving gases and breathing gas mixtures for ship's diving system.

**Gas distribution board** means an element of gas supply system of ship's diving system equipped with shut-off and control valves and instrumentation and intended for controlled distribution of gases and breathing gas mixtures during operation of ship's diving system.

**Decompression chamber** means a bounce diving compression chamber within the bounce diving system divided into two or more compartments with strong tight partitions with transfer hatches and intended for decompression of one or several groups of divers.

**Breathing gas mixture** means a specially prepared artificial mixture of gases used for breathing of divers during diving operations in compartments of compression chamber, diving bell or hyperbaric evacuation system or for breathing from diving breathing apparatuses.

**Compression chamber living compartment** means a manned compartment of saturation compression chamber intended for accommodation and life support of divers during saturation diving.

**Hyperbaric evacuation system** means an emergency lifesaving system as a part of evacuation system of saturation diving system intended for accommodation and life support of divers at high gas medium pressure in manned hyperbaric compartment (compression chamber), with a mating device to evacuate them from the support ship in distress with subsequent decompression.

**Hyperbaric lifeboat (boat)** means a hyperbaric evacuation system designed as a self-propelled or towed collective survival craft.

**Saturation diving system** means a diving system which ensures diving to depths exceeding 60 m.

**Closed-loop diving (recirculation) breathing system** means a gas supply system for divers in saturation diving outfit as a part of the saturation diving system intended for supply conditioned breathing gas mixture from the support ship for breathing of

divers and return gas exhaled by divers to the ship for regeneration (removal of carbon dioxide, oxygen enrichment etc.) and re-use.

**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).

**Viewport of manned submersible, compression chamber and diving bell** means a device used to close an opening in the pressure hull of the manned submersible, compression chamber or diving bell and to provide visual contact of personnel from the manned submersible, compression chamber and diving bell compartments with external environment, maintaining strength and tightness of manned compartment, with a water-resistant window as a main element.

**Tightness tests** mean testing of welds and structure of hulls as a whole, bulkheads, hatches, covers, viewports, piping connections, valves and pressure vessels by the methods approved by the Register under the following conditions: with internal working gas medium pressure equal to the operating pressure – for hyperbaric compartments of diver lockout submersibles, diving bell, compartments of compression chambers and other ship's diving system vessels operating under internal overpressure;

with internal air pressure specified by the designer and approved by the Register – for the manned submersible compartments and tanks operating under higher hydrostatic pressure;

with internal working medium pressure equal to the operating pressure, no matter what the pressure (internal or external) they work under on the manned submersibles or vessels of ship's diving systems – for pipe to fitting connections.

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

**Strength tests** mean testing of pressure-resistant structures of manned submersibles, diving bells, compression chambers and other pressure vessels as a part of the manned submersible and ship's diving system for strength as an assembly by applying test pressure (pressure equal to test diving depth or test gas medium pressure) as agreed upon with the Register by one of the following methods:

with external pressure in a test chamber;

by submersion into the sea;

with internal hydraulic pressure.

**Test diving depth of manned submersible/diving bell** means a depth to which the manned submersible or diving bell dives (if provision is made for use of diving bell as an observation chamber at atmospheric pressure inside the compartment) during tests after construction, repair or modification, as well as in-service surveys.

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

**Test pressure of ship's diving system in strength tests** means an internal hydraulic pressure which exceeds the operating pressure and created during strength tests of compartments of diver lockout submersible, compression chamber, diving bell and other pressure vessels as a part of ship's diving system.

**Umbilical** means structurally jointed cables and hoses connecting the support ship (floating facility) with the non-self-sustained manned submersible or diving bell and also connecting the diver with the support ship or with the diving bell which usually consists of cables and hoses of power supply, control and life-support systems (gas supply, electrical or water heating, gas analysis, communications and video monitoring).

**Oxygen system of manned submersible and ship's diving system** means a gas supply system of the manned submersible and ship's diving system intended for

storage and utilization of oxygen gas for life support of the manned submersible crew/passengers and the ship's diving system divers in the tight compartments.

Competent authorities mean organizations supervising construction and operation of the manned submersible and ship's diving system or their components as for issues not regulated by the RS rules.

Mass of manned submersible means the mass of the manned submersible with regular crew and outfit.

Mobile (deck) diving system means a modular diving system made as one or several transportable modules designed so that they can be transported and temporarily mounted on the deck of the support ship (floating facility).

Modular diving system means a diving system made as large assembly units (functional modules).

Manned submersible means a submersible intended for diving into bulk of water and equipped for accommodation and life support of people therein.

Manned compartment means a compartment of the manned submersible, compression chamber and diving bell equipped with special life support systems and arrangements providing vital activity of manned submersible crews (passengers) inside it or of ship's diving system divers.

Search submersible means a manned submersible intended for search and examination of underwater objects.

Fire-resisting materials mean materials having properties according to the requirements of IMO resolution MSC.307(88).

Viewport window of manned submersible, compression chamber and diving bell means a transparent tight and pressure-resistant insert for a viewport.

Suspended manned submersible means a manned submersible mechanically linked with the ship (floating facility) from which it is launched into water and designed to operate during lowering, surfacing and holding at a specified operational depth at negative buoyancy.

Survey means an integral part of technical supervision including checking availability of approved technical documentation on the items of technical supervision; checking availability of the RS documents, recognized and competent organizations or persons on the items of technical supervision; examinations, including (where necessary) opening-up and dismantling; participation in measurements and tests; assessment of the measurement and test results; drawing-up, endorsement, renewal and extension of the RS documents; branding and sealing (where necessary) of the items of technical supervision.

Compression chamber compartment means a part of compression chamber volume separated with a pressure-resistant and tight intercompartment bulkhead in which pressure can differ from pressure in adjacent compartments and which is large enough to accommodate at least one person.

Passenger submersible means a manned submersible specially equipped for accommodation and life-support of passengers or other persons which are not the manned submersible crew members and are allowed aboard the submersible for diving into water.

Buoyancy volume of a manned submersible (diving bell) means the volume of water displaced by all the watertight structures of the manned submersible (diving bell).

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

Control station of manned submersible and ship's diving system means a specially equipped room on the manned submersible and ship's diving system support

ship (floating facility) intended for location of equipment and operators which control activities of the manned submersible crew, divers under water as well as in diving bells and compression chambers and monitor and control equipment, life support systems and arrangements of ship's diving systems to ensure safety of diving and underwater operations.

Tethered manned submersible means a manned submersible having a free mechanical link with the attendant ship (floating facility) from which it is launched into water by means of a rope, cable or umbilical and intended for operation in towed mode or mode of free diving and surfacing with its own electrically driven propellers.

Pressure-resistant structures of manned submersibles and ship's diving system mean pressure hulls, pressure tanks, pressure vessels and other elements in the manned submersible, diving bell, compression chamber, hyperbaric evacuation system as a part of the ship's diving system which directly take up and balance the operational loads resulted from overpressure of water or gas medium.

Panel of breathing gas mixture supply to divers means an element of the ship's diving system gas supply system intended for controlled supply of diving air or breathing gas mixture into diving outfit and compartments of compression chamber, diving bell, diver lockout submersible and hyperbaric evacuation system.

Operating (diving) depth of a manned submersible and 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.

Design pressure of manned submersible and ship's diving system means a maximum pressure (external or internal) for which the manned submersible, compression chamber or diving bell hulls or their structural members are designed.

Operating weight of diving bell or diving stage means the maximum weight of completely equipped stage or diving bell, including weight of completely equipped divers. In this case, the weight load is applied during the following:

lowering and lifting in air; and

lowering and lifting in water, together with maximum negative buoyancy of rope, flexible cable, stage or diving bell at the maximum diving depth.

Operating manned submersible means a manned submersible intended for examination and underwater technical work.

Operating pressure of ship's diving system means the maximum pressure of air or artificial breathing gas mixture which can be built up in the compression chamber, diving bell (lockout submersible compartment) for the secured number of times and maintained during the specified period of time.

Recompression chamber means a bounce diving compression chamber intended for treatment of divers who got sick during diving with particular diving diseases under high gas medium pressure conditions.

Diver water heating system means a system of active heating of divers in diving bell and in diving outfit with hot water.

Life support system means a complex of structurally and functionally combined technical means, special arrangements, instruments, etc. intended for life support of manned submersible crews under conditions of tight compartments of manned submersible and divers under conditions of high water or gas medium pressure during diving by means of ship's diving system.

Breathing gas mixture conditioning and cleaning (regeneration) system means a recirculation life support system of tight compartments of manned submersible and ship's diving system which provides specified parameters of breathing gas composition (contents of oxygen, carbon dioxide and harmful substances) within the maximum



permissible concentrations and keeps required temperature and humidity in compartments of manned submersible, compression chamber and diving bell.

**Airlock system** means an element of the gas supply system of compression chamber and diving bell intended for use of air locks.

**Breathing gas mixture recovery system** means a life support system of ship's diving system used to collect and purify used diving breathing gas mixtures for re-use and extract pure helium from them.

**Pressure vessel** means a pressure container whose body can withstand internal operating overpressure exceeding or equal to 1 bar.

**Handling system** means a combination of equipment, mechanisms, systems and arrangements intended for lowering and lifting the manned submersible, diving bell, hyperbaric evacuation system or diving stage from the support ship (floating facility) to/from water or for diving to a place of underwater works and back.

**Fixed breathing system** means a gas emergency life support system which supplies breathing gas from bottles to individual insulating masks in compartments of compression chamber, manned submersible or diving bell under conditions of atmosphere unsuitable for breathing. Such system can be used for breathing with oxygen or other medical gases during decompression (therapeutic recompression) of divers.

**Fixed diving system** means a diving system which is structurally and functionally connected to the support ship structures, systems and arrangements and requires, when being dismantled, structural disintegration of the support ship and ship's diving system.

**Mating device** means a device intended for tight connection of diving bell, diver lockout submersible or hyperbaric evacuation system to the ship's diving system compression chamber, to enable transfer of divers from a compartment to another one under conditions of continuous high gas medium pressure.

**Support ship of manned submersible and ship's diving system** means a ship or floating facility intended for accommodation and delivery of the manned submersible or ship's diving system to the area of diving operations, for support of diving of the manned submersible and divers, as well as for in-service maintenance of the manned submersible and ship's diving system.

**Ship's diving system** means a diving system permanently or temporarily installed on the support ship or floating facility.

**Ship's diving system <12** means the ship's diving system (diving station) 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 >60** means a ship's bounce or saturation diving system intended for underwater operations at depths exceeding 60 m and consisting at least of diving equipment of one multicompartiment compression chamber or several compression chambers combined in a single compression system, a diving bell (diver lockout submersible), a handling system of diving bell (diver lockout submersible) and means for providing artificial breathing gas mixtures to divers and a life support system.

**Airlock compartment (compression chamber airlock)** means a compartment of the compression chamber intended for transfer of people and airlock transfer of bulky equipment under conditions of high gas medium pressure of compression chamber and back without changing pressure inside this compartment.

**Airlock of compression chamber or diving bell** means an arrangement on the pressure hull of the compression chamber or diving bell to intended to transfer food, life

support means, etc. into and out of the pressurized compression chamber or diving bell without changing pressure inside them.

Evacuation compression chamber means a hyperbaric evacuation system as a part of the saturation diving system, usually having positive buoyancy and intended for emergency evacuation of divers from the support ship in distress, from compression chambers with high breathing gas mixture pressure to the salvage ship with subsequent decompression of divers.

Manned submersible crew means a complement of operating personnel of the manned submersible directly participating in diving of the submersible.

Ship's diving system crew means a complement of divers which can be nominally accommodated in compartments of compression chamber, diving bell and hyperbaric evacuation system as a part of the ship's diving system.

## **2 CLASSIFICATION AND OTHER ACTIVITY**

**2.1** The Register is a non-commercial organization performing classification of civil ships and floating facilities, as well as manned submersibles and ship's diving systems. Besides, being authorized by the government of the Russian Federation (RF) and by the governments of other countries to act on their behalf, the Register monitors within its terms of reference the compliance with the requirements of international conventions, agreements and contracts, to which the above governments are parties, and issues relevant documents.

**2.2** The Register carries out classification and survey of all types of manned submersibles and ship's diving systems under construction and in service having a pressure hull for protection of the crew from the environment.

**2.3** Survey of the manned submersibles and ship diving system includes the following:

review and approval (agreement) of technical documentation;

survey during manufacture of materials and products specified in the nomenclature and intended for use in construction, repair and conversion 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, reinstatement and reassignment of the class (a class to mobile deck ship's diving systems is assigned when these are installed on the carrier ship).

**2.4** The items of the manned submersibles and ship's diving systems to be surveyed by the Register during their manufacture, installation and testing are set by the Nomenclature of Items of Manned Submersibles and Ship's Diving Systems Surveyed (refer to [Appendix 1](#), Part I "Classification").

Technical requirements for the items to be surveyed 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 in terms of survey by the Rules, shall be performed by the relevant competent authorities.

**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.

The RS competence does not cover supervision of life support systems of manned submersibles and ship's diving systems as regards the materials used for their construction; their compatibility with the working media; choice of qualitative and quantitative parameters of breathing gas media and mixtures; supervision of medical, physiological and professional diving aspects, which shall also be effected by the relevant specialized competent authorities.

**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 and Guidelines 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.

**2.8** The responsibility for fulfillment of the Rules and additional requirements rests with designers, owners of manned submersibles and ship's diving systems and firms (manufacturers) of materials and components.

**2.9** The RS survey does not supersede the activities of technical inspection bodies of the manned submersibles and ship's diving systems owners and firms (manufacturers) of materials and components.

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

**2.11** 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 RS 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** these Rules;
- .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** Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships;
- .7** IMO codes of safety for diving systems (resolution A.831(19), 1995) and hyperbaric evacuation systems (resolution A.692(17), 1991);
- .8** Guidelines for Design, Construction and Operation of Passenger Submersible Craft (IMO Circular MSC/Circ. 981 dated 29 January 2001).

**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 Survey of Maimed Submersibles and Ship's Diving Systems under Construction and in Service;
- .2** Guidelines for Technical Supervision of Ships in Service;
- .3** Procedure for Technical Supervision during Manufacture of Materials and Products for Ships;
- .4** Procedure for Technical Supervision of Ships under Construction.

### **3.2 APPLICATION OF THE RULES**

**3.2.1** Newly adopted Rules and amendments thereto come into force 6 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 and ship's diving systems, as well as their components, the designs of which are submitted to the Register for approval after the date of coming into force of new editions of the Rules or amendments thereto, shall comply with the requirements of the Rules or amendments.

**3.2.3** The manned submersibles and ship's diving systems and their components under construction, technical documentation for which has been approved by the Register prior to coming into force of the new edition of the Rules or amendments thereto, shall comply with the requirements that were in force at the time of approval of that documentation.

**3.2.4** The manned submersibles and ship's diving systems in service and built not under the RS rules shall meet the requirements of the RS-recognized classification body, to which these manned submersibles and ship's diving systems have been built.

**3.2.5** 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.

### **3.3 DEPARTURES FROM THE REQUIREMENTS OF THE RULES**

**3.3.1** 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 specified 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.

**3.3.2** If the structure of the manned submersible and ship's diving system, their separate systems, machinery, arrangements and outfit components, as well as types of materials used cannot be recognized as being adequately proved in service, the Register may require special tests to be carried out during construction and, when in service, may reduce the intervals between periodical surveys or extend the scope of these surveys.

Where deemed necessary by the Register, appropriate service restrictions for the manned submersibles and ship's diving systems may be made in the classification or other documents issued by the Register for these the manned submersibles and ship's diving systems.

The restrictions may be withdrawn subsequently if the requirements of the RS rules are met, the satisfactory results of the additional tests agreed by the Register are presented or the positive operating experience of the manned submersible or ship's diving system is documented.

## **4 DOCUMENTS**

**4.1** Upon the results of a survey of the manned submersibles and ship's diving systems, the Register shall issue the appropriate confirmatory documents.

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

**.1** Classification Certificate for the manned submersible with the record of accepted equipment;

**.2** Classification Certificate for the ship's diving system with the record of accepted equipment (for the ship's diving system designed for depth of up to 12 m, the Classification Certificate shall not be issued, but the Certificate (form 6.5.30) shall be issued and the respective information shall be recorded in the Classification Certificate of the carrier ship);

**.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 the passenger submersibles) with the record of accepted equipment;

**.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 documents specified in [4.2.1](#), [4.2.2](#) and [4.2.5](#) shall be issued for a period of 5 years and shall be confirmed annually within 3 month before or after anniversary date of the survey. The Certificate specified in [4.2.4](#) shall be issued for a period of 1 year.

The issue (renewal) and endorsement of the documents specified in [4.2](#) are based on reports, notifications or certificates.

**4.4** The documents, which confirm the compliance of materials and products (including parts and equipment of the manned submersible or ship's diving system handling system), manufactured under the RS supervision, with the Rules and additional requirements of the Register and also confirm the results of the required tests are the following:

**.1** the RS Certificates 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.

**4.5** 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.

**4.6** The Register may recognize fully or partially the documents of other classification societies, technical supervision bodies and other competent authorities.

**4.7** The documents issued by the Register for the manned submersible and ship's diving system shall be kept on board the manned submersible ship's diving system support ship (floating facility).

**4.8** The Classification Certificates for the manned submersible and ship's diving system, the Safety Compliance Certificate, as well as the Passenger Certificate for the 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 time;

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



- .4** after repair or refit of the maimed submersible or ship's diving system parts affecting operation of the manned submersible or ship's diving system which have been carried out at ship repair yards without the RS supervision;
  - .5** if the operating conditions stated in the Classification Certificate have been violated;
  - .6** if terms or instructions of the Register have not been followed; and
  - .7** if the area of navigation of the passenger submersible has been changed.
- 4.9** The Register may renew the validity of documents if the reasons of losing the validity are eliminated.

## **PART I. CLASSIFICATION**

### **1 GENERAL**

#### **1.1. APPLICATION**

**1.1.1** The requirements of this Part of the Rules apply to all types of the manned submersibles with pressure hulls for protection of the crew from the environment and to the ship's diving systems ensuring diving operations by different methods.

**1.1.2** The Rules specify the requirements for the manned submersibles and ship's diving systems, which shall be met in order that they may be assigned the RS class.

## **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 RS SUPERVISION**

**2.1.1** The character of classification of the manned submersibles and ship's diving systems built in compliance with these Rules and under the RS supervision consists of the distinguishing marks added as follows:

**KM** — for the types of manned submersibles with their own means of propulsion for movement in water and for the ship's diving systems comprising diver lockout submersibles or another self-propelled self-sustained means of propulsion for underwater movement;

**K** — for the types of manned submersibles without their own means of propulsion for movement in water, and for the ship's diving systems not comprising diver lockout submersibles or another self-sustained means of propulsion for underwater movement;

**⊗** — for manned submersibles and ship's diving systems confirming their construction in compliance with these Rules and under the RS supervision;

**MS** — for manned submersibles;

**SDS** — for ship's diving systems;

**SURFACE AIR** — for the types of ship's bounce diving systems intended for dives from atmospheric pressure conditions (from surface) to depths of up to 60 m using breathing air;

**SURFACE Mixed-Gas** — for the types of bounce diving system intended for dives from atmospheric pressure conditions to depths exceeding 60 m using breathing gas mixtures;

**SAT** — for the types of saturation diving systems intended for saturation dives from high gas medium pressure conditions;

**(...)** — indication of maximum operating depth determined during classification tests of the manned submersible (diving bell) and ship's diving system, in m;

**KM⊗MS (...)** — class notation of self-propelled manned submersibles, self-sustained and tethered with their own means of propulsion for movement in water,

**K⊗MS (...)** — class notation of suspended and towed manned submersibles (diving bells) without their own means of propulsion for movement in water,

**K⊗SDS SURFACE Air(60)** — class notation of ship's bounce diving systems intended for dives from atmospheric pressure conditions using breathing air to maximum depth of up to 60 m inclusive;

**K⊗SDS SURFACE Mixed-Gas(160)** — class notation of bounce diving systems, intended for dives from atmospheric pressure conditions using breathing gas mixtures to maximum depth of up to 160 m inclusive;

**K⊗SDS SAT(300)** — class notation of saturation diving systems intended for saturation dives to maximum depth of up to 300 m inclusive;

**KM⊗SDS SAT(300)** — class notation of saturation diving systems intended for saturation dives to depths of up to 300 m inclusive and comprising diver lockout submersibles.

The class notation is not assigned to the ship's diving systems with operating depth of up to 12 m that do not comprise compression chambers.

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

If the manned submersible (diving bell) or ship's diving system has been built in compliance with these Rules and under supervision of another classification body and then classed by the Register, the character of classification consists of distinguishing marks **K** or **KM** followed by ★ and **MS** — for manned submersibles or ship's diving system type ★ thereon. This requirement applies to class transfer of the manned submersible (diving bell) and ship's diving system to the **RS** class from an IACS member society's class.

If the manned submersible (diving bell) or ship's diving system has been built without technical supervision of a classification body and then classed by the Register, the character of classification consists of distinguishing marks (**K**) or (**KM**) followed by ★ and **MS** — for manned submersibles or ship's diving system type thereon. ★

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

Depending on the manned submersible type and provided that it complies with the relevant requirements of the Rules, one of the following descriptive notations is added to the character of classification: **Self-sustained, Tethered, Suspended, Towed, Passenger, Dive.**

Depending on the ship's diving system type and provided that it complies with the relevant requirements of the Rules, one of the following descriptive notations is added to the character of classification: **Fixed, Mobile.**

### **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 and Ship's Diving Systems of these Rules. This activity includes examination and approval of technical documentation, supervision during manufacture of materials and components of the manned submersibles and ship's diving systems at the firms (manufacturers), as well as supervision during construction of the manned submersibles and ship's diving systems.

**3.2** The items of the RS survey and its forms during production at the firms (manufacturers), installation and testing of the manned submersibles and ship's diving systems are specified in the Nomenclature (refer to [Appendix 1](#)). Technical requirements for the surveyed items are specified in the relevant parts of the Rules.

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

Depending on the specific conditions of production and the extent to which the surveyed items comply with the RS requirements, the survey form established in the Nomenclature may be changed by the Register Head Office (RHO).

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

### **4.1 GENERAL**

**4.1.1** The initial survey for assigning a class is aimed to determine a possibility to classify the manned submersible and ship's diving system initially submitted to the Register for classification.

**4.1.2** The scope of the initial survey of the manned submersible and ship's diving system is determined in each particular case based on the scope of special survey depending on the technical condition of the items to be surveyed.

**4.1.3** Special survey for class renewal is intended to ascertain that the technical condition of the manned submersible and ship's diving system complies with these Rules and additional RS requirements on the expiry of operational period permitted by results of previous survey. Each special survey shall be carried out at 5 years intervals to renew the class.

**4.1.4** Annual survey for class confirmation is intended to ascertain that the manned submersible and ship's diving system comply with the conditions of retaining the class to a satisfactory degree, as well as to check the operation of the most essential arrangements, systems and equipment covered by the requirements of the Rules. Annual surveys shall be carried out within a period between special surveys (or between initial and special surveys) within 3 months before and after the due date of the annual survey.

**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 replacing the components that are subject to the survey, 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.

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 review.

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 review 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**

### **4.2.1 Surveys.**

**4.2.1.1** Survey of the passenger submersibles in service is carried out in accordance with the provisions of the Guidelines for the Design, Construction and Operation of Passenger Submersible Craft (refer to IMO Circular MSC/Circ. 981 dated 29 January 2001).

**4.2.1.2** Each passenger submersible shall be subject to the following surveys:

**.1** initial survey before the Safety Compliance Certificate specified in 4.2.5 of Chapter 4, Part I "General Regulations for the Classification and Other Activity Relating to Manned Submersibles and Ship's Diving Systems" is issued to the submersible for the first time. Initial survey shall include the whole package of organizational and technical measures in accordance with the requirements of these Rules for both the passenger submersible and materials, its components, arrangements and systems. This survey shall ensure full compliance of the passenger submersible with the applicable provisions of these Rules;

**.2** annual survey to confirm the compliance of the passenger submersible design, its technical means, arrangements, systems and equipment with the applicable provisions of these Rules, as well as to confirm that the surveyed items are in good condition suitable for safe operation. Such survey shall be endorsed in the Safety Compliance Certificate. Annual survey shall include a test dive to the design depth. Annual surveys shall be performed within 3 months before or after the anniversary date of the previous dry-docking survey or the anniversary date of the safety compliance test as specified in the Certificate if dry-docking surveys have not been performed yet. The Safety Compliance Certificate is renewed at annual survey;

**.3** dry-docking survey to be performed at intervals specified by the Maritime Administration, but not less than every 3 years. Dry-docking survey of the passenger submersible shall be generally combined with annual survey. It shall be a complete examination of the passenger submersible, its technical means, arrangements, systems and components for compliance with the applicable provisions of these Rules. Additional dry-docking surveys may be required at the discretion of the Register if needed and if underwater components of the passenger submersible are inaccessible during annual surveys.

**4.2.1.2** Dry-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 one depending on the circumstances) shall be performed every time a defect is revealed or an accident occurs, which affects the safety and certificates issued to the passenger submersible. The examination shall verify that the repairs or equipment replacements carried out have been done effectively and in full compliance with the applicable provisions of the Rules.

**4.2.1.4** After any survey or inspection of the passenger submersible in accordance with this Section has been completed, no changes in the passenger submersible design, its systems and arrangements, which affect the passenger submersible operating safety or the RS certification conditions, except for temporary changes required by the equipment repair procedure or the passenger submersible maintenance procedure, shall be made without the agreement by the Register, Maritime Administration or any organizations (persons) duly authorized by the Maritime Administration. The management of passenger submersible operations shall comply with the general requirements of the International Safety Management Code (ISM Code).

**4.2.2 Passenger submersible documentation.**

**4.2.2.1** The document confirming compliance of the passenger submersible design and construction is a list of applicable standards used in design and construction of the passenger submersible or a copy of the conclusion letter of approval specifying the 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.

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

**4.2.3 Approvals.**

It is recommended the owner of the passenger submersible and the Maritime Administration (or the Register on its behalf) commence discussions at the earliest possible stages, so that the Maritime Administration (the 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 these 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 passenger submersible operating safety.**

**4.2.5.1 General.**

**.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;

**.2** engagement of insufficiently trained and inadequately qualified crew to operate the passenger submersible, as well as inadequate personnel licensing procedures may impair the safe operation of the passenger submersible. The safety of passengers and crew, as well as the property protection during the passenger submersible operations require careful attention to the selection of the crew, training program and licensing procedures.

**4.2.5.2 Chain of commands.**

The chain of commands shall be well defined for each passenger submersible operation so that each member of the crew knows who is in charge and his individual responsibilities in each particular case, as well as crew members (support ship operating personnel) to be contacted in emergency. The chain of commands shall be documented by the passenger submersible means and means of support forces and shall be readily available for inspection.

**4.2.5.3 Operational preparation and planning.**

**.3** A passenger submersible operation manual containing normal and emergency working procedures shall be prepared. It shall be kept on board and be available for everybody concerned. This manual shall include the following:

working checklists including checklists before and after diving;

emergency procedures for situations like loss of power, loss of propulsion, break of life support system hoses, pumping/jettisoning of ballast, loss of communications, faults in life support systems, fire, entanglement, high level of explosive and flammable gases (hydrogen, oxygen, etc.), internal and external leakages of oxygen, setting down on bottom, partial flooding, and characteristics of specific emergency situations for special systems;

operational capabilities of the passenger submersible with regard to the diving time and depth;

sea state allowed for navigation;

geographic restrictions with regard to the diving location and depth;  
procedures for launching and lifting;  
organization of communications with support ships;  
special restrictions associated with the uniqueness of the project and its operational conditions;  
manning levels;

**.5** emergency drills shall be regularly conducted. These drills shall clearly demonstrate the effectiveness of the established emergency procedures;

**.6** the passenger submersible Maintenance Manual containing procedures for periodical inspections and scheduled maintenance of its equipment and arrangements shall be provided as a part of the passenger submersible operating documentation and promptly submitted for inspection during survey. This Manual shall include the expected lifetime of the pressure hull and other main components/equipment (for example, viewports, batteries, etc.), as well as the instructions for maintenance of components requiring special attention. The Manual together with the operation and maintenance documents shall be available at the submersible work location;

**.7** in addition to the operating documentation describing the crew actions under normal and emergency operating conditions, the main drawings of the passenger submersible arrangements and systems shall be available onboard the submersible.

**4.2.5.4** Passenger submersible pilot certification.

The passenger submersible pilot shall be certified for operating the specific passenger submersible. The passenger submersible operating certificate is issued only after successful completion of the training course and set number of practical dives with direct personal control of the passenger submersible.

**4.2.5.5** Training.

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 and practical aspects of normal operational of the passenger submersibles and procedures to be followed 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: normal life support conditions in the passenger submersible; permissible gas concentrations in the passenger submersible compartments; properties and effects of high and low level of carbon dioxide, oxygen, carbon monoxide and other gases, which may be present in the submersible; low temperature effects, oxygen systems, carbon dioxide removal systems, effects of humidity and shelf life period on efficiency of carbon dioxide absorbent; gas monitoring systems and instruments; emergency life support systems and arrangements; colour coding of gas bottles;

**.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 on passenger submersibles and their causes; fire extinguishing systems and their effects on life support; flooding and entanglement; failure of life support systems; toxic hazards; loss of communication; loss of power; physical and physiological effects on passengers and crew members as a result of prolonged stay in underwater environment (sensory and perceptive disorder and overcooling); 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: operational training of crew members shall be conducted under the direct supervision of an experienced pilot and culminate practical and operational tests including simulation of emergency situations.

**4.2.5.6** 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.

**4.2.5.7** 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 Maritime 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.**

Prior to construction of the manned submersible and ship's diving system, 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 specified in [5.1.2 - 5.1.11](#).

Documentation marked with (\*) is the documentation, which review results are documented by stamping according to 8.3.1, Part II "Technical Documentation" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

Documentation marked with (\*\*) is the documentation, which review results are documented by stamping according to 8.3.2, Part II "Technical Documentation" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

#### **5.1.2 General:**

- .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, firm (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 (refer to 2.4, Part V "Fire Protection").
- .7 documentation that confirms the test operation results of specific products or materials with indication of where they were applied, test results and service life (\*);
- .8 documentation that confirms organization of occupational safety in operation of the manned submersibles and ship's diving systems: personnel training programs, etc. (\*).

#### **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<sup>1</sup>;
- .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<sup>1</sup>;
- .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 of permissible

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<sup>1</sup> To be submitted at the stage of consideration of working documentation.

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;

**.8** strength calculation procedures for mating devices of the manned submersibles and ship's diving systems (\*).

**5.1.5** Documentation on buoyancy and stability of the manned submersibles, diving bells and evacuation system of the ship's diving systems:

**.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, drawings and calculations of fire-fighting systems for the spaces specified in [5.1.6.1](#) (they may be submitted together with the support ship's design documentation) (\*);

.3 diagrams and calculations of fire extinguishing media stores for fixed fire extinguishing systems and their capacity, as well as number of portable fire extinguishers (\*);

.4 diagram of fire detection and alarm system and alarm system for the spaces specified in [5.1.6.1](#) and layouts of the devices to monitor explosion/fire-hazardous concentrations of combustible gases in the storerooms for cylinders with flammable gases, compressors, accumulator batteries, etc. (may be submitted together with the support ship's design documentation) (\*);

.5 detailed description of fire protection of the spaces with indication of insulating and finishing materials, their location and a combustibility rate for the spaces specified in [5.1.6.4](#), as well as for the compartments of the manned submersibles (including diving bells) and manned compartments of the compression chambers as part of the ship's diving systems (\*);

.6 similarly to listed in [5.1.6.5](#), but for the spaces specified in [5.1.6.1](#) (may be submitted in the form of a fire protection plan together with the support ship's design documentation) (\*);

.7 list of materials used for manufacture 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 (\*\*);

.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, devices and systems of the manned submersibles and ship's diving systems:

.1 order records and layouts of machinery, devices and equipment (\*);

.2 description with basic details and specifications for propulsion plant components (\*);

.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's structures and machinery and their main parts (\*);

.6 diagrams and drawings of hydraulic system (\*);

.7 diagrams and drawings of submergence and surfacing, compensating and trim systems (\*);

.8 diagrams of life-support systems and technical documentation for their equipment and devices (compressors, heat exchangers, pressure vessels, pumps, valves, instrumentation, etc.) (\*):

compressed air systems for diving operations of the ship's diving systems with gas distribution board diagrams (\*);

single-component gas and gas mixture (helium, oxygen, nitrogen, etc.) transfer system with gas distribution board diagrams (\*);

artificial breathing mixture preparation systems of the ship's diving systems with gas distribution board diagrams (\*);

gas supply systems of the manned submersibles, compression chambers, diving bells and divers in diving outfit with gas distribution board diagrams (\*);

systems of regeneration and conditioning of gas atmosphere in the compression chambers, diving bells and breathing gas mixture supplied to diving bells and to diving outfits for breathing (\*);

emergency life-support systems in the compartments of the manned submersibles, compression chambers and diving bells (\*);

breathing gas mixture disposal system (\*);

system of helium regeneration from the disposed breathing gas mixtures (\*);

gas analysis systems with documentation for gas control devices (\*);

heating system for the manned submersible, compression chamber and diving bell compartments and for the divers in diving outfit (\*);

sanitary systems and devices of the manned submersibles and compression chambers (domestic water supply system, sewage system) (\*);

**.9** other systems not specified in [5.1.7.6 - 5.1.7.8](#) (\*\*);

**.10** calculations on systems and piping confirming compliance with the requirements of these Rules:

strength calculations of the piping, hulls and vessels operating under external and internal overpressure as part of the life-support systems of the manned submersibles and ship's diving systems (\*);

calculation of gas storage and gas supply system capacity: compressed air system for diving operations, oxygen systems, gases and gas mixtures, disposal, emergency breathing systems of the manned submersibles, compression chambers and diving bells (\*);

calculations of the systems of regeneration and conditioning of the manned submersible, compression chamber and diving bell compartments (\*);

capacity calculations of devices and units for carbon dioxide absorption, filters (filter units) for removal of harmful substances, as well as reserves of regenerating and absorbent materials for all (both normal and emergency) operating conditions of the manned submersibles and ship's diving systems (\*).

**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 specified 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;

**.13** calculation of accumulator battery capacities (\*).



**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 of navigational equipment (\*);

**.3** arrangement plans of main and emergency power sources;

**.5** arrangement plans of aerials (\*).

**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 (refer to [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 of these trials shall be submitted.

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

Symbols:

P - survey by the RS surveyor;

C - RS Certificate. Form of the document to be issued depends on type of technical supervision at the firm (manufacturer) (refer to Appendix 1 to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships);

СТО - Type Approval Certificate;

СПИ - Recognition Certificate for Manufacturer;

K - branding of items of technical supervision.

K – branding.

Table

| Code of item of technical supervision | Item of technical supervision   | Technical supervision of the Register |  |                            |          |  |                |   |
|---------------------------------------|---|---------------------------------------|--|----------------------------|----------|--|----------------|---|
|                                       |   | of prototype                          | Type Approval/ recognition of manufacturer | at the firm (manufacturer) |          | during construction of the manned submersibles and ship's diving systems |                |   |
|                                       |   |                                       |  | document to be issued      | branding | installation   | mooring trials | sea trials of the manned submersibles and ship's diving systems on carrier ship |
| 27000000                              | <b>MANNED SUBMERSIBLES</b>  |                                       |  |                            |          |  |                |   |
| 27000010                              | <b>MANNED SUBMERSIBLES (LOCKOUT SUBMERSIBLES AND PASSENGER SUBMERSIBLES)</b>    | P                                     | СПИ  | C <sup>3</sup>             |          | P  | P              | P   |
| 27000020                              | <b>SHIP'S DIVING SYSTEMS</b>  | P                                     | СПИ  | C <sup>3</sup>             | –        | P  | P              | P   |
| 27010000                              | <b>HULL</b>   |                                       |  |                            |          |  |                |   |
| 27010100                              | Pressure hull (spherical, conical and cylindrical shells and stiffening, heads) | P                                     | –  | C <sup>2</sup>             | K        | P  | P              | P   |

Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)

| Code of item of technical supervision | Item of technical supervision   | Technical supervision of the Register |   |                            |          |  |                |   |
|---------------------------------------|---|---------------------------------------|---|----------------------------|----------|--|----------------|---|
|                                       |   | of prototype                          | Type Approval/<br>recognition of manufacturer | at the firm (manufacturer) |          | during construction of the manned submersibles and ship's diving systems |                |   |
|                                       |   |                                       |   | document to be issued      | branding | installation   | mooring trials | sea trials of the manned submersibles and ship's diving systems on carrier ship |
| 27010200                              | Pressure tanks  | P                                     | СПИ   | C <sup>2</sup>             | K        | P  | P              | P   |
| 27010300                              | Tight enclosures of external electrical equipment of the manned submersibles, ship's diving systems and passenger submersibles: power sources, switchboards, etc. | P                                     |   | C <sup>2</sup>             | K        | P  | P              | P   |
| 27010400                              | Parts fitted on the pressure hull (welded– in pieces and flanges of hatches, view ports, tight penetrators)   | P                                     | СТО/СПИ                                       | C <sup>2</sup>             |          | P  | P              | P   |
| 27010500                              | Foundations for main equipment  | P                                     | –   | C <sup>2</sup>             | –        | P  | P              | P   |
| 27010600                              | External hull:  | P                                     | –   | C <sup>2</sup>             | –        | P  | P              | P   |
| 27010610                              | ballast tanks   | P                                     | –   | C <sup>2</sup>             | –        | P  | P              | P   |
| 27010620                              | Buoyancy units  | P                                     | СТО   | C                          | –        | P  | P              | P   |
| 27020000                              | <b>ARRANGEMENTS</b>   |                                       |   |                            |          |  |                |   |
| 27020100                              | Hatch covers  | P                                     | СТО   | C <sup>2</sup>             | K        | P  | P              | P   |
| 27020200                              | View ports in assembly  | P                                     | СТО   | C                          | K        | P  | P              | P   |
| 27020210                              | View port glasses   | P                                     | –   | C                          | K        | P  | P              | P   |
| 27020300                              | Hatch cover drives  | P                                     | –   | C                          | –        | P  | P              | P   |
| 27020400                              | Steering gears of the manned submersible and their drives   | P                                     | –   | C <sup>2</sup>             | K        | P  | P              | P   |
| 27020500                              | Emergency release devices of jettisonable ballast, diving hell support wire rope, umbilical, and other equipment external to the pressure hull                    | P                                     |   | C <sup>2</sup>             | K        | P  | P              | P   |
| 27020600                              | Mating devices for connection of diving hells and lock-out submersibles with compression chambers, and compression chambers to one another                        | P                                     |   | C <sup>2</sup>             | K        | P  | P              | P   |

*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| Code of item of technical supervision | Item of technical supervision  | Technical supervision of the Register  |   |                            |          |  |                |   |
|---------------------------------------|--|--|---|----------------------------|----------|--|----------------|---|
|                                       |  | of prototype   | Type Approval/<br>recognition of manufacturer | at the firm (manufacturer) |          | during construction of the manned submersibles and ship's diving systems |                |   |
|                                       |  |  |   | document to be issued      | branding | installation   | mooring trials | sea trials of the manned submersibles and ship's diving systems on carrier ship |
| 27030000                              | Signal and emergency signal means  | P  | –   | C                          | –        | P  | P              | P   |
| 27040000                              | <b>RADIO AND SONAR EQUIPMENT</b>   | Refer to applicable requirements of Section "Radio Equipment" of Appendix I to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships (code 04000000MK)        |   |                            |          |  |                |   |
| 27050000                              | <b>NAVIGATIONAL EQUIPMENT</b>  | Refer to applicable requirements of Section "Navigational Equipment" of Appendix I to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships (code 05000000MK) |   |                            |          |  |                |   |
| 27060000                              | <b>FIRE PROTECTION</b>   | Refer to applicable requirements of Section "Fire Protection" of Appendix I to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships (code 06000000)          |   |                            |          |  |                |   |
| 27070000                              | <b>PROPELLERS AND STEERING UNITS</b>   | P  | –   | C                          | K        | P  | P              | P   |
| 27080000                              | <b>SYSTEMS AND PIPING</b>  |  |   |                            |          |  |                |   |
| 27081000                              | Life support systems:  |  |   |                            |          |  |                |   |
| 27081100                              | gas transfer system and breathing gas mixture  | P  | –   | –                          | –        | P  | P              | P   |
|                                       |  |  |   |                            |          | P  | P              | P   |
| 27081200                              | systems of regeneration and conditioning of gas atmosphere in the manned submersible, compression chamber, diving bell and breathing gas mixture compartments supplied for breathing |  |   |                            |          | P  | P              | P   |
| 27081300                              | Compressed air system for diving operations of the ship's diving systems   | –  |   | –                          |          | P  | P              | P   |
| 27081400                              | Artificial breathing gas mixture preparation system  | –  | –   | –                          | –        | P  | P              | P   |

Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)

| Code of item of technical supervision | Item of technical supervision   | Technical supervision of the Register  |  |                            |          |  |                |   |
|---------------------------------------|---|--|--|----------------------------|----------|--|----------------|---|
|                                       |   | of prototype   | Type Approval/ recognition of manufacturer | at the firm (manufacturer) |          | during construction of the manned submersibles and ship's diving systems |                |   |
|                                       |   |  |  | document to be issued      | branding | installation   | mooring trials | sea trials of the manned submersibles and ship's diving systems on carrier ship |
| 27081500                              | Gas supply systems for manned submersibles, compression chambers, diving bells, and the divers in diving outfit |  |  |                            |          | P  | P              | P   |
| 27081600                              | Heating systems for the divers in diving outfit   | –  | –  | –                          | –        | P  | P              | P   |
| 27081700                              | Sanitary systems of the manned submersibles and compression chambers (water supply system, sewage system)       |  |  |                            |          | P  | P              | P   |
| 27081800                              | Emergency life-support systems  | –  | –  | –                          | –        | P  | P              | P   |
| 27081010                              | Distribution boards of gas supply systems   | P  | –  | C <sup>2</sup>             | –        | P  | P              | P   |
| 27081020                              | Modules of life support systems   | P  | –  | C                          | –        | P  | P              | P   |
| 27081030                              | Hoses of umbilicals   | P  | CTO  | C                          |          |  |                |   |
| 27082000                              | Pipe and other regulating fittings:   |  |  |                            |          |  |                |   |
| 27082100                              | breathing gas mixture disposal systems  | –  | –  | –                          | –        | P  | P              | P   |
| 27082200                              | system of helium regeneration from the disposed breathing gas mixtures  | –  | –  | –                          | –        | P  | P              | P   |
| 27082300                              | ventilation system of the ship's diving system spaces   | –  | –  | –                          | –        | P  | P              | P   |
| 27082400                              | Hydraulic system  | –  | –  | –                          | –        | P  | P              | P   |
| 27084100                              | Hydraulic drives (hydraulic cylinders, hydraulic motors)  | P  | –  | C                          | –        | P  | P              | P   |
| 27085000                              | Submergence and surfacing system  | –  | –  | –                          | –        | P  | P              | P   |
| 27086000                              | Compensating system   | –  | –  | –                          | –        | P  | P              | P   |
| 27087000                              | Trimming system   | Refer to applicable requirements of Section "Systems and Piping" of Appendix I to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships (code 08030000) |  |                            |          |  |                |   |
| 27080010                              | Valves (stop, control, safety, etc.), flexible and mechanical joints of pipes                                   |  |  |                            |          |  |                |   |

Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)

| Code of item of technical supervision | Item of technical supervision  | Technical supervision of the Register  |   |                            |          |  |                |   |
|---------------------------------------|--|--|---|----------------------------|----------|--|----------------|---|
|                                       |  | of prototype   | Type Approval/<br>recognition of manufacturer | at the firm (manufacturer) |          | during construction of the manned submersibles and ship's diving systems |                |   |
|                                       |  |  |   | document to be issued      | branding | installation   | mooring trials | sea trials of the manned submersibles and ship's diving systems on carrier ship |
| 27080020                              | Instrumentation (pressure gauges, depth gauges, gas analyzers)   | P  | СТО   | СТО                        | –        | P  | P              | P   |
| 27090000                              | <b>MACHINERY</b>   |  |   |                            |          |  |                |   |
| 27091000                              | Compressor plants, air filters (purification units), refrigerating units and life-support system pumps                                 | P  |   | с                          |          | P  | P              | P   |
| 27100000                              | <b>PRESSURE VESSELS AND APPARATUS<sup>1</sup></b>  |  |   |                            |          |  |                |   |
| 27100100                              | Compression chambers   | P  | СТО/СПИ                                       | С                          | К        | P  | P              | P   |
| 27100200                              | Diving bells   | P  | СПИ   | С                          | К        | P  | P              | P   |
| 27100300                              | Containers on the support ship of the manned submersibles and ship's diving systems for storage of gases and gas mixtures <sup>1</sup> | P  |   | С                          | К        | P  | P              | P   |
| 27100400                              | Pressure vessels and apparatus within the life support systems   | P  | СТО   | С                          | –        | P  | P              | P   |
| 27110000                              | <b>ELECTRICAL EQUIPMENT</b>  | Refer to applicable requirements of Section "Electrical Equipment" of Appendix I to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships (code 11000000) |   |                            |          |  |                |   |
| 27110100                              | Means of communication with support ship (service telephone communication, radiotelephone communication, sonar communication)          | P  |   | С                          |          | P  | P              | P   |
| 27110110                              | Speech unscrambles   | P  | –   | С                          | –        | P  | P              | P   |
| 27110200                              | Electrical monitoring (actual/limit values), control and alarm systems for: propulsion plants, handling system, machinery, life-       |  |   |                            | P        | P  | P              | P   |



*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| Code of item of technical supervision | Item of technical supervision   | Technical supervision of the Register   |   |                            |          |  |                |   |
|---------------------------------------|---|---|---|----------------------------|----------|--|----------------|---|
|                                       |   | of prototype  | Type Approval/<br>recognition of manufacturer | at the firm (manufacturer) |          | during construction of the manned submersibles and ship's diving systems |                |   |
|                                       |   |   |   | document to be issued      | branding | installation   | mooring trials | sea trials of the manned submersibles and ship's diving systems on carrier ship |
|                                       | support system devices, fire detectors, diving depth, composition and other   |   |   |                            |          |  |                |   |
|                                       | parameters of breathing gas mixture, positions of remotely controlled valves of submergence, surfacing and trimming systems, liquid levels, battery charge, insulation resistance of electric circuits and other systems of the manned submersibles and ship's diving systems |   |   |                            |          |  |                |   |
| 27110300                              | Electrical equipment of the systems of manned submersibles and ship's diving systems  | P   | CTO   | C                          |          | P  | P              | P   |
| 27120000                              | <b>MATERIALS</b>  | Refer to applicable requirements of Section "Materials" of Appendix I to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships (code 13000000)         |   |                            |          |  |                |   |
| 27130000                              | Welding materials   | Refer to applicable requirements of Section "Welding Materials" of Appendix I to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships (code 14000000) |   |                            |          |  |                |   |
| 27140000                              | <b>HANDLING SYSTEMS OF THE MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS</b>  | P   |   | C                          | K        | P  | P              | P   |
| 27140100                              | Cargo handling gear   | Refer to applicable requirements of Section "Hoisting Gears" of Appendix I to Part I "General Regulations for Technical Supervision" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships (code 14000000MK)  |   |                            |          |  |                |   |
| 27140200                              | Steel wire ropes for handling systems   | P   | –   | C                          | –        | P  | P              | P   |
| 27140300                              | Vertical and horizontal motion compensators   | P   | –   | C                          | –        | P  | P              | P   |

*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| Code of item of technical supervision   | Item of technical supervision  | Technical supervision of the Register |   |                            |          |  |                |   |
|---|--|---------------------------------------|---|----------------------------|----------|--|----------------|---|
|   |  | of prototype                          | Type Approval/<br>recognition of manufacturer | at the firm (manufacturer) |          | during construction of the manned submersibles and ship's diving systems |                |   |
|   |  |                                       |   | document to be issued      | branding | installation   | mooring trials | sea trials of the manned submersibles and ship's diving systems on carrier ship |
| 27140400  | Transportation platforms on the support ship for movement and mating of lock-out submersible to ship's diving system | P                                     |   | C                          |          | P  | P              | P   |
| 27140500  | Structures of diving stages and half-bells   | P                                     | -   | C                          | -        | P  | P              | P   |
| <sup>1</sup> Portable bottles and transportable groups of bottles with diving breathing gas mixtures are not subject to survey.<br><sup>2</sup> RS Certificate is issued only when the product is supplied to the manufacturer by cooperation.<br><sup>3</sup> For the manned submersibles and mobile ship's diving systems, a Certificate (form 6.5.30) may be issued upon results of factory acceptance tests. After installation and necessary testing on board the carrier ship, documents specified in Section 4 of "General Regulations on Classification and other Activity for the Manned Submersibles and Ship's Diving Systems" are issued. |  |                                       |   |                            |          |  |                |   |

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

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;

I – tests by a proof load;

3 – replacement.

Table

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

*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| 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          |
| 1.6  | External hull   | C  | C               | C               | C               | O                 | C               | C               | C               | C               | O           | C               | C               | C               |                 |             |
| .1   | ballast tanks   | O  | O               | O               | O               | OH <sup>3</sup>   | O               | O               | O               | O               | OMH         | O               | O               | O               | C               |             |
| 2    | <b>ARRANGEMENTS</b>   |  |                 |                 |                 |                   |                 |                 |                 |                 |             |                 |                 |                 | O               | OMH         |
| 2.1  | Hatch covers  | OH <sup>6</sup>  | OH <sup>6</sup> | OH <sup>6</sup> | OH <sup>6</sup> | OH <sup>2</sup>   | OH <sup>6</sup> | OH <sup>6</sup> | OH <sup>6</sup> | OH <sup>6</sup> | OH          | OH <sup>6</sup> | OH <sup>6</sup> | OH <sup>6</sup> |                 |             |
| 2.2  | View ports  | CH <sup>6</sup>  | CH <sup>6</sup> | CH <sup>6</sup> | CH <sup>6</sup> | OH <sup>2</sup>   | CH <sup>6</sup> | CH <sup>6</sup> | CH <sup>6</sup> | CH <sup>6</sup> | OH          | CH <sup>6</sup> | CH <sup>6</sup> | CH <sup>6</sup> | OH <sup>6</sup> | OH          |
| 2.3  | Hatch cover drives  | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP          | P               | P               | P               | CH <sup>6</sup> | OH          |
| 2.4  | Steering gear   | Refer to 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 of the manned submersibles and diving bells        | 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 and other emergency release gear                                    | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP          | P               | P               | P               | P               | OP          |
| 2.7  | Emergency quick-release gear  | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP          | P               | P               | P               |                 |             |
| 2.8  | Mating devices for connection of diving bells and lock-out submersibles with compression chambers and compression chambers to one another               | HP   | HP              | HP              | HP              | OHP               | HP              | HP              | HP              | HP              | OHP         | HP              | HP              | HP              | P               | OP          |
|      |   |  |                 |                 |                 |                   |                 |                 |                 |                 |             |                 |                 |                 | HP              | OHP         |
| 2.9  | Lifting lugs and lifting gear of the manned submersibles and diving bells Signal and emergency signal means of the manned submersibles and diving bells | C  | C               | C               | C               | CM                | C               | C               | C               | C               | CM          | C               | C               | C               | C               | OHP         |
|      |   |  |                 |                 |                 |                   |                 |                 |                 |                 |             |                 |                 |                 |                 |             |
| 2.10 | Signal and emergency signal means of the manned submersibles and diving bells   | P  | P               | P               | P               | OH <sup>2</sup> P | P               | P               | P               | P               | OHP         | P               | P               | P               | P               |             |

*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| Nos. | Item of survey   | Survey of the manned submersibles, ship's diving systems and passenger submersibles  |                 |                 |                 |                   |                 |                 |                 |                 |                |                 |                 |                 |                 |                |
|------|--|--|-----------------|-----------------|-----------------|-------------------|-----------------|-----------------|-----------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|----------------|
|      |  | 1st<br>annual  | 2nd<br>annual   | 3rd<br>annual   | 4th<br>annual   | 1st<br>special    | 1st<br>annual   | 2nd<br>annual   | 3rd<br>annual   | 4th<br>annual   | 2nd<br>special | 1st<br>annual   | 2nd<br>annual   | 3rd<br>annual   | 4th<br>annual   | 3rd<br>special |
| 1    | 2  | 3  | 4               | 5               | 6               | 7                 | 8               | 9               | 10              | 11              | 12             | 13              | 14              | 15              | 16              | 17             |
| 3    | <b>FIRE PROTECTION</b>   | Refer to Section 3 of Table 2.1.1, Part II "Survey Procedure and Scope" of the Rules for the Classification Surveys of Ships |                 |                 |                 |                   |                 |                 |                 |                 |                |                 |                 |                 |                 |                |
| 4    | <b>PROPELLERS</b>  | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP             | P               | P               | P               | P               |                |
| 5    | <b>SYSTEMS AND PIPING</b>  |  |                 |                 |                 |                   |                 |                 |                 |                 |                |                 |                 |                 |                 | OP             |
| 5.1  | Life support systems:  | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP             | P               | P               | P               | P               | OP             |
| .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             |
| .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             |
| .7   | breathing gas mixture disposal system  | 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               | OHP            |
| .2   | pipng  | PH <sup>6</sup>  | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | OH <sup>2</sup> P | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | OHP            | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | OP             |
| 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               | OHP            |

*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| 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                |
| 5.6  | Piping and fittings of other systems and systems listed in <a href="#">5.1</a> , <a href="#">5.3-5.5</a> ; hoses as part of the umbilical: | PH <sup>6</sup>  | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | OH <sup>2</sup> P | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | OHP               | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | PH <sup>6</sup> | OP                |
| .1   | safety valves  | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP                | P               | P               | P               | P               | OP                |
| 5.7  | Ventilation and air conditioning system not specified in <a href="#">5.1</a>   | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP                | P               | P               | P               | P               |                   |
| 6    | <b>MACHINERY</b>   |  |                 |                 |                 |                   |                 |                 |                 |                 |                   |                 |                 |                 |                 |                   |
| 6.1  | Compressors (air, gas)   | Refer to 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 <sup>7</sup> P | P               | P               | P               | P               | OP                |
| 6.3  | Pumps of the life support system   | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP                | P               | P               | P               | P               |                   |
| 7    | <b>PRESSURE VESSELS AND APPARATUS<sup>8</sup></b>  |  |                 |                 |                 |                   |                 |                 |                 |                 |                   |                 |                 |                 |                 |                   |
| 7.1  | Containers on the support ship of the manned submersibles and diving bell for storage of gases and gas mixtures                            | P  | P               | P               | P               | OH <sup>2</sup> P | P               | P               | P               | P               | OH <sup>4</sup> P | P               | P               | P               | P               | OH <sup>6</sup> P |
| 7.2  | Pressure vessels and apparatus in the life support system and their fittings:  | P  | P               | P               | P               | OH <sup>2</sup> P | P               | P               | P               | P               | OH <sup>4</sup> P | P               | P               | P               | P               | OH <sup>6</sup> P |
| .1   | safety valves  | P  | P               | P               | P               | OH <sup>2</sup> P | P               | P               | P               | P               | OH <sup>4</sup> P | P               | P               | P               | P               | OH <sup>6</sup> P |
| 7.3  | Vessels and apparatus in sewage, drinking and washing water supply systems of compression chambers and their fittings:                     | P  | P               | P               | P               | OH <sup>2</sup> P | P               | P               | P               | P               | OHP               | P               | P               | P               | P               | OHP               |
| .1   | safety valves  | P  | P               | P               | P               | OP                | P               | P               | P               | P               | OP                | P               | P               | P               | P               | OP                |

| 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          |
| 8    | <b>MEASURING INSTRUMENTS (PRESSURE GAUGES AND DEPTH METERS)</b>  | E   | E          | E          | E          | E           | E          | E          | E          | E          | E           | E          | E          | E          | E          | E           |
| 9    | <b>ELECTRICAL, RADIO, NAVIGATIONAL AND SONAR EQUIPMENT</b>   |   |            |            |            |             |            |            |            |            |             |            |            |            |            |             |
| 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         |
| .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 <a href="#">2.2</a> , <a href="#">5.1.1 – 5.1.6</a> and <a href="#">10.4</a> 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         |

*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| Nos. | Item of survey  | Survey of the manned submersibles, ship's diving systems and passenger submersibles |               |               |               |                |               |               |               |               |                |               |               |               |               |                |
|------|---|---|---------------|---------------|---------------|----------------|---------------|---------------|---------------|---------------|----------------|---------------|---------------|---------------|---------------|----------------|
|      |   | 1st<br>annual   | 2nd<br>annual | 3rd<br>annual | 4th<br>annual | 1st<br>special | 1st<br>annual | 2nd<br>annual | 3rd<br>annual | 4th<br>annual | 2nd<br>special | 1st<br>annual | 2nd<br>annual | 3rd<br>annual | 4th<br>annual | 3rd<br>special |
| 1    | 2   | 3   | 4             | 5             | 6             | 7              | 8             | 9             | 10            | 11            | 12             | 13            | 14            | 15            | 16            | 17             |
| 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 penetrates   | MC  | MC            | MC            | MC            | OM             | MC            | MC            | MC            | MC            | OM             | MC            | MC            | MC            | MC            | OM             |
| 9.8  | Earthing devices and cathodic protection  | MC  | MC            | MC            | MC            | OM             | MC            | MC            | MC            | MC            | OM             | MC            | MC            | MC            | MC            | 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            |
| 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            |
| 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 | MP  | MP            | MP            | MP            | OMP            | MP            | MP            | MP            | MP            | OMP            | MP            | MP            | MP            | MP            | OMP            |



*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| 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          |
|      | trimming systems, liquid levels, accumulator battery discharge, insulation resistance of electric circuit               |   |            |            |            |             |            |            |            |            |             |            |            |            |            |             |
| 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         |
| 10   | <b>HANDLING SYSTEMS OF THE MANNED SUBMERSIBLES, DIVING BELLS AND HYPERBARIC EVACUATION SYSTEMS</b>                      |   |            |            |            |             |            |            |            |            |             |            |            |            |            |             |
| 10.1 | Structures with permanently fitted fixed components (masts, posts, ties of counter-weights, foundations, etc)           | C   | C          | C          | C          | OIP         | C          | C          | C          | C          | OIP         | C          | C          | C          | C          | OIP         |
| 10.2 | Loose gear (blocks, axles, eyes, catches, etc.)   | C   | C          | C          | C          | OIP         | C          | C          | C          | C          | OIP         | C          | C          | C          | C          | OIP         |
| 10.3 | Steel wire ropes for handling systems   | CM  | CM         | CM         | CM         | 3           | CM         | CM         | CM         | CM         | 3           | CM         | CM         | CM         | CM         | 3           |
| 10.4 | Machinery (including emergency machinery) for hoisting and lowering, luffing, slewing and motion of the handling system | P   | P          | P          | P          | OIP         | P          | P          | P          | P          | OIP         | P          | P          | P          | P          | OIP         |
| 10.5 | Lead screws, rollers, racks, arresting devices  | P   | P          | P          | P          | OIP         | P          | P          | P          | P          | OIP         | P          | P          | P          | P          | OIP         |
| 10.6 | Safety devices (stops, limit switches, outreach indicators, hose and rope length indicator, brakes, etc.)               | P   | P          | P          | P          | OP          | P          | P          | P          | P          | OP          | P          | P          | P          | P          | OP          |
| 10.7 | Handling system control panel   | P   | P          | P          | P          | OP          | P          | P          | P          | P          | OP          | P          | P          | P          | P          | OP          |

*Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems (Part I)*

| 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              |
| 10.8 | Compensators of vertical and horizontal motions of the manned submersibles, diving bells and passenger submersibles                              | P   | P               | P               | P               | OP              | P               | P               | P               | P               | OP              | P               | P               | P               | P               | OP              |
| 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               | OIP             | P               | P               | P               | P               | OIP             | P               | P               | P               | P               | OIP             |
| 11   | <b>LIFE-SAVING APPLIANCES OF THE PASSENGER SUBMERSIBLE</b>   |   |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |                 |
| 11.1 | Inflatable lifejackets immersion suits and thermal protective aids   | CE <sup>9</sup>   | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> | CE <sup>9</sup> |
| 11.2 | Lifebuoys and rigid lifejackets  | C   | C               | C               | C               | CE <sup>9</sup> | C               | C               | C               | C               | CE <sup>9</sup> | C               | C               | C               | C               | CE <sup>9</sup> |
| 12   | <b>MEASURING INSTRUMENTS (WATER LEAKAGE, INDICATION OF AVAILABLE POWER, AMOUNT OF WATER BALLAST, VOLTAGE OF EACH ELECTRICAL SOURCE OF POWER)</b> | E   | E               | E               | E               | E               | E               | E               | E               | E               | E               | E               | E               | E               | E               | E               |

Note. 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, an appropriate 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 responsibility for 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.

| Nos.  | Item of survey | Survey of the manned submersibles, ship's diving systems and passenger submersibles |               |               |               |                |               |               |               |               |                |               |               |               |               |                |
|---|----------------|---|---------------|---------------|---------------|----------------|---------------|---------------|---------------|---------------|----------------|---------------|---------------|---------------|---------------|----------------|
|   |                | 1st<br>annual   | 2nd<br>annual | 3rd<br>annual | 4th<br>annual | 1st<br>special | 1st<br>annual | 2nd<br>annual | 3rd<br>annual | 4th<br>annual | 2nd<br>special | 1st<br>annual | 2nd<br>annual | 3rd<br>annual | 4th<br>annual | 3rd<br>special |
| 1   | 2              | 3   | 4             | 5             | 6             | 7              | 8             | 9             | 10            | 11            | 12             | 13            | 14            | 15            | 16            | 17             |
| <p><sup>1</sup> 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 depth of 10 — 15 m. 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.</p> <p><sup>2</sup> 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.</p> <p>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.</p> <p><sup>3</sup> Strength tests may be omitted if it is proved during external examination and internal survey (without removal of insulation) and by nondestructive inspection that such tests are not justified.</p> <p><sup>4</sup> Only for apparatus and vessels inaccessible for internal survey.</p> <p><sup>5</sup> At the discretion of the Register, hydraulic tests may be omitted.</p> <p><sup>6</sup> Tightness tests.</p> <p><sup>7</sup> Pneumatic strength tests during each special survey beginning from the 2nd survey after construction.</p> <p><sup>8</sup> Portable bottles are not subject to survey by the Register.</p> <p><sup>9</sup> 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.</p> |                |   |               |               |               |                |               |               |               |               |                |               |               |               |               |                |

## **PART II. HULL**

### **1 GENERAL**

#### **1.1 APPLICATION**

The requirements of this Part of the Rules apply to welded and not welded hulls of the manned submersibles (diving bells), ship's diving systems, hyperbaric evacuation systems, tanks and pressure vessels manufactured of low-alloy steels with yield stress  $R_{eH} \leq 690$  MPa and operated under external or internal hyperbaric pressure.

The application of the methods specified in this Part of the Rules when using low-alloy steels with yield stress  $R_{eH} > 690$  MPa or austenitic high-alloyed steel, titanium and aluminum alloys, composite materials, as well as the application of glass-reinforced plastic for the pressure hull and equivalent structures may be allowed subject to special agreement with the Register. Besides steel, glass-reinforced plastic may be used for construction of the external hull in accordance with the recommendations of [Appendix 1](#).

## 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  $T_d \geq -5^\circ\text{C}$ . If, due to the operating conditions,  $T_d < -5^\circ\text{C}$  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 stresses  $\sigma_0$  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  $\sigma_1$  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  $\nu$ . 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  $\nu = 0,3$ , and for steel  $E = 2 \times 10^5 \text{MPa}$ .

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:

$$n_{conv} = \sum_i n_{H_i} \left( \frac{H_i}{H_{op}} \right)^{m_i} < 1000, \quad (1.2)$$

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

where  $H_i$  = maximum depth in the narrow range of depths (e.g. from  $0,8H_{op}$  to  $0,9H_{op}$ );  
 $n_{H_i}$  = 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  $\sigma^t$  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 RS 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) and other pressure-resistant structures (tanks, containers, etc.) which take up pressure;

**.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;

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

$\Delta H$  = depth margining;

$P$  = 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;

$L_p$  = design length of the conical 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;

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

$\gamma$  = bend angle of the conical shell;

$\delta$  = maximum possible measurement error;

$\theta$  = 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) (refer to [Fig. 3.4.1-1](#));

$Z_{fr}$  = 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 frame cross-section;  
 $S_A$  = thickness of the reinforced plate;  
 $S_r$  = thickness of the reinforcement;  
 $r_1, r_{H_0}, r_{cg}, r_B, r_H, \alpha, \beta$  = dimensions defining the openings for hatches and view ports to be inserted (refer to [Fig. 3.7.9](#));

**.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;  
 $\nu$  = 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;  
 $\theta_1$  = force equivalent to the load applied to coaming on the shell side;  
 $\theta_2$  = force equivalent to the load applied to coaming on the view port side;  
 $\theta_3, \theta_4$  = forces due to pressure exerted on the coaming surface;  
 $[\sigma]$  = allowable stresses;  
 $\sigma_0$  = general membrane stresses;  
 $\sigma_1$  = local membrane stresses;  
 $\sigma_t$  = total stresses;  
 $\sigma^t$  = tensile stresses;  
 $\sigma_c$  = 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;

$\alpha_1$  = number of camber half-waves along the meridian;

$\beta_1$  = spacing parameter;

$\eta', \eta'', \eta_1, \eta_c, \eta_{1c}$  = 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 this Section and Part XIII "Materials" of the Rules for the Classification and Construction of Sea-Going Ships. Application of steel that differ in chemical composition and specified mechanical properties from those specified in the requirements of Part XIII of the Rules, as well as the application of steel with yield stress of  $R_{eH} \geq 690$  MPa, is subject to special consideration by the Register in each case. The possibility of particular materials and products supply for manned submersibles and ship's diving systems shall be confirmed by the RS certificates.

**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 %;

**.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

$$T_t = T_d - 20 \text{ } ^\circ\text{C} \quad (2.1.2.2)$$

where  $T_d$  is assumed according to [1.2](#).

**.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;

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    |

**.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](#) this 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 %. The tests are carried out according to the procedure approved by the Register,

**.6** properties of the material used in the structure (after bending, the 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 %.

**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. In case of using weld metal of lower strength, bend test method shall be agreed with the Register.

**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 (refer to [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  $S < 40$  mm and not less than  $(120 + 0,5(S - 40))$  when  $S \geq 40$  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  $S < 40$  mm, and not less than  $(180 + 0,5(S-40))$  when  $S \geq 40$  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  $0,5 S$  when  $S < 40$  mm (but not less than 25 mm) and not less than 100 mm when  $S \geq 40$  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  $0,5 S$  when  $S < 40$  mm (but not less than 25 mm) and not less than 60 mm when  $S \geq 40$  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.

**2.2.4** The scope and methods of welding joints non-destructive testing, as well as assessment criteria of weld quality shall be approved by the Register.

### 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<sup>2</sup>, moments of inertia, in cm<sup>4</sup>.

**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 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

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

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

The value  $\Delta H$  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  $\Delta H \geq 50$  m. When specifying  $\Delta H$  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 % for a depth of 6000 m and not more than 1 % 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  $\sigma^0$ :

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

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

$$n_T = 1,5(R_{eH} - 400)/400 \leq 2,0 \quad (3.3.1.1-2)$$

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  $\sigma^l$  and total  $\sigma^t$  stresses:

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

**.3** where stresses (tensile  $\sigma^t$  and compressive  $\sigma_c$ )<sup>1</sup> 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  $|\sigma_0| > p$ :

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

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

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

where  $n_b$  and  $n_T$  are specified as indicated in [3.3.1.1](#).

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

**.4** when using steel with  $R_{eH} > 690$  MPa, austenitic steel, titanium and aluminum alloys, allowable tensile stress levels shall comply with the requirements of [2.1.1](#) and agreed with Register.

**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  $[\sigma_c^0]$ :

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

tensile  $[\sigma_t^0]$ :

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

<sup>1</sup> 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.

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

$$[\sigma^l] = 1,1[\sigma^0]; \quad (3.3.2.2)$$

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

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

The safety factors are taken equal to:

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

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

**.4** when using steels with  $R_{eH} > 690$  MPa, austenitic steels, titanium and aluminum alloys, the safety factor shall be taken equal to  $n_{T_c} = 1,5$ ,  $n_{T_t} = 2$  for assessment of their effectiveness, with possible adjustment after reviewing the issue in accordance with the requirements of [2.1.1](#) considering proposed design solutions.

For example, for torospherical heads, when under internal pressure, compressive stresses can arise and, in case of small thickness, even local buckling can take place in the tor, as well as tensile stresses may take place under external pressure;

**.5** it is allowed, especially when using numerical methods, to use equivalent stresses (von Mises stress intensity) instead of maximum stresses with mandatory verification of the maximum tensile stresses. In this case, check in compliance with the requirements of [3.3](#) is not conducted.

Note.  $n_{T_c}$  may be increased for titanium alloys in structures being continuously under the pressure for a long period;  $n_{T_t}$  shall be corrected after determination of proposed material's resistance to crack development under static and repeated loads.

**3.3.3** Where stresses (tensile  $\sigma_t$  and compressive  $\sigma_c$ ) different in sign are present at some hull section loaded by external pressure, the following conditions shall be met<sup>1</sup>:

$$\sigma_T \leq [\sigma_t]; \quad (3.3.3-1)$$

$$|\sigma_t| + |\sigma_c| \leq |\sigma_c|. \quad (3.3.3-2)$$

### 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 midpoint of frame spacing (point A in [Fig. 3.4.1.1](#)) by the formula

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

Note. Structures with  $k_2^0 < 0,6$  are not allowed.

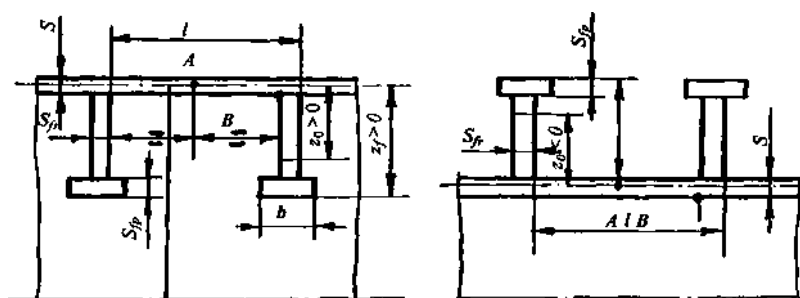


Fig. 3.4.1-1:

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

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

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

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

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

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

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

$$\sigma_{fr}^0 = k \frac{P_r}{S} \left( 1 + \frac{F}{r S_{fr} (1 + Z_0/r)} \right) \leq [\sigma^0]; \quad (3.4.1.5-1)$$

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 (refer to [Fig. 3.4.1.1](#)).

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

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

$$\beta = ls(1 - Z_0/r)/F \quad (3.4.1.5-3)$$

by calculations according to [Tables 3.4.1.1](#) and [3.4.1.2](#).

Table 3.4.1.1

| $u$                   | $k_2^0$                      | $k_1$                       | $k$                             |
|-----------------------|------------------------------|-----------------------------|---------------------------------|
| $u > 4,5$             | 1,00                         | $0,5 + 1,54u/(u + \beta)$   | $0,85\beta/(u + \beta)$         |
| $0,6 \leq u \leq 4,5$ | $1 - F_4/(1 + \beta F_1)$    | $0,5 + F_2/(1 + \beta F_1)$ | $0,85\beta F_1/(1 + \beta F_1)$ |
| $u < 0,6$             | $(\beta + 0,15)/(\beta + 1)$ | $0,5 + 1,03u^2/(1 + \beta)$ | $0,85\beta/(1 + \beta)$         |

Table 3.4.1.2

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

In case of external pressure, the values of  $k_2^0, k_1, k$  may be determined according to [Figs. 3.4.1-2, 3.4.1-3](#) and [3.4.1-4](#) instead of calculations by the formulae specified in [Table 3.4.1.1](#). Diagrams for the values of  $k_2^0, k_1$ , with an error on the safe side may be also used in case of internal pressure.

A more accurate strength calculation to substantiate more rational structure dimensions can be made according to the procedures and with application of the software approved by the Register.

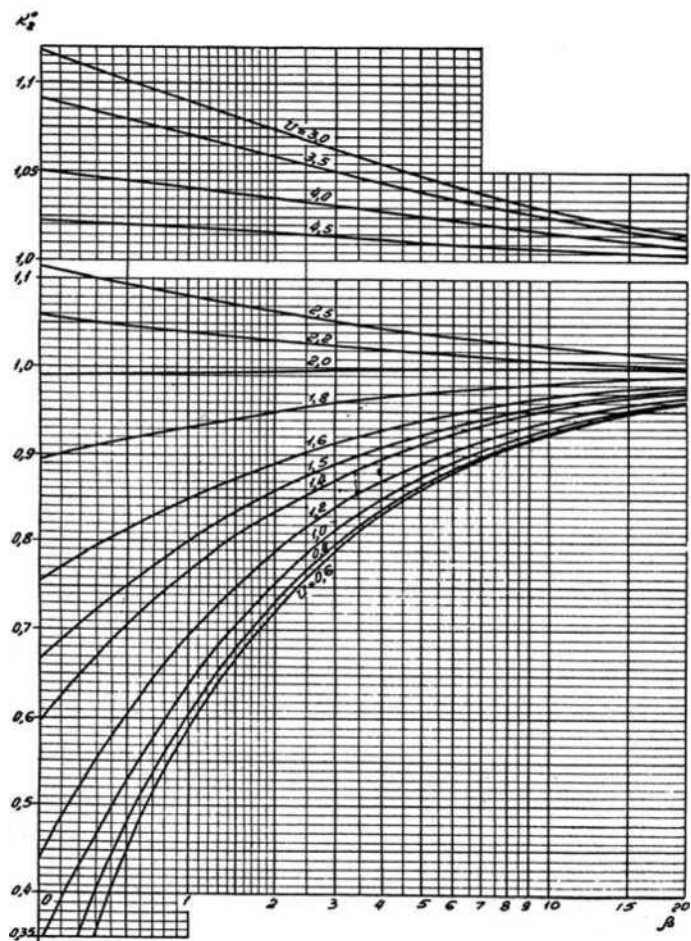


Fig. 3.4.1-2

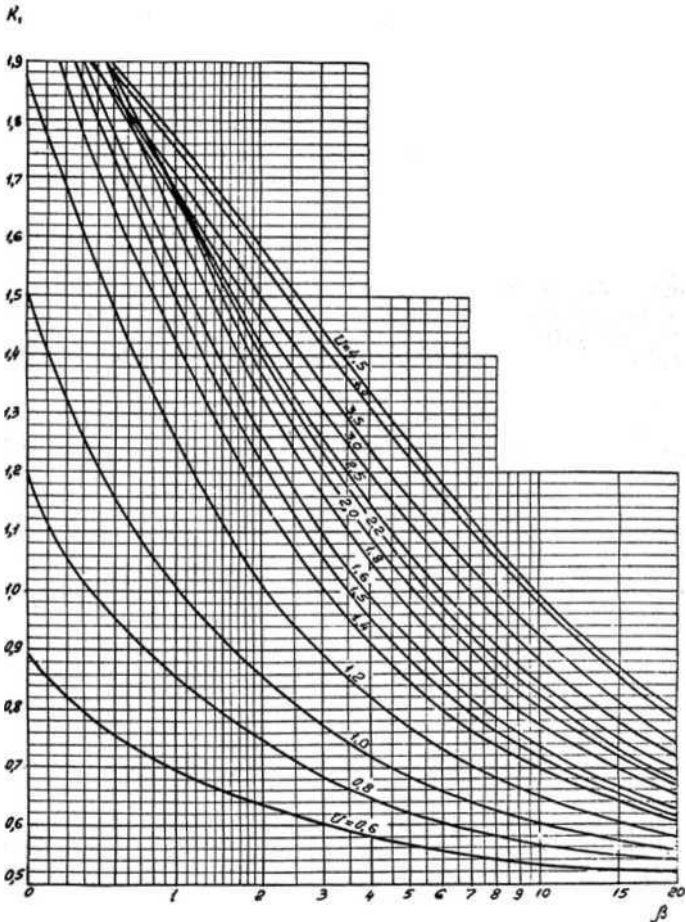


Fig. 3.4.1-3

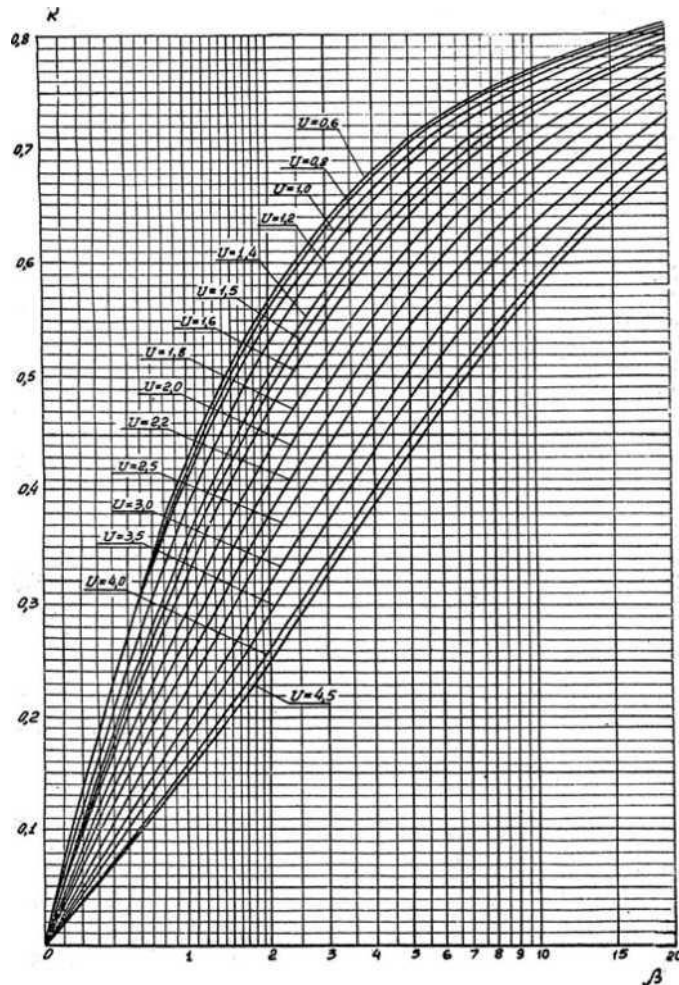


Fig. 3.4.1-4

### 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

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

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:

$$P \leq P_{1c} / n_s; P \leq P_{2c} / n_s; \quad (3.4.3)$$



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

$$P_{1c} = \eta' P_1' \quad (3.4.3.1-1)$$

$P_1'$  is determined by the formulae:

$$P_1' = 0,944E(S/r)^3 \text{ when } u \leq 1; \quad (3.4.3.1-2)$$

$$P_1' = 0,59E(S/r)^2(1 + 0,4/u_k + 0,2/u_k^2)/(k_2^0 u) \quad (3.4.3.1-3)$$

when  $1 < u < u_g = 2,15r/S$ ;

$$u_k = u/(2 - 1k_2^0).$$

Note. When determined by Formula (3.4.3.1-3),  $P_1' = 0,944E(S/r)^2$  shall be taken as follows:

$$P_1' = 0,944E(S/r)^2;$$

$$P_1' = 0,944E(S/r)^3 \text{ when } u > u_g. \quad (3.4.3.1-4)$$

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  $\eta'$  is determined by the formulae given in [Table 3.4.3.1](#).

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

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

$$\sigma = k_2^0 P_1' r / SR_{eH}. \quad (3.4.3.1-7)$$

Table 3.4.3.1

| Value $u$          | Formula for $\eta'$  |
|--------------------|--|
| $u \leq 0,1u_g$    | $\eta' = \eta_k = \eta_1 / \sqrt[4]{1 + \frac{2}{3}[\eta_1(1 + \bar{f}_1)\sigma]^4}$   |
| $0,1u_g < u < u_g$ | $\eta' = \frac{\eta_k}{1 + 3(\eta_k/\eta_g - 1)[(u - 0,1u_g)/0,9u_g]^2 \left[1 - \frac{2}{3} \left(\frac{u - 0,1u_g}{0,9u_g}\right)\right]}$   |
| $u \geq u_g$       | $\eta' = \eta_g = \frac{1}{2} \left[ \frac{1}{\sqrt[4]{1 + \frac{9}{16}\bar{\sigma}^4}} + 5,46\bar{f}_1 + \frac{2}{\sqrt{3}\bar{\sigma}} - \sqrt{\left( \frac{1}{\sqrt[4]{1 + \frac{9}{16}\bar{\sigma}^4}} + 5,46\bar{f}_1 + \frac{2}{\sqrt{3}\bar{\sigma}} \right)^2 - \frac{8}{\sqrt{3}\bar{\sigma}^4 \sqrt{1 + \frac{9}{16}\bar{\sigma}^4}}} \right]$ |

**3.4.3.2** Buckling of the shell together with frames.

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

$$P_{2c} = \eta^n P_2' \quad (3.4.3.2-1)$$

$$\text{where } P_2' = \frac{E}{n^2-1+\alpha_1^2/2} \{ \bar{I}_0(n^2-1)^2/r^3 l + S^3(n^2-1+\alpha_1^2)^2/10,9r^3 + (S/r)\alpha_1^4/(n^2+\alpha_1^2)^2 + [F(1-Z_0/r)/(l_r)Z_0/(r-Z_0)](n^2-1) + [(0,3n^2-\alpha_1^2)\alpha_1^2/(n^2+\alpha_1^2)^2]/(1+1/\beta_1) \} \quad (3.4.3.2-2)$$

In Formula (3.4.3.2-2):

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

$$\alpha_1 = \pi r / L_d \quad (3.4.3.2-3)$$

where  $L_d$  = design length of the cylindrical shell (refer to Fig. 3.4.3.2-1);

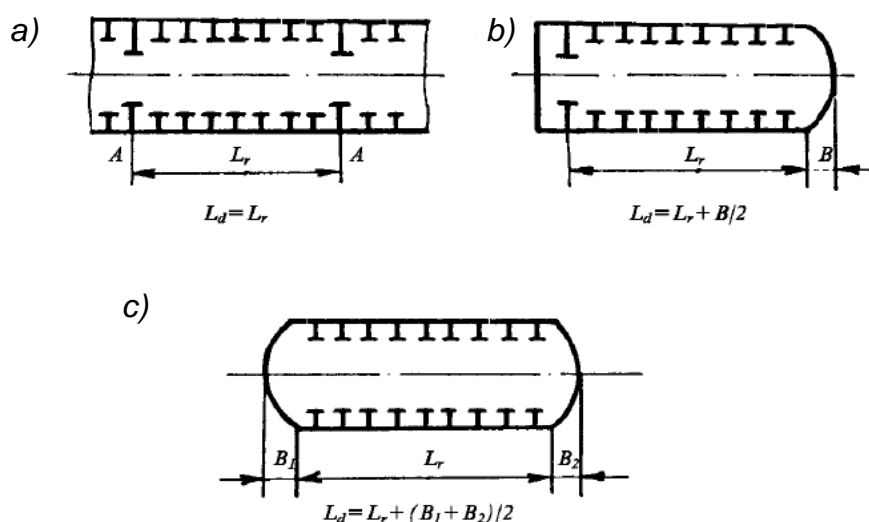


Fig. 3.4.3.2-1

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

where  $Z_0$  = distance of the frame center of gravity from the median surface of plating (with its own sign - refer to Fig. 3.4.1.1);

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

where  $l_{np}$  is determined from Table 3.4.3.2-1;

Table 3.4.3.2-1

| Value $u$         | Internal frame<br>( $Z_0 > 0$ ) | External frame<br>( $Z_0 < 0$ )  |
|-------------------|---------------------------------|--|
| $u \leq 0,75$     | $l_{np} = l$                    | $l_{np} = l$   |
| $0,75 < u \leq 1$ | $l_{np} = l$                    | $l_{np} = l / [1 + H_1^2(u - 0,75)]$<br>$H_1 = 1 + [  Z_0 /r +  Z_0  ] (n^2 - 1)^{1)}$ |
| $u > 1$           | $l_{np} = 1,55\sqrt{rS}$        |  |

<sup>1)</sup>  $l_{np}$ , at  $Z_0 > 0$  is calculated for each  $n$ .

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

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

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

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

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

$$\bar{\sigma}_2 = \sqrt[4]{3/2} \frac{kP_2^1 r}{(1 - Z_{fr}/r) SR_{eH}^{fr}} \quad (3.4.3.2-10)$$

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

$$\text{at } \bar{\sigma} = \bar{\sigma}_1 \geq 1 \quad c_1 = R_{eH}/R_{eH}^{fr} \quad (3.4.3.2-11)$$

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

$$\text{at } \bar{\sigma} = \bar{\sigma}_2 \geq 1 \quad c_1 = 1; \quad (3.4.3.2-13)$$

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

**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 (3.4.1.6), the design length of the compartment  $L_d$  shall be inserted therein instead of the spacing  $l$ , according to [Fig. 3.4.3.2-1, 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  $\alpha_1$  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

$$S \geq 0,76(1 + \bar{f}_1) k_2^0 n_s (P_r / R_{eH}) \times \sqrt{1 + \sqrt{1 + 50 \left[ \frac{u(R_{eH})^2}{(1 + \bar{f}_1)^2 \eta_1 (k_2^0)^2 (1 + 0,4/u_k + 0,2u_k^2) E n_s P} \right]^2}} \quad (3.4.8-1)$$

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

$$S \geq k_2^0 Pr / [\sigma^0]. \quad (3.4.8-2)$$

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  $u \geq 2$  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 (refer to also Fig. 3.4.1.4-1) shall be met:

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

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

**3.4.10** The formulae specified in 3.4.3, Formula (3.4.9) and the relevant formulae specified Section 3.5 can be used for calculation of critical pressure for structures made of carbon steels, low-alloy steels and titanium alloys of any strength, as well as aluminum alloys with  $R_{eH} \geq 250$  MPa. In such case,  $E = 1,15 \cdot 10^5$  shall be assumed for titanium alloys,  $E = 0,7 \cdot 10^5$  for aluminum alloys, and Poisson's ratio  $\nu = 0,3$  for all alloys.

Where austenitic steels or aluminum alloys with  $R_{eH} \geq 250$  MPa are used, buckling strength calculation methods shall be agreed with the Register.

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 | $\leq 2/3$ | $P \leq 0,6ESS_{fr}^2 / [kr( Z_{fr}  - S_{fr})^2]$  |
|          |          | $> 2/3$    | $P \leq (4/15) \{ES^2 / [kr( Z_{fr}  - S_{fr})^2]\}$  |
|          | Internal | $\leq 2/3$ | $P \leq 0,6 [ESS_{fr}^2 / [kr( Z_{fr}  - S_{fr})^2]] \frac{1}{1 + 5,4[F/rS_{fr} - (2/3)( Z_{fr} /r)]}$          |
|          |          | $> 2/3$    | $P \leq (4/15) \{ES^3 / [kr( Z_{fr}  - S_{fr})^2]\} \frac{1}{1 + 8,1[F/rS_{fr} - (2/3)( Z_{fr} /r)](S_{fr}/S)}$ |
| Internal | External | $\leq 2/3$ | $P \leq (9/80)ESS_{fr}^3 / [kF( Z_{fr}  - S_{fr})^2] \frac{1}{1 - (2/3)( Z_{fr} S_{fr})/F}$                     |
|          |          | $> 2/3$    | $P \leq (1/30) \{ES^4 / [kF( Z_{fr}  - S_{fr})^2]\} \frac{1}{1 - [(2/3)( Z_{fr} S_{fr})/F]}$                    |
|          | Internal | Any        | No checking   |

### 3.5 CALCULATION OF CONICAL SHELLS

**3.5.1** The calculation of a conical shell with permanent taper (refer to [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](#).

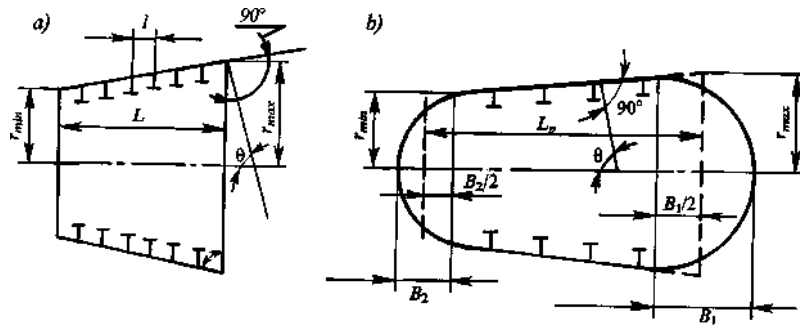


Fig. 3.5.1:

a - shells without torospherical or elliptical ends; b - shells with torospherical or elliptical ends.

Table 3.5.1

| No. of formula or table  | Values in formula (cylinder)                        | Substitution in calculation of conical shells  |
|--|---|--|
| 1  | 2   | 3  |
| Formulae <a href="#">(3.4.1.1)</a> , <a href="#">(3.4.1.2)</a> , <a href="#">(3.4.1.3)</a> , <a href="#">(3.4.1.5-1)</a> , <a href="#">(3.4.2.1)</a>   | $Pr/S$  | $P \cdot \max(r/S \sin \theta)$<br>where $\max(r/S \sin \theta)$ is the maximum value of the ratio on the cone portion under consideration <sup>1</sup>              |
| Formulae <a href="#">(3.4.1.5-2)</a> , <a href="#">(3.4.1.5-3)</a>   | $u = 0,624l/\sqrt{rS}$<br>$\beta = ls(1 - Z_0/r)/F$ | $u = 0,624(l/r_{cp})\sqrt{\max(r/S \sin \theta)}$<br>$\beta = ls(1 - Z_0/r)/F \sin \theta$   |
| Tables <a href="#">1</a> and <a href="#">2</a> of Appendix 2. Formulae <a href="#">(3.4.3)</a> , <a href="#">(3.4.3.1-1)</a> , <a href="#">(3.4.3.1-6)</a> , <a href="#">(3.4.3.1-7)</a> , <a href="#">(3.4.3.2-1)</a> | To be used unchanged                                |  |
| Formulae <a href="#">(3.4.3.1-2)</a> , <a href="#">(3.4.3.1-3)</a> , <a href="#">(3.4.3.1-4)</a>   | $S/r$   | $\sin \theta / \max(r/S)$  |
| Formulae <a href="#">(3.4.3.2-2)</a>   | $\alpha_1 = \frac{E}{\pi r/L_d}$                    | $\alpha_1 = \frac{E \sin^3 \theta}{\pi \cos \theta \ln(r_{max}/r_{min})}$<br>at $r_{max}/r_{min} \leq 1,3$<br>$\alpha_1 = \pi r_{cp} \sin \theta / L_d$ may be taken |

| No. of formula or table  | Values in formula (cylinder)  | Substitution in calculation of conical shells  |
|--|---|--|
| 1  | 2   | 3  |
|  | $\left. \begin{array}{l} \bar{I}_0/r^3 l \\ F/lr \\ Z_0/(r - Z_0) \end{array} \right\}$ | The formulae do not change, but inserted therein are $\bar{I}_0, F, l, Z_0, r$ 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 <sup>1</sup> |
|  | $\beta_1 = l_{np}S/F(1 - Z_0/r)$  | $\beta_1 = l_{np}S/[F(1 - Z_0/r) \sin \theta]$<br>where values $F, Z_0, l$ (in $l_{np}$ ) are assumed as specified above   |
| Formulae <a href="#">(3.4.3.1-1)</a> ,<br><a href="#">(3.4.3.2-1)</a>  | To be used unchanged  |  |
| Formulae <a href="#">(3.4.3.2-6)</a>   | $m, k_2^0, k$<br>$Z_{fr}/r$<br>$r/S$  | 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 <a href="#">(3.4.8-1)</a> ,<br><a href="#">(3.4.8-2)</a>  | $r$   | $r/S \sin \theta$  |
| <a href="#">Table 3.4.9</a>  | To be used unchanged  |  |
| <sup>1</sup> For the hull of permanent thickness with equidistant frames of permanent section, $r = r_{max}$ shall be taken.<br>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. |   |  |

**3.5.2** The formulae of [Table 3.5.1](#) are applicable to:

shells unstiffened by frames

at  $r_{max}/r_{min} \leq 1,5$   $\theta \geq 60^\circ$ ;

shells stiffened by frames

at  $r_{max}/r_{min} \leq 1,5$ ,  $\theta \geq 70^\circ$  within the spacing; and

at  $r_{max}/r_{min} \leq 3$ ,  $\theta \geq 70^\circ$  for the hull as a whole.

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 (refer to [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:

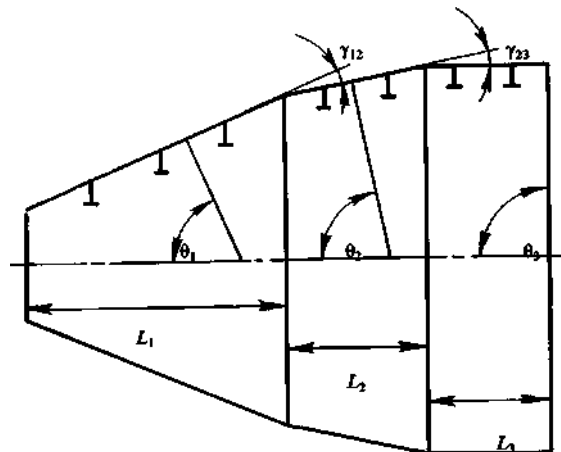


Fig. 3.5.3

.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  $\alpha_1$  shall be determined by the formula

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

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

At  $r_{max}/r_{min} < 1,3$ , the expression  $\ln(r_{max}/r_{min}) \cos \theta$ , 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.

A more accurate strength calculation to substantiate more rational structure dimensions can be made according to the procedures and with application of the software approved by the Register.

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

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

In Formula ([3.5.3.2](#)) the greatest values of  $\gamma$  – bend angle (refer to [3.5.3](#)),  $r/S$  and  $r/\sin_0$  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 (refer to [Fig. 3.6.1](#)) are calculated by the formulae for checking:

.1 strength:

$$\sigma^0 = PR/2S_s \leq [\sigma^0]; \quad (3.6.1-1)$$

.2 buckling strength:

$$P \leq P_{sc}/n_s; \quad (3.6.1-2)$$

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

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

$$\eta_s = \eta_{1s} / \sqrt{1 + \eta_{1s} \bar{\delta}^2 [a \bar{f}_s + \eta_{1s} (1 + \bar{f}_s)^2]} \quad (3.6.1-5)$$

$$a = 0 \text{ at } \bar{f}_s \leq 0,1; \quad a = 2\sqrt{\bar{f}_s - 0,1} \text{ at } \bar{f}_s > 0,1$$

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

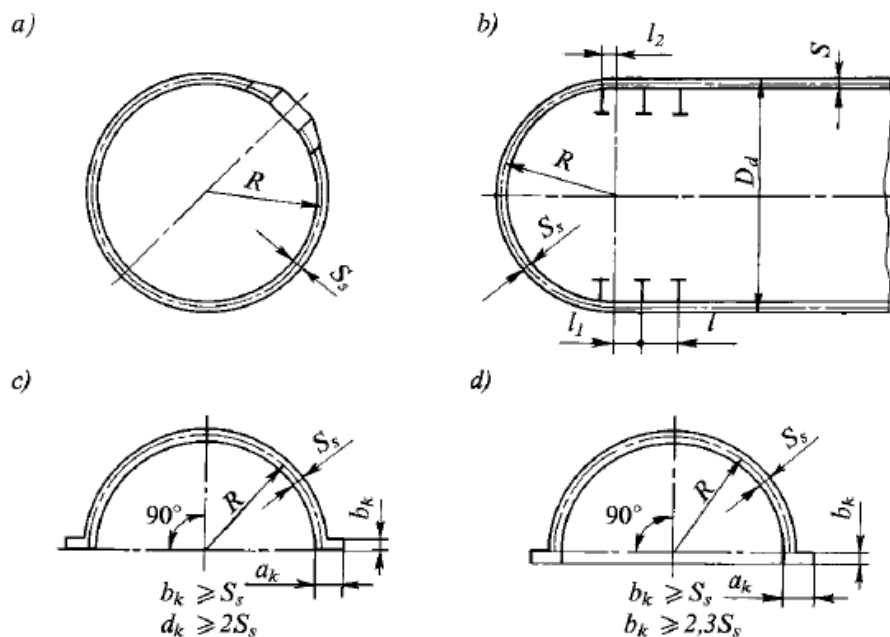


Fig. 3.6.1:

a - spherical hull; b - semispherical end of a cylindrical hull; c and d - semispherical caps

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



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

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

$$S_s \geq n_s PRA / (2\sqrt{2}R_{eH}), S_s \geq PR / (2[\sigma^0]), \quad (3.6.1-9)$$

$$\text{where } A = \sqrt{[a\bar{f}_s\eta_{1s} + (1 + \bar{f}_s)^2][1 + \sqrt{1 + 43,7R_{eH}^4\{En_sP[a\bar{f}_s + (1 + \bar{f}_s)^2]\eta_{1s}}]}; \quad (3.6.1-10)$$

Where internal radius  $R_i = R - S_s/2$  of the sphere is specified for designing, required  $S_s$  shall be taken as higher of the following:

$$S_s \geq [n_s PR_i / (2\sqrt{2}R_{eH})]A / [1 - An_s P / (4\sqrt{2}R_{eH})], \quad (3.6.1-11)$$

$$S_s \geq PR_i / (2[\sigma^0] - P/2).$$

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:

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

**3.6.2** Torospherical and elliptical ends and caps (refer to 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 (refer to Fig. 3.6.2).

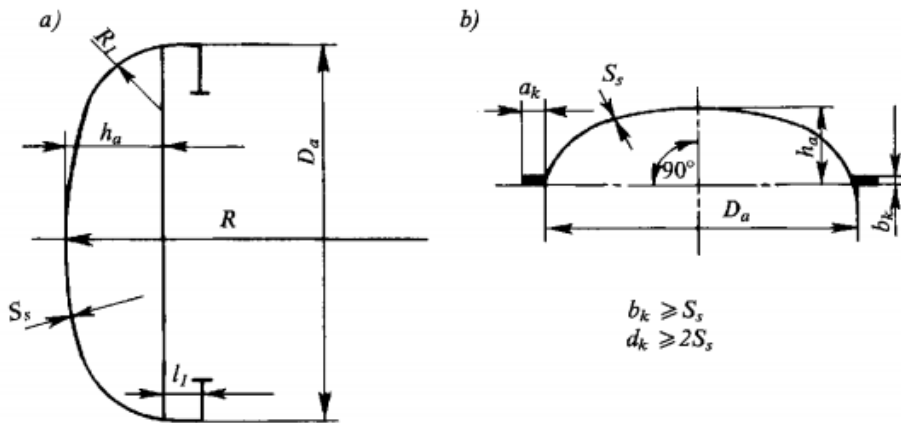


Fig. 3.6.2:

a - torospherical end; b - elliptical cap

The following conditions shall be met:  
for torospherical ends and caps:

$$R \leq D_a - S_s; \quad (3.6.2-1)$$

$$R_1 > (D_a - S_s)/6; \quad (3.6.2-2)$$

for elliptical ends and caps:

$$h_a \geq (D_a - S_s)/4; \quad (3.6.2-3)$$

$$R = (D_a - S_s)^2 / 4h_a \leq D_a - S_s \quad (3.6.2-4)$$

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

Where such ends are used for conical hulls, bend angle  $\gamma$  of the generatrix in way of the butt (refer to [Fig. 3.5.3](#)) shall not exceed  $5^\circ$ .

**3.6.3** The formulae specified in [Section 3.6](#) can be used for calculation of critical pressure for structures made of carbon steels, low-alloy steels and titanium alloys of any strength, as well as aluminum alloys with  $c R_{eH} \geq 250$  MPa.

Where austenitic steels or aluminum alloys with  $R_{eH} < 250$  MPa are used, buckling strength calculation methods shall be agreed with the Register.

### 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. Where  $a/r < 0,4$  (refer to Figs. 3.7.2 and 3.7.6), cylindrical and conical shells can be calculated by the formulae specified in 3.7.7. In other cases, calculation methods shall be agreed with the Register.

Below are set forth the recommendations for pre-selection of thickness and cross-sections of the reinforcing members with methods for their calculation.

These recommendations and calculation methods, when applied to various steel structures with  $R_{eH} > 690$  MPa, titanium and aluminum alloys, can be used only as a first approximation and its use shall be agreed with the Register.

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

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

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

For cylindrical and conical shells:

$$h_1 \geq S_r + (1/2)a^2/r; \quad (3.7.2-3)$$

$$h_2 \geq S_r + (1/2)a^2/r; \quad (3.7.2-4)$$

For spherical shells:

$$h_1 \geq S_r, \quad (3.7.2-5)$$

$$h_2 \geq S_r \quad (3.7.2-6)$$

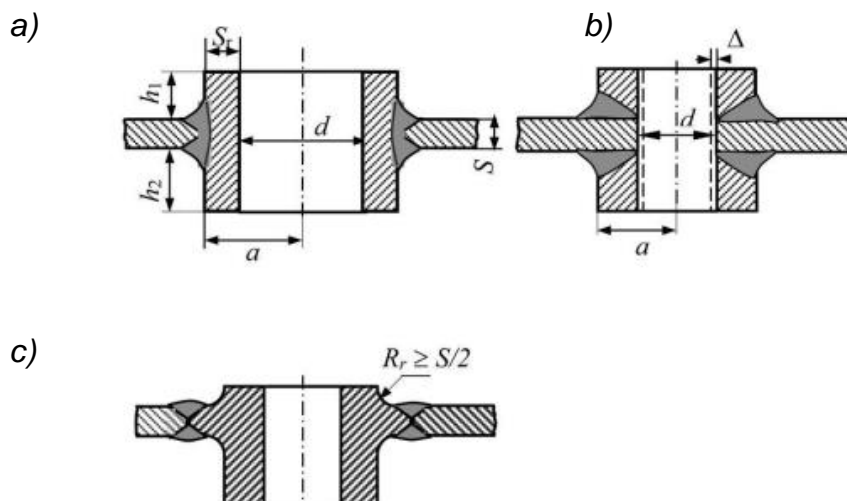


Fig. 3.7.2:

- 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"

The following condition shall be met for all shells:

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

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

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

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

Distance between the centers of the nearest openings shall not be less than the sum of their radii  $a$  (refer to [Fig. 3.7.2](#)) multiplied by 2,5.

**3.7.3** Where an opening in a thickened plate is reinforced (refer to [Fig. 3.7.3](#)) the following conditions shall be met:

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

$$B_{bl} \geq 5(S_A - S), \quad (3.7.3-2)$$

$$S_r \geq S_A \text{ at } d \geq 2S_A; \quad (3.7.3-3)$$

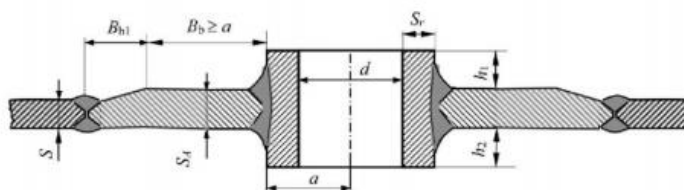


Fig. 3.7.3

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

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

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

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 (refer to [Fig. 3.7.2, a](#)) or a double-sided butt weld, when the coaming is made with a "collar" to ensure smooth transition (refer to [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  $\Delta$  that assures removal of the defective portion of the weld root (refer to [Fig. 3.7.2, c](#)).

Longitudinal welds in stamp-welded coamings shall be located in a section perpendicular to the hull axis.

**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.

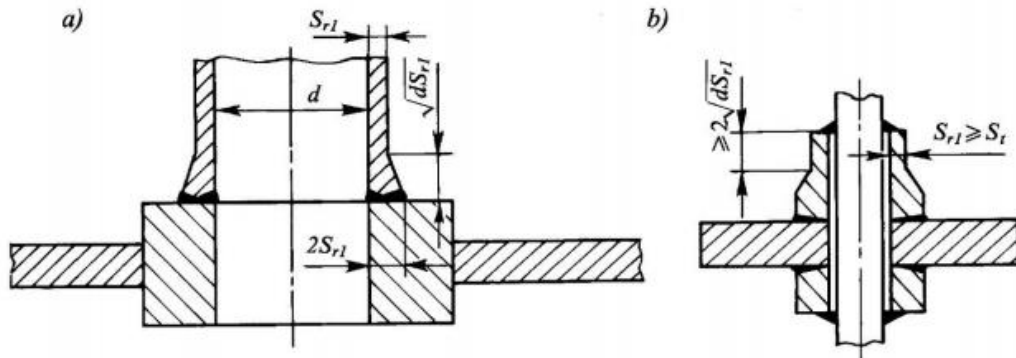


Fig. 3.7.5:

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** In cylindrical and conical shells, where coamings intersect frames, the continuous frames nearest thereto on either side of the coaming shall be so strengthened (refer to Fig. 3.7.6) that the moments of inertia of the frame section with effective flange  $I_{str}$  shall not be less than

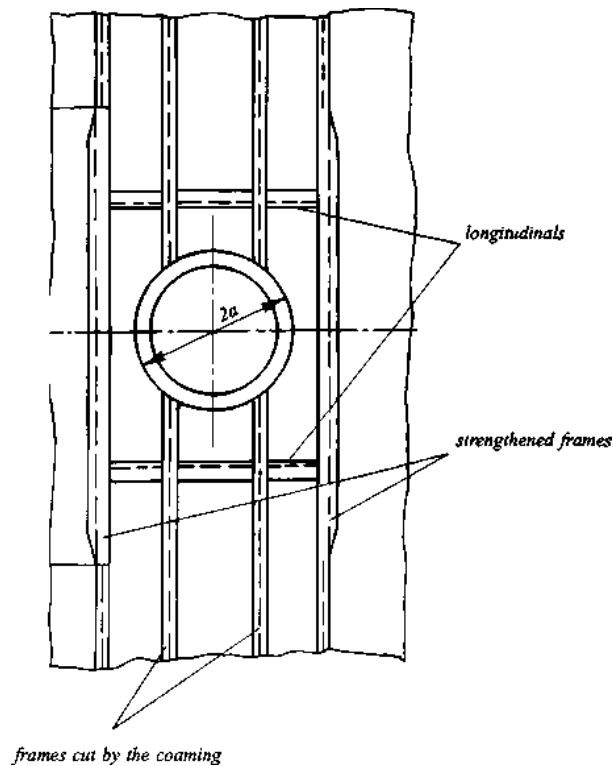


Fig. 3.7.6

$$I_{str}^{req} = (1 + 0,3m_p)I, \quad (3.7.2.4-1)$$

where  $m_p$  = number of intercostal frames;

$I$  = moments of inertia of the ordinary frame with effective flange with the area of  $lS$ .  
Structural elements of each specified reinforced frames shall be selected based on the following condition:

$$I_{str} = \bar{I}_{0,str} + \frac{F_{str}Z_{0,str}^2}{\left(1 - \frac{Z_{0,str}}{r}\right)\left(1 + \frac{1}{\beta_{1,str}}\right)} \geq (1 + 0,3m_p)I. \quad (3.7.2.4-2)$$

Geometric meaning of  $\bar{I}_{0,str}$ ,  $F_{str}$ ,  $Z_{0,str}$ ,  $\beta_{1,str}$  is the same as of the similar values without  $_{str}$  index.

Longitudinal stiffeners with the same profile as of the ordinary (not strengthened) frames shall be set on either side of the coaming, between continuous frames at the distance not more than  $l/2$  away from the outside of the coaming.

### 3.7.7 Strength calculations for cylindrical shells with openings.

Strength of the cylindrical shell's openings area under an external pressure shall be checked by maximum normal membrane stresses appearing in the weakest section along the generatrix; those stresses shall be calculated by formula

$$\sigma_2^{0,max} = K_\sigma \frac{pr}{S}, \quad (3.7.7-1)$$

where  $K_\sigma$  = concentration factor of membrane stresses.

The condition shall be met  $0,9\sigma_2^0 \leq \sigma_2^{0,max} \leq 1,1[\sigma^0]$ , where  $\sigma_2^0$  is the stress in this area if there had not been an opening here. If  $\sigma_2^{0,max} < 0,9\sigma_2^0$  is obtained, opening reinforcement is excessive and shall be reduced.

Note. Where an opening is arranged in a thickened plate complying with the requirements of 3.7.3,  $S = S_A$  shall be assumed in Formula (3.7.7-1) and in all relations specified in 3.7.7.1 and 3.7.7.2.

#### 3.7.7.1 Coefficient $K_\sigma$ is determined by the following formula:

$$K_\sigma = \bar{K}_\sigma(\mu) + \Phi(b_1)\chi(\mu) \text{ if } 2a > l \quad (3.7.7.1-1)$$

$$K_\sigma = [\bar{K}_\sigma(\mu) + \Phi(b_1)\chi(\mu)]k_1^0(u) \text{ if } 2a > l$$

where  $\bar{K}_\sigma(\mu)$  = stress concentration factor of a boundless plate with the opening reinforced by coaming under two-side compression at the "infinity" distance in case  $\sigma_1^0/\sigma_2^0 = 1/2$ ; it shall be determined depending on parameter  $\mu$  from the diagram specified in [Fig. 3.7.7-1](#);

$\chi(\mu)$  = function determined depending on parameter  $\mu$  from the diagram specified in [Fig. 3.7.7-2](#);

$$\Phi(b_1) = 0,25b_1(1 - e^{-b_1});$$

$$b_1 = \sqrt[4]{3(1 - v^2)} \frac{a}{r} \sqrt{r/S};$$

$\mu = \frac{F_{req}}{aS}$  – parameter defining the extent of the opening compensation by the reinforcing coaming;

$$F_{req} = \beta(u_c, u_h)S_r\sqrt{aS_r} + S_rS - \text{coamings cross-sectional area reduced to the ring};$$

$\beta(u_c, u_h)$  – factor determined from the diagrams specified in [Fig. 3.7.7-3](#) depending on parameters  $u_h$  and  $u_c$ ;

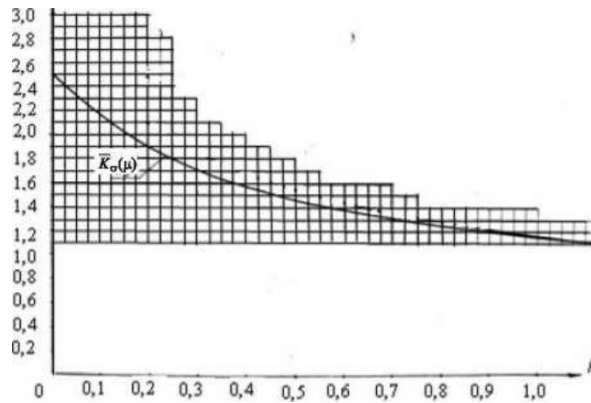


Fig. 3.7.7-1.

Dependence of membrane stress concentration factor  $\bar{K}_\sigma$  from parameter  $\mu$  Plane problem for a boundless plate with reinforced openings loaded on edges at "infinity" with stresses  $\sigma_1^0$  and  $\sigma_2^0$  when  $\sigma_1^0 = 0,5\sigma_2^0$

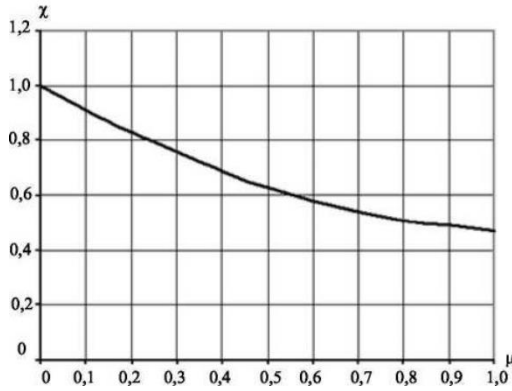


Fig. 3.7.7-2.

Dependence of value  $\chi$  from parameter  $\mu$

$$u_h = 1,285 \frac{h_1 + h_2}{\sqrt{as_r}};$$

$$u_h = 1,285 \frac{c}{\sqrt{as_r}};$$

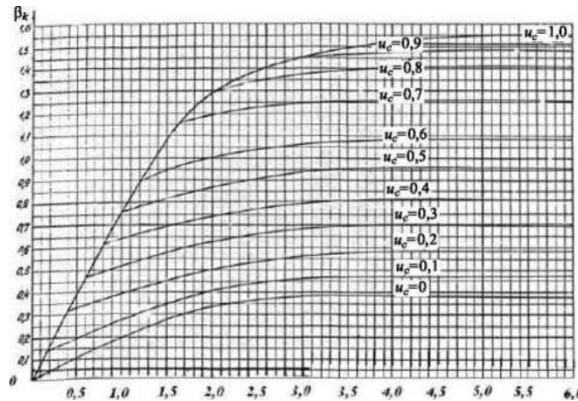


Fig. 3.7.7-3.

Value of coefficient  $\beta_k$

$c$  – average distance of the nearest coaming edge from the median surface of shell plating

$$c = \frac{(c_1 + c_2)}{2} \quad (\text{refer to Fig. 3.7.7-4})$$

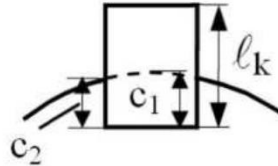


Fig. 3.7.7-4

**3.7.7.2** To improve structural quality of the cylindrical body near openings that cut one or more frames, it is recommended to additionally perform the following refining procedure to slightly reduce scantlings in such an area:

initially, specify structural members of the specified structural assembly using the following formula for determining membrane stress concentration factor:

$$K_{\sigma} = \bar{K}_{\sigma}(\mu) + f_2(b_2)\chi(\mu), \quad (3.7.7.2-1)$$

where

$$b_2 = \frac{a^4}{r} \sqrt{\frac{r^2 S l}{4I}};$$

$$f(b_2) = \frac{6}{100} (b_2^2 - 0,4b_2^2 + 0,2b_2^4);$$

final stressed condition in the opening area shall be determined according to the methods and using software approved by the Register.

**3.7.8** The angle between the axis of any opening and the normal at the hull axis shall not exceed  $10^\circ$  (refer to Fig. 3.7.8).

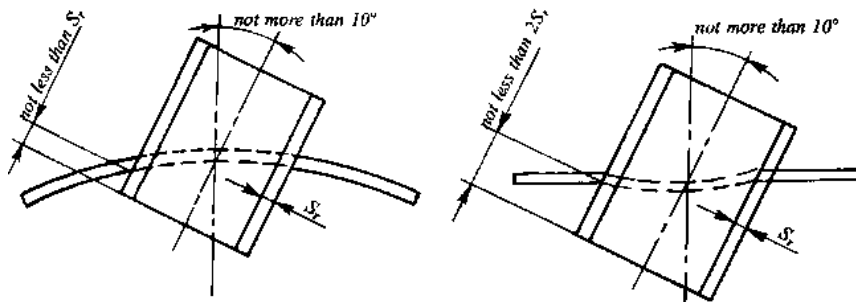


Fig. 3.7.8

**3.7.9** The openings in spherical shells for hatches and view ports shall be reinforced by coamings as shown in Fig. 3.7.9.

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

$$\text{where } Q_1 = PR/2; \quad (3.7.9-1)$$



$$Q_2 = P_{rHO}^2 / [r_{HO} + r_B] \sin v; \quad (3.7.9-2)$$

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

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

$$3,2 Q_{\Sigma} r_{og} S / (PR) \geq F \geq 2,7 Q_{\Sigma} r_{og} S / (PR); \quad (3.7.9-3)$$

$$Q_{\Sigma} = P \left[ \sqrt{R^2 - r_H^2} r_H / 2r_{og} - r_{H0}^2 \text{ctg} v / 2r_{og} + (r_H^2 - r_1^2) \text{ctg} \Phi / 2r_{og} \right]. \quad (3.7.9-4)$$

Values of  $r_{H0}, r_B, r_{og}, r_H, r_1, \gamma, v$  shall be determined in accordance with [Fig. 3.7.9](#). Calculation methods for other openings in spherical shells shall be subject to the RS review.

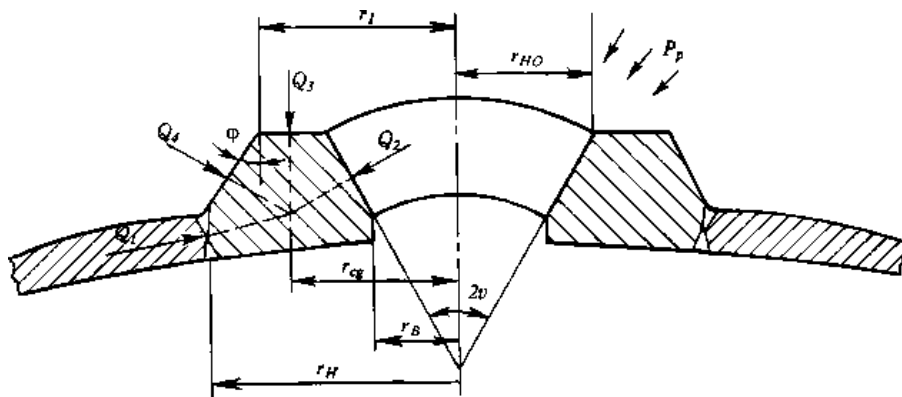


Fig. 3.7.9

### 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 % 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

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

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  $\sigma$  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** Out-of-roundness of non-reinforced shells  $f_1$  shall be measured in several cross-sections along the length:

if  $L_d \leq 4r$  - at the mid length and at the ends of the cylinder;

if  $L_d > 4r$  - at the mid length, at the ends, and in other (intermediate) cross sections of the cylinder so that those cross-section were  $2r$  or less apart

**3.8.1.7** 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 (refer to [Fig. 3.8.1.11, b](#)) (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.

**3.8.1.8** The variable wall difference is not to exceed  $1,2f_1$  or  $0,2S$ , whichever is less.

**3.8.1.9** Deviations of frames from the regular shape measured at the flange and web are shown in [Fig. 3.8.1.9](#).

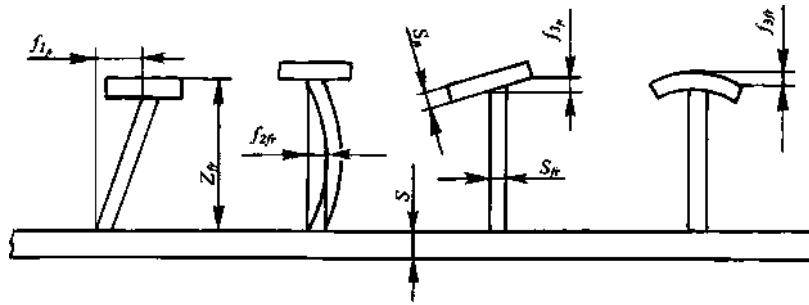


Fig. 3.8.1.9

The allowable values of  $f_{1fr}$ ,  $f_{2fr}$  and  $f_{3fr}$  are given in [Table 3.8.1.9](#) where  $f_1$  is the value of local deviation input in the calculation in accordance with [3.8.1.11](#).

Table 3.8.1.9

| 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.

**3.8.1.10** 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.

**3.8.1.11** 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 (refer to [Fig. 3.8.1.11](#)) on the frames attachment side or in accordance with [3.8.1.1 — 3.8.1.6](#).

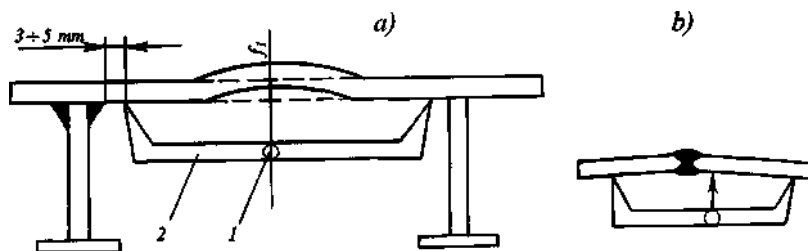


Fig. 3.8.1.11:

1 - instrument; 2 - instrument base

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

$$N_{1min} = 14(r/l)\sqrt{u}\sqrt{1 - 0,72/u + 1/8u^2}. \quad (3.8.1.12)$$

When  $u < 1$ ,  $u = 1$  shall be inserted in Formula (3.8.1.12), and at  $N_{1min} < 16$ , it is necessary to take  $N_{1min} = 16$ .

When  $0,1u_g < u < u_g$ ,  $f_1$  shall be measured both in accordance with Fig. 3.8.1.11 and 3.8.1.1–3.8.1.6, and the greatest deviations measured shall be assumed. The number of measurement points according to both schemes is determined by Formula (3.8.1.12).

When  $u \geq u_g$ , measurements are carried out only in accordance with 3.8.1.1–3.8.1.6 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 base 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.

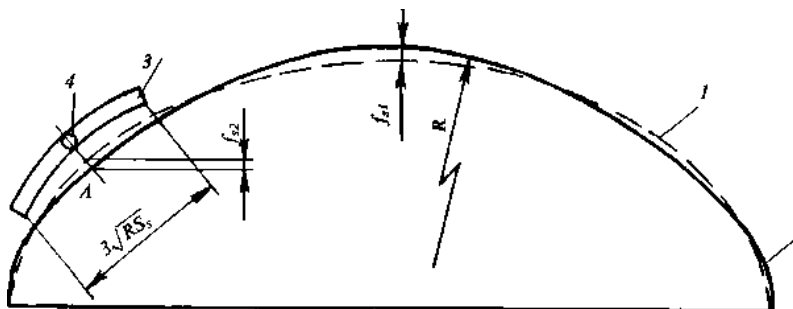


Fig. 3.8.2.2:

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 (refer to 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.

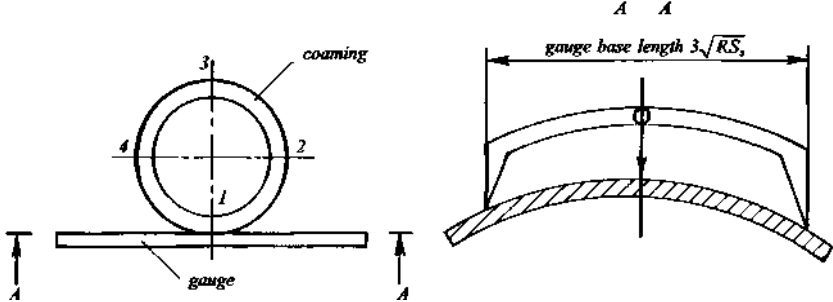


Fig. 3.8.3

### 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 (refer to [Fig. 3.9.1](#)), etc.

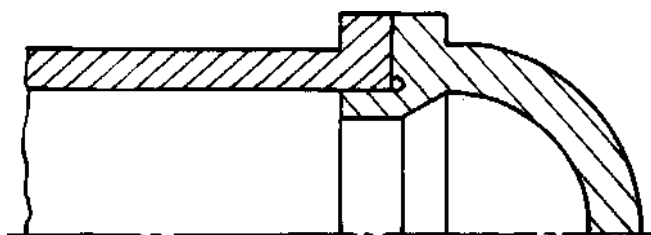


Fig. 3.9.1

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, and the external hull as a whole, shall be calculated for specified loads, which are adopted with due regard to salient features of their functioning.

**3.9.4** 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 manned 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.

**3.9.5** 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 from the displacement and principal particulars of the submersible in accordance with the general methods of structural mechanics.

**3.9.6** 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 of the manned submersible. The dynamic factor is determined proceeding from the high sea conditions, parameters of the support ship motions and parameters of the handling 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 this Rules and the requirements of [3.9.10](#) and [3.9.11](#) of this Section without regard to the added water masses.

**3.9.7** 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.

**3.9.8** 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.

**3.9.9** 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.

**3.9.10** 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.

**3.9.11** 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 3g.

**3.9.12** 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.

**3.9.13** 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

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

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

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

Upon 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

$$P_t = \left(1,25 + \frac{R_{eH}-400}{400}\right)P \leq 1,5Pb$$

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.

**4.1.6** It is recommended to conduct hydraulic tests together with acoustic emission testing to identify and locate possible damages during the test.

## **4.2 TESTING OF LIGHT STRUCTURES**

**4.2.1** 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](#). 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.

**5.1.4** The transverse flaming 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 flaming system is substantiated by the designer.

**5.1.5** The flame 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.

**5.1.6** 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 2](#) 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](#).

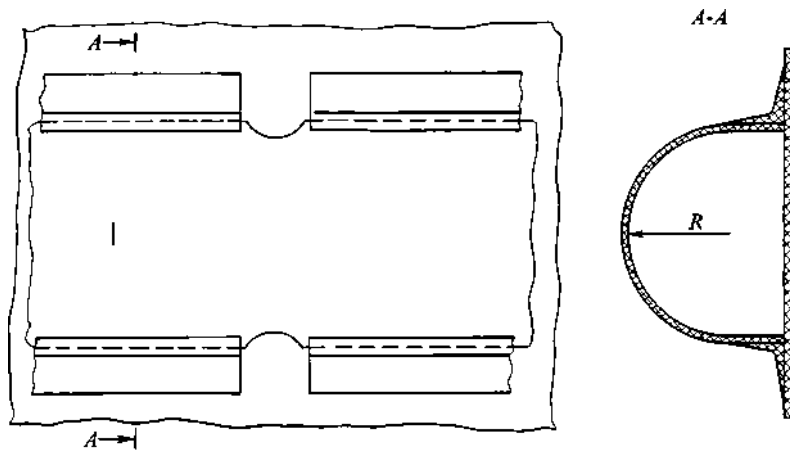


Fig. 5.1.11

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 shall 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 and watertight bulkheads laminate shall be not less than 5 mm for a single-layer structure with any reinforcement pattern.

**5.2.2** Any local increase in the hull laminate thickness shall be formed by additional reinforcing material layers alternated with the parent 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 (refer to [Fig. 5.3.1-1](#)), rectangular section (refer to [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-shaped 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 (refer to [Fig. 5.3.2](#)) to provide the reliable filling of the gap between the stiffener web and shell.

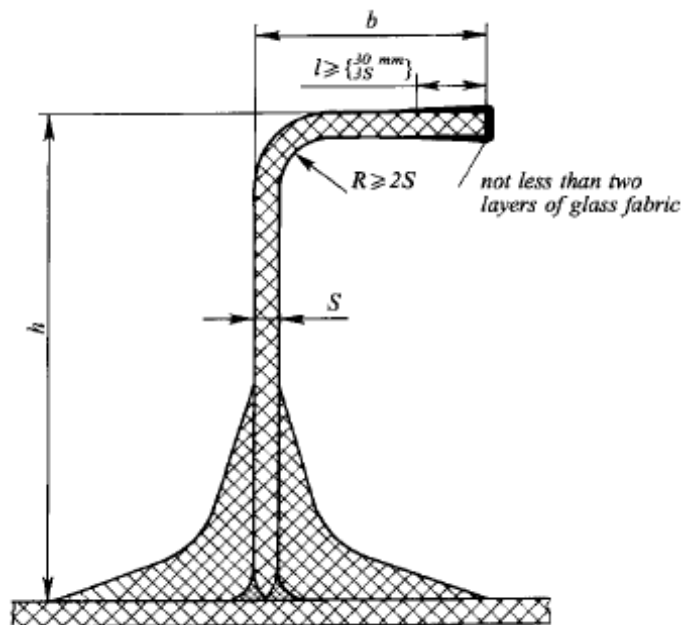


Fig. 5.3.1-1:

|                  |                     |
|------------------|---------------------|
| $b$              | $S$                 |
| $(0,5 \dots 1)h$ | $(1/10 \dots 1/3)h$ |

$$h > 50 \text{ mm}$$

**5.3.3** In all the hull framing members water courses and air holes (refer to 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.

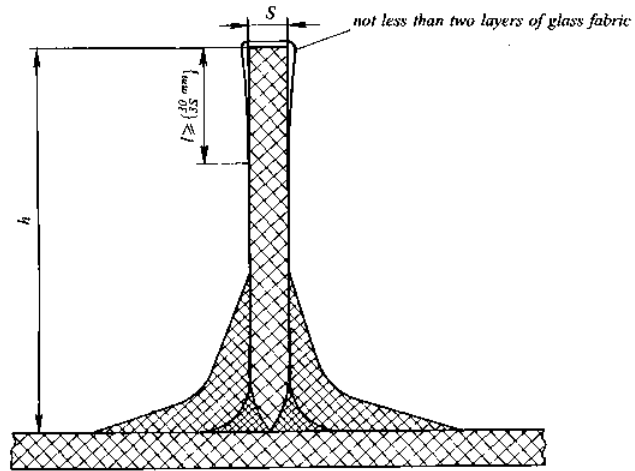
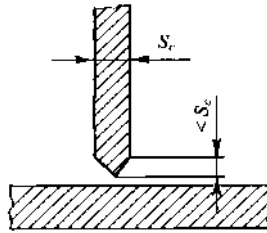


Fig. 5.3.1-2:

$$S = (1/8 + 1/3)h$$

$$h \geq 50 \text{ mm}$$

a)



b)

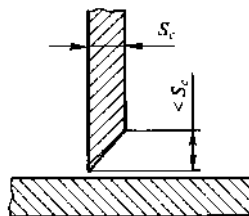


Fig. 5.3.2:

a -  $S_c \geq 10 \text{ mm}$ ; b -  $10 \geq S_c > 3 \text{ mm}$

## 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 (refer to [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 reinforcement design used for openings of other shape is subject to approval by the Register in each case.

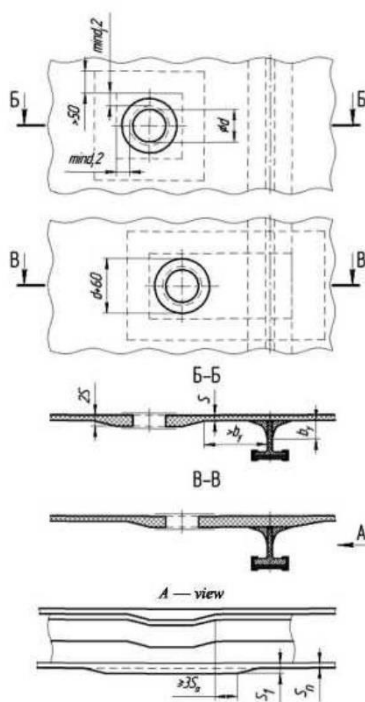


Fig. 5.4.2

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](#).

| Class of joint | Type of members      | Mutual arrangement (type of joint) | Material of structures to be joined<br>Operational characteristic            | adhesive joints             |
|----------------|----------------------|------------------------------------|--|-----------------------------|
| fastenings     | 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<br>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](#).

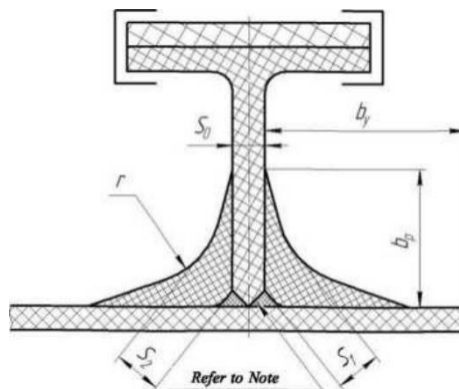


Fig. 5.5.4:

$$b_y \geq 7S_0 \geq 30 \text{ mm};$$

$$S_1 \geq (1/8)b_y;$$

$$S_2 = (1/4)b_y$$

$$r = S_2$$

|            |    |    |    |    |    |    |    |     |
|------------|----|----|----|----|----|----|----|-----|
| $b_y$ , 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  |

Note. Space is filled with chopped fiber glass with hinder.

**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  $r \geq S$ , 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 (refer to Fig. 5.5.6). Butts shall be located in the zone of the minimum bending moment at the general bending of the hull.

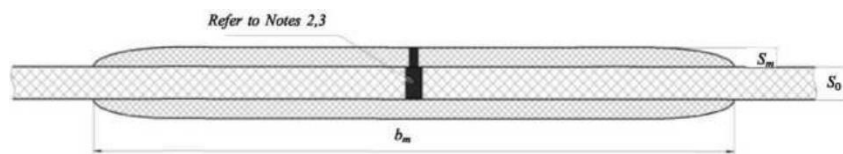


Fig. 5.5.6:

$b_m$  = width of the matted-on strap;  $b_m = 200 + 15S_0$ , mm;  
 $S_m$  = thickness of the matted-on strap;  $0,8S_0 \geq S_m \geq 0,5S_0$ ;  $S_0$  = 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. 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

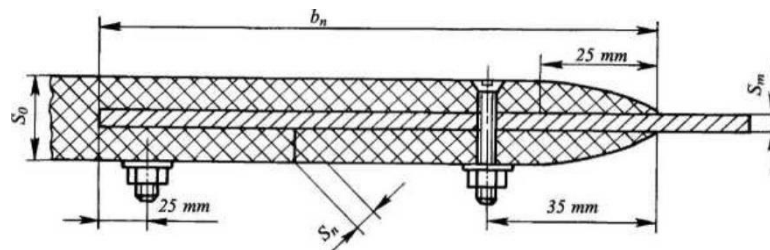


Fig. 5.5.7:

$b_n \geq 30S_n \geq 15S_0$ ;  
 $S_n \geq S_m \geq 0,5S_n \geq 3$  mm

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

$$S \geq d \geq 0,6S$$

where  $S$  = 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 (refer to 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](#) shall be agreed with 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 % 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 % of the glass fabric layers are laid with their warp in one direction, while 25 % of the layers are laid at + 45° to the direction of a parallel warp portion, 25 % 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.

**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, in % | Average density, t/m <sup>3</sup> | 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>I</i> <sub>1</sub> | 49                          | 1,65                              | $\frac{1,80 \times 10^4}{1,20 \times 10^4}$ | 0,30 × 10 <sup>4</sup>         | $\frac{0,15}{0,10}$ | $\frac{300}{180}$     | $\frac{270}{180}$         | 90                              |
| 2    | <i>I</i> <sub>2</sub> | 52                          | 1,70                              | $\frac{1,90 \times 10^4}{1,30 \times 10^4}$ | 0,32 × 10 <sup>4</sup>         | $\frac{0,15}{0,10}$ | $\frac{320}{190}$     | $\frac{290}{180}$         | 100                             |
| 3    | <i>I</i> <sub>3</sub> | 55                          | 1,75                              | $\frac{2,00 \times 10^4}{1,35 \times 10^4}$ | 0,33 × 10 <sup>4</sup>         | $\frac{0,15}{0,10}$ | $\frac{350}{210}$     | $\frac{330}{210}$         | 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, in % | Average density, t/m <sup>3</sup> | 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>II<sub>1</sub></i> | 49                          | 1,65                              | 1,50×10 <sup>4</sup> | 0,30×10 <sup>4</sup>           | 0,15            | 240                   | 220                       | 90                              |
| 2    | <i>II<sub>2</sub></i> | 52                          | 1,70                              | 1,60×10 <sup>4</sup> | 0,32×10 <sup>4</sup>           | 0,15            | 250                   | 240                       | 100                             |
| 3    | <i>II<sub>3</sub></i> | 55                          | 1,75                              | 1,70×10 <sup>4</sup> | 0,33 ×10 <sup>4</sup>          | 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, in % | Average density, t/m <sup>3</sup> | 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>III<sub>1</sub></i> | 49                          | 1,65                              | <u>1,40×10<sup>4</sup></u> | 0,47×10 <sup>4</sup>           | <u>0,30</u>     | <u>240</u>            | <u>220</u>                | 115                             |
|      | <i>IV<sub>1</sub></i>  |                             |                                   | 1,10×10 <sup>4</sup>       |                                | 0,24            | 160                   | 170                       |                                 |
| 2    | <i>III<sub>2</sub></i> | 52                          | 1,70                              | <u>1,60×10<sup>4</sup></u> | 0,52×10 <sup>4</sup>           | <u>0,30</u>     | <u>250</u>            | <u>240</u>                | 125                             |
|      | <i>IV<sub>2</sub></i>  |                             |                                   | 1,20×10 <sup>4</sup>       |                                | 0,24            | 170                   | 180                       |                                 |
| 3    | <i>III<sub>3</sub></i> | 55                          | 1,75                              | <u>1,70×10<sup>4</sup></u> | 0,57×10 <sup>4</sup>           | <u>0,30</u>     | <u>270</u>            | <u>260</u>                | 135                             |
|      | <i>IV<sub>3</sub></i>  |                             |                                   | 1,30×10 <sup>4</sup>       |                                | 0,24            | 180                   | 190                       |                                 |

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.

## 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

$$P_d = kP_t, \quad (1.3-1)$$

where  $P_t$  = test pressure determined according to [4.2](#);  
 $k$  = coefficient determined by the formula

$$k = \max \left\{ \begin{array}{l} 1, 1(1 + 0,1H/P_t) \\ 1,25 \end{array} \right\} \quad (1.3-2)$$

where  $H$  = tank height, m.

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

$$[\sigma] = R_m/n_b, \quad (1.4-1)$$

$$[\tau] = \tau_m/n_b \quad (1.4-2)$$

where  $R_m, t$  = 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:

$$E_d = n_m E; \quad (1.5-1)$$

$$G_d = n_m G \quad (1.5-2)$$

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 exposure 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 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

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

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;  
 $\bar{E}_{1d} = E_m/(1 - v_m^2)$  = 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;  
 $v_m = (v_1 + v_2)/2$  = average Poisson's ratio;

$E_{1d}, E_{2d}$  = design Young's moduli in warp direction and parallel portion weft direction, respectively, MPa;  
 $v_1, v_2$  = 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 formula

$$\omega = k_1 P_d b^4 / (E_d S^3) \quad (2.2-1)$$

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

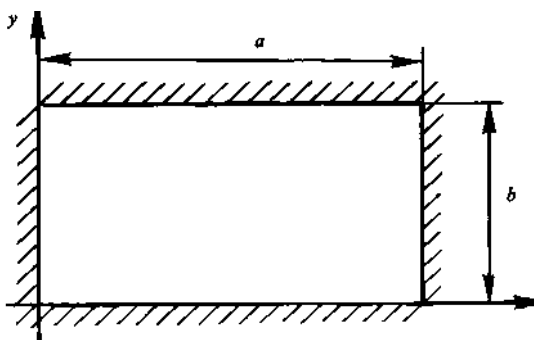


Fig. 2.2

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

$$M_1 = k_2 P_d b^2. \quad (2.2-2)$$

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

$$M_2 = k_3 P_d b^2.. \quad (2.2-3)$$

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

$$M_2' = k_5 P_d b^2. \quad (2.2-4)$$

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   |        |
| $k_3$ | 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 |
| $k_3$ | 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 |
| $k_3$ | 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<sup>1</sup>.

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

<sup>1</sup> Where the ratio of the generatrix length to the directrix length  $\geq 0,7$ .

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

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

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

in transverse section:

$$\sigma_2(o) = (P_d R / S) (\bar{k}_4 + v_2 \bar{k}_1). \quad (2.3-3)$$

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

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

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

$$\sigma_2^{(1)} = (P_d R / S) \bar{k}_3 \quad (2.3-5)$$

where  $P_d$  = design internal pressure, MPa;  
 $R$  = median radius of curvature of the panel, cm;  
 $S$  = thickness of the panel plating, cm;

$\bar{E}_{2d} = E_{2d} / (1 - v_1 v_2)$  = reduced design Young's modulus of the panel material along the directrix, MPa;

$v_1 v_2$  = Poisson's ratios along the generatrix and along the directrix, respectively;

$\bar{k}_0, \bar{k}_1, \bar{k}_2, \bar{k}_3, \bar{k}_4$  = coefficients determined by the formulae:

$$\bar{k}_1 = 1 + (S \sin \beta / 2R \alpha_4) [S / 6R \pm (1 - \alpha_5)]; \quad (2.3-6)$$

$$\bar{k}_2 = 1 + (S \sin \beta / 2R \alpha_4) [S \cos \beta / 6R \pm 1]; \quad (2.3-7)$$

$$\bar{k}_3 = (F_{tb} / h_{bp} R) \pm 3\bar{K} / S R d^2; \quad (2.3-8)$$

$$\bar{k}_4 = (F_{tb} / h_{bp} R) \pm (6\bar{K} / S R d^2) l^{-4} (2 \sin u + \cos u); \quad (2.3-9)$$

$$\bar{k}_0 = 1 + \alpha_6 - (\alpha_5 / \alpha_4) \sin \beta \quad (2.3-10)$$

$$\text{where } \alpha_5 = \sin \beta / \beta; \quad (2.3-11)$$

$$\alpha_4 = (\sin^2 \beta) - \frac{1+\rho}{2} (\beta + \cos \beta \sin \beta); \quad (2.3-12)$$

$$\alpha_6 = (\sin^2 \beta / \alpha_4) - \left[ \frac{\cos \beta}{\beta} + \frac{1+\rho}{2} \sin \beta \right] \cos \beta; \quad (2.3-13)$$

$$p = S^2 / 12R^2 \quad (2.3-14)$$

$$u = (l/2)d,$$

where  $\beta$  = half angle of the cylindrical panel development, deg;

|          |   |   |
|----------|---|---|
| $F_{tb}$ | = | transverse bulkhead area, cm <sup>2</sup> ; |
| $h_{bp}$ | = | 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:

$$w_0 = (P_d R^2 / E_{2d} S) F_1. \quad (2.4-1)$$

Stress in the sheathing at the longitudinal section at the mid-point of the spacing is determined by the formula

$$\sigma_2 = (P_d R / S) F_2. \quad (2.4-2)$$

Stress in the sheathing at the transverse section in way of the frame is determined by the formula

$$\sigma_1 = (P_d R / S) F_3. \quad (2.4-3)$$

The greatest shear force is determined by the formula

$$N_1 = (P_d l_d / 2) F_4. \quad (2.4-4)$$

Auxiliary functions of  $F$  are determined by the following formulae:

$$F_1 = 1 - [4uR^2(chu \sin u + shu \cos u)] / [2uR^2(sh2u + \sin 2u + AE_{2d}S(ch2u - \cos 2u))] \quad (2.4-5)$$

$$F_2 = F_1 + v_2 \{ \pm 3l_d^2 R(chu \sin u + shu \cos u) / (Su[2R^2u(sh2u + \sin 2u) + E_{2d}Sl_dA(ch2u - \cos 2u)]) + F_{tb}/(h_{bp}R) \}; \quad (2.4-6)$$

$$F_3 = \pm(3/2)(l_d^2 R/SU)(shu - \sin 2u) / [2R^2u(sh2u + \sin 2u) + AE_{2d}Sl_d(ch2u - \cos 2u)] + F_{tb}/(h_{bp}R); \quad (2.4-7)$$

$$F_4 = 2R^2(ch2u - \cos 2u) / [2uR^2(sh2u + \sin 2u) + AE_{2d}l_dS(ch2u - \cos 2u)]. \quad (2.4-8)$$

Compliance of the frame  $A$  is determined by formula

$$A = (2R_{fr}^2 / E_{frd} F_{fr}) [1 + \alpha_6 - \alpha_5 / \alpha_4] \sin \beta \{ 1 + l_{1u}(sh2u + \sin 2u) / [l_d(ch2u - \cos 2u)] \} \times \{ 1 / [(R_{fr} / R)^2 (E_{2d} / E_{frd}) (Sl_1 / F_{fr}) + 1] \} \quad (2.4-9)$$

$$\text{where } u = (l_d / 2)^4 \sqrt{3E_{2d}(1 - v_1 v_2) / (E_{1d} R^2 S^2)}. \quad (2.4-10)$$

|      |            |   |   |
|------|------------|---|---|
| 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; |
|      | $v_1, v_2$ | = | 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  $l_1$  = is determined by the formula

$$l_1 = S_f + (1/2)b_m; \quad (2.4-11)$$

$S_f$  = flame web thickness, cm;

$b_m$  = mating-in angle flange width, cm;

$E_{f2d}$  = design Young's modulus of the flame material assumed as the basic one, MPa;

$R_{fr}$  = radius of the flame neutral axis (refer to Fig. 2.4.1), cm;

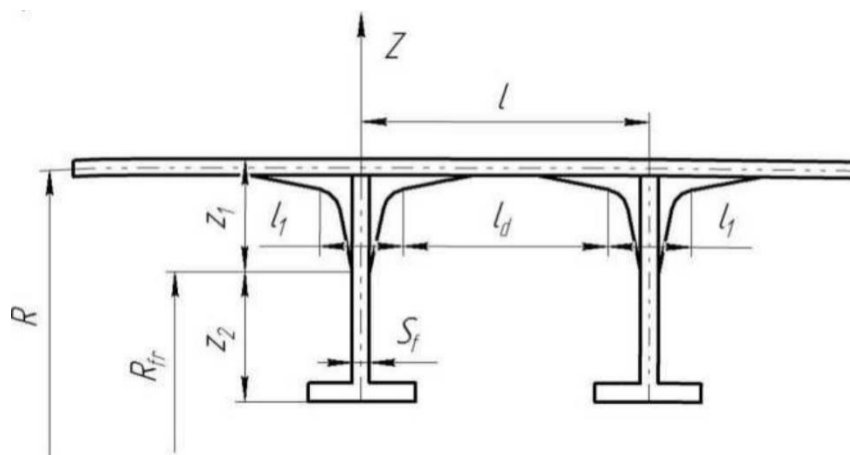


Fig. 2.4.1

$F_{fr}$  = area of the frame with effective flange, cm<sup>2</sup>;

$\alpha_4, \alpha_5, \alpha_6$  = determined by Formulae (2.3-11) – (2.3-13)

where  $\rho = J_{fr}/E_{fr}R_{fr}^2$ ; (2.4-12)

$J_{fr}$  = moment of inertia of the frame section with effective flange equal to  $l_1$  cm<sup>4</sup>.

Stress of the frame at fixation is determined by the formula

$$\sigma_{fr} = (P_d R_{fr} / F_{fr}) [1 + \rho \sin \beta \cos \beta / \alpha_4 + [(Z_i \sin \beta / R_{eH} \alpha_4)] (\cos \beta - \sin \beta / \beta)] \varphi_i; \quad (2.4-13)$$

where  $\alpha_4$  = determined by Formula (2.3-12);

$\beta$  = half angle of flame 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 SCOPE OF APPLICATION**

The requirements of this Part of the Rules apply to equipment, arrangements and outfit of the manned submersibles and ship's diving systems.

## **1.2 DEFINITIONS AND EXPLANATIONS**

The definitions and explanations relating to the general terminology of the Rules are specified in the General Regulations for the Classification and other Activity Relating to Manned Submersibles and Ship's Diving Systems 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 and ship's diving systems are given in the General Regulations on Classification and other Activity for the Manned Submersibles and Ship's Diving Systems and in Part I "Classification" of the Rules for the Classification and Construction of Sea-Going Ships.

**1.3.2** Subject to survey by the Register during manufacture, installation and testing of the manned submersibles and ship's diving systems are equipment and products being part thereof, which are listed in Appendix 1 to Part I "Classification" of these Rules.



## **2 ARRANGEMENTS AND CLOSING DEVICES OF PRESSURE HULL AND PRESSURE BULKHEADS OF MANNED SUBMERSIBLES, DIVING BELLS AND COMPRESSION CHAMBERS**

### **2.1 GENERAL**

**2.1.1** The number and arrangement of access and transfer hatches, viewports and tight penetrators of the manned submersibles, diving bells and compression chambers, as well as airlocks of diving bells and compression chambers, are determined at the design stage depending on the purpose and operating conditions of the manned submersible, diving bell or compression chamber.

**2.1.2** The number and arrangement of access and transfer hatches of the passenger submersibles shall be agreed with the Register 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** number and properties of access and transfer hatches for safe operation and evacuation of passengers 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** number of hatches shall not exceed the safe minimum;

**.4** number of penetrators for electric cables and hoses, as well as rods for various purposes in the pressure hull of the manned submersibles, compression chambers and diving bells shall be minimal.

**.5** electric cables, hoses and pipes, as well as rods for various purposes, shall penetrate the pressure hull through gas- and watertight gland inlets and connectors of a type approved by the Register, which are capable of withstanding water or gas pressure equal to the test pressure of the pressure hull of the manned submersible, pressure chamber or diving bell.

## **2.2 GENERAL REQUIREMENTS FOR HATCHES OF MANNED SUBMERSIBLES, DIVING BELLS AND COMPRESSION CHAMBERS**

**2.2.1** Hatch covers of the manned submersibles, diving bells and compression chambers shall be hinged or attached using any other devices approved by the Register.

**2.2.2** Hatch covers of the compression chambers, diving bells and diving compartments of the lock-out submersibles shall be provided with devices for their opening (closing) by an effort not in excess of 118 N when there is no pressure difference between the inner and outer sides of the cover.

Covers of external hatches of the manned submersibles shall be provided with devices for their opening (closing) by an effort not in excess of 245 N. Devices for covers of external hatches opening (closing) 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, 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. Securing devices shall be so designed as to exclude possibility of pressure on the hatch covers until they are fully closed.

**2.2.6** Covers of hatches in the pressure hull and pressure bulkheads of the manned submersibles, diving bells and compression chambers shall have an arrangement for efficient holding them in the end open position.

**2.2.7** Hatch covers that open and close by gravity shall not pose any risk to personnel operating them.

**2.2.8** Hydraulic hatch covers shall meet the following additional requirements:

**.1** in case of hydraulic system failure, the doors shall be capable of being opened manually;

**.2** hydraulic system intended for doors and hatch covers shall be designed in compliance with the specified working pressure. Hydraulic liquid shall be suitable for use in compression chambers giving off no vapors or gases which may be toxic or flammable.

## **2.3 HATCHES OF MANNED SUBMERSIBLES AND DIVING BELLS**

**2.3.1** Access hatches of the manned submersibles and diving bells can 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 submersible with open covers.

**2.3.4** Hatch covers and their sealings shall provide tightness of the manned submersibles and diving bells in submerged and surface positions. If a gas medium under an overpressure is used inside the manned submersibles or diving bells, the tightness of hatches shall be ensured at such an overpressure from 0,01961 MPa to the test pressure.

**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 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, 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.

**2.3.10** The design of hatches of air lock chambers of lock-out submersibles and access hatches of diving bells shall enable lifting (extraction) of unconscious diver with complete diving outfit.

**2.3.11** The passenger submersible with open hatches shall remain on surface without flooding under all normal design weather conditions and all operating loading conditions.

## **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. 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.

**2.4.9** 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.

**2.4.11** Air locks of compression chambers shall be located to maintain visual contact via air locks between operators during opening and closing of hatches inside and outside of the compartment.

**2.4.12** For initial compression of the cover sealing, a clamping device shall be provided. 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.

**2.4.13** The design and material of the hatch and air lock covers hinges of the compression chambers shall prevent spark formation.

**2.4.14** Air lock dimensions shall correspond to their purpose: they shall be sufficient to accommodate cartridges for internal CO<sub>2</sub> scrubbers, diving helmets, breathing apparatuses, food, etc. Air locks dimensions and design shall be such as to minimize the loss of gas, as far as practicable.

**2.4.15** Air lock chambers for people transfer into compression chamber shall be provided with internal and lighting arrangements, communication means and other life support systems to provide safety of transfer into the high pressure compartment.

**2.4.16** Air locks of compression chambers with possibility of supplying a gas medium from external sources shall be provided with pressure gauges and safety valves.

**2.4.17** It is allowed to provide a removable cover maximum 30 kg in weight for air lock access hatch of a compression chamber with design pressure up to 1 MPa (10 kgf/cm<sup>2</sup>), provided that this cover can be handled by attending personnel outside the compression chamber.

## **2.5 VIEWPORTS**

**2.5.1** Viewports of the manned submersibles and hyperbaric components of ship's diving systems shall be made of glasses of a type approved by the Register. As a rule, acrylic glasses are used at manned submersibles and ship's diving systems.

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 and Standard for Pressure Vessels for Human Occupancy<sup>1</sup>. 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** Viewports of manned submersibles and ship's diving systems shall be designed and located so as to prevent them from accidental mechanical damages.

**2.5.3** Viewports of compression chambers, diving bells and diving compartment of lock-out submersible of ship's diving system for saturation diving made of silicate glass shall be fitted with strong and tight protective covers to be closed from the inside in case of the viewport damage and held down by internal pressure.

**2.5.4** For viewports, it is recommended to use standard shapes and dimensions.

**2.5.5** Viewports taking under the pressure on both sides shall be designed for the maximum pressure irrespective of whether it is external or internal.

**2.5.6** Convex glasses of viewports may take pressure from the convex side only.

**2.5.7** Flanges of viewports shall be so designed as to meet the strength requirements.

**2.5.8** Technical documentation including specifications, working drawings, calculations, test methods and programs, design service life, maximum permissible working pressure, range of working temperatures and other technical data in accordance with ASME standard shall be prepared for development and manufacture of viewports and submitted to the Register.

**2.5.9** Glass manufacturer shall issue necessary certificates/test reports for the viewport glasses with description of all manufacture stages such as cutting, gluing, polishing, moulding, quenching and tempering, material test results and required marking.

**2.5.10** Pressure testing.

**.1** each assembled viewport shall be subject to hydraulic tests by the test pressure that may be carried out in a testing arrangement prior to installation in hull of compression chamber, diving bell or manned submersible or after installation during pressure hull hydraulic testing. The test pressure shall be 1,5 times the working pressure. Each viewport shall be tested prior to commissioning and in the presence of the RS representative;

**.2** viewports glasses undergone the tests shall be marked as required by the approved technical documentation. Marking shall be so located as to be readable from the side of higher pressure.

**2.5.11** Viewports shall be installed according to the process instruction of the firm (manufacturer) agreed with the Register.

**2.5.12** When external lighting fixtures are used for illumination of compression chamber compartments through viewports, such external lighting fixtures shall be designed to provide effective heat dissipation. Those lighting fixtures shall not heat viewport organic class outer surface to more than  $(40\pm 3)$  °C. When quartz glasses are used in viewports, this temperature shall not exceed 80 °C.

**2.5.13** Temperature difference between external and internal surfaces of the quartz glass shall not exceed the relevant parameters specified in the regulatory documents for the glasses.

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<sup>1</sup> Refer to Collection of the IMO Resolutions Relating to the RS Activities, No. 4, Part 5.

### **3 MANOEUVRING AND DIRECTIONAL STABILITY FACILITIES OF MANNED SUBMERSIBLES**

**3.1.** Each manned submersible shall be provided with efficient maneuvering and directional stability facilities to move on water surface and under water. Such facilities may be steerable propellers or nozzles, propellers in fixed and steering nozzles, Voith-Schneider cycloidal propellers, thrusters of different types, as well as vertical and horizontal rudders, stabilizers, diving planes and ballast tanks.

**3.2.** The choice of main particulars, number and location of the manoeuvring and directional stability facilities of 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 technical facilities of the manned submersible shall be submitted to the Register with appropriate supporting calculations and results of model experiments and/or full-scale trials.

#### **4 PROPULSIVE SYSTEMS**

**4.1** Submersibles equipped with propulsive systems or propulsion devices and steering gears shall be suitable for respective operation.

**4.2** Capacity of propulsive systems or propulsion devices shall be sufficient to achieve the required speed and manoeuvring performance of the submersible and shall be capable of continuously operating at respective depth.

**4.3** Drive motor cases shall be calculated for respective submergence depth or shall be compensated by internal pressure.

**4.4** The use of internal combustion engines on the manned submersibles shall be agreed with the Register.

**4.5** Self-sustained manned submersibles shall be equipped with respective control systems for control of propulsion machinery and display of information on its operation conditions. The control systems shall be tested by a test team. Test results shall be submitted to the Register.

**4.6** Where propulsors with capacity not exceeding 20 kW (25 h.p.) with shafts not entering the submersible's pressure hull are provided in the design, manufacturer's information and test results proving serviceability of the proposed propulsor at expected depth shall be submitted to the Register for review. Information submitted by the manufacturer shall also include design electrical capacity, overheating temperature and insulation class.



## **5 SUBMERGENCE AND BALLASTING FACILITIES**

Self-propelled manned submersibles shall be equipped with facilities for trimming them in submergence/submerged position and for compensating the changes in load and buoyancy.

**5.1** The mandatory requirement for the specified facilities is to remain operable at any admissible heels and trims which may arise at any normal and emergency operating conditions not resulting in damage of the pressure hull;

**5.2** Buoyancy control tanks, compensating tanks and trim tanks shall be designed and arranged to meet the following conditions:

**.1** manned submersible shall maintain stability under all the specified operating conditions;

**.2** manned submersible shall maintain manoeuvring at ultimate sea state;

**.3** prior to submergence, the manned submersible shall provide the possibility of performing necessary technical inspections of the systems;

**.4** possibility of leveling the manned submersible in heel and trim under water shall be provided;

**.5** manned submersible shall continuously maintain the capability of safe surfacing;

**.6** manned submersible's capability of surfacing by ballast jettisoning and/or emergency blowing of the buoyancy control tanks and keeping the submersible afloat in stable upright position shall be provided;

**.7** holes in sea chests and bottom shall be closed with gratings, filters which exclude their covering or clogging;

**.8** possibility of the tank system control shall be provided;

**.9** possibility of the manned submersible lifting by means of umbilical shall be provided for tethered submersibles connected to the support ship via umbilical with lifting cable;

**.10** all the positive and negative buoyancy control devices shall be grouped together and appropriately marked on the manned submersible control panel;

**.11** submergence control panel shall be provided with indicators constantly showing the manned submersible position in terms of depth and trim;

**.12** buoyancy control tanks:

buoyancy control tanks shall enable submergence of the manned submersibles once filled with water and surfacing once blown by air;

buoyancy control tank structure and manufacturing method shall ensure their withstanding to wave and internal pressure loads;

volume of the buoyancy control tanks shall be specified so as to provide to the manned submersible a sufficient height above water when afloat and the required buoyancy reserve;

tanks are usually filled with water through inlets located near the tank bottom. Valves located in the upper part of the tank are used for blowing the tanks. Compressed air supplied at closed vent valves or a pump are used for blowing;

buoyancy control tanks shall have vent valves providing the possibility of their full flooding. The ventilation system shall have separate isolating valves for each tank. The vent valves shall be so designed as to exclude their accidental opening. If inlets of the buoyancy control tanks are not closed, the air pipes shall be provided with two stop valves;

if compressed air is used for blowing the buoyancy control tanks, the blowing lines of the tanks shall be capable of being closed separately in case of emergency. Blowing the tanks shall not result in overpressure;

if the buoyancy control tanks are drained by pumps, the inlets shall be provided with closing devices. Measures shall be also taken to exclude underpressure in the tanks when pumping out;

if pumping-out may be carried out only by means of pumps, the system shall be provided with a standby pump;

if the manned submersible has several buoyancy control tanks for fast manoeuvring during submergence and surfacing, each tank shall have separate controls;

**.13** compensating tanks:

compensating tanks shall provide control of the selected submergence depth and compensation of buoyancy change caused by consumption of the carried supplies under water, change of sea water density, taking and release of payload, as well as other factors which may add or take buoyancy;

materials, manufacturing procedure, structure and calculation methods of the compensating tanks located outside the pressure hull shall comply with the requirements of these Rules;

if compressed air is used for tank drainage, maximum allowable pressure in the compressed air system shall be taken into account during designing;

compensating tanks located inside the pressure hull may be designed as overhead tanks to be drained by pumps only. If compressed air is used for draining them, maximum allowable pressure in the compressed air system shall be taken into account during designing;

compensating tanks shall be located as to avoid considerable changes in submersible's attitude above water resulting from filling or draining;

volume of the compensating tanks shall be sufficient for compensation of any buoyancy changes at planned submergences. At least 10 % capacity shall be additionally provided as a reserve;

compensating tanks may be drained by means of compressed air or evacuation pumps. The amount of water taken when flooding or evacuated when blowing or pumping-out shall be indicated by measuring instruments which shall be provided in the compensating tanks;

structure and arrangement of the compensating tank air pipes shall exclude the possibility of unnoticed water ingress in the hull. Cross-section of air pipes shall provide maximum inlet and outlet flow rate;

compensating tanks shall be provided with protection against too high and too low overpressure.

**.14** trim tanks:

trim tanks shall maintain horizontal position of the submersible when moving at the same depth and create nose-down or nose-up trim when surfacing or submerging;

materials, manufacturing procedure, structure and calculation methods of the trim tanks located outside the pressure hull shall comply with the requirements of these Rules;

if compressed air is used for tank drainage, maximum allowable pressure in the compressed air system shall be taken into account during designing;

trim tanks located inside the pressure hull may be designed as pressure vessels. If compressed air is used to change filling of the tanks, maximum allowable pressure in the compressed air system shall be taken into account during designing;

to obtain a longer arm, the trim tanks shall be located as close as possible to the submersible's forward and aft parts;

it is required to design volume of the trim tanks sufficient to create any normal trim of the submersible by their flooding or pumping-out;

water may be removed by means of air blowing or by pumping-out. The closing valves shall provide water flow only in the required direction. Amount of water supplied into the tanks shall be displayed by means of indicators;

if the trim tanks have equipment for direct pumping-out in case of emergency, the manned submersibles shall have facilities preventing unintended pumping-out of the tanks;

there shall be at least two stop valves attached to the pressure hull and serving the trim tanks outside the pressure hull. Combined compensating and trim systems shall be agreed with the Register.

**.15** additional trim control weight:

if weights capable of being shifted in longitudinal direction are used to control trim of the manned submersible, measures shall be taken to exclude their accidental shift;

if the weights are secured outside the manned submersible's pressure hull and their position can not be controlled, they may be used additionally to jettisonable ballast. If the movable weights can not be observed visually, indicators shall be provided at the control panel to display their positions;

**.16** ballast systems:

change of mass (payload, number of crew members, etc.) may be compensated by the use of solid or liquid ballast;

trim, compensating or individual ballast tanks are used to take liquid ballast;

if solid ballast is used and a payload is expected to be taken during the mission, the ballast shall be so attached that it could be jettisoned;

if solid ballast is used to obtain the neutral buoyancy, it shall include safety secured and non-jettisonable weights;

having the maximum amount of ballast, the manned submersible emergency shall be still capable of creating a residual positive buoyancy in case of emergency.

## **6 EMERGENCY RELEASE DEVICES FOR JETTISONABLE BALLAST AND OTHER EQUIPMENT EXTERNAL TO THE PRESSURE HULL**

**6.1** To ensure positive buoyancy in emergencies, the manned 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 and that can be used as emergency ballast. Jettisoning of the devices used as emergency ballast shall not result in unacceptable heel or trim during surfacing or when afloat.

**6.2** The release device shall be operated from the inside of the pressure hull of the manned submersible or diving bell. Duplication of the release device actuator is recommended.

**6.3** At least two manual operations shall be required for the activation of the emergency ballast release device in the manned submersibles and diving bells. The manually-operated release device actuator shall be independent of electric power supply.

**6.4** Arrangements shall be made to prevent spontaneous or accidental operation of the release device actuator.

**6.5** The release device actuator shall have marking showing the direction of rotation or movement of the control.

**6.6** Controls of electromagnetic or pyrotechnic actuator of the emergency release devices for jettisonable ballast shall be protected by sealed covers or other safety arrangements against unauthorized actuation. These controls shall have inscriptions indicating the type of the equipment to be released.

**6.7** Effort at the manual control of the device shall not exceed 245 N.

**6.8** 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.

**6.9** The crew compartment of a manned submersible may be designed to be separable from the other parts of the manned submersible for surfacing in case of emergency. In such case, it shall remain positive buoyancy and comply with all the requirements for stability in the surface and submerged positions.

**6.9.1** Manipulators, anchors and other rigging elements, which may prevent surfacing of the submersible, shall have an emergency release function. Towlines shall also have a release device. Emergency release (separation) devices shall operate even in case of main power supply failure. Ballast jettisoning shall not result in unacceptable heel or trim during surfacing or when afloat

**6.11** Emergency surfacing arrangements of passenger submersibles.

**6.11.1** For the passenger submersible, provision shall be made for two independent facilities for to the surface in stabilized condition, without heel or trim. One such facility shall ensure surfacing without use of electric power.

**6.11.2** Provision shall be made for emergency surfacing through jettisoning cargo of such a 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 passenger submersible or combination thereof. As an alternative, if the passenger compartment has a positive buoyancy, it may be provided with means to separate it from all other parts of the submersible, including separable parts.

**6.11.3** Separation of the parts of the passenger 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.

**6.11.4** If so required for emergency activities, provision shall be made for jettisoning lifting cables and hoses.

**6.11.5** Cargo jettisoning systems, if provided, shall be actuated manually, be independent of electric power and actuated after at least two operations.

**6.11.6** The hull of passenger submersible shall have external devices for lifting the submersible to surface and on board of the carrier ship in case of emergency.

## **7 MATING SYSTEM FOR CONNECTION OF LOCK-OUT SUBMERSIBLES, DIVING BELLS TO COMPRESSION CHAMBERS AND COMPRESSION CHAMBERS TO ONE ANOTHER**

**7.1** Mating systems for connection of lock-out submersibles, diving bells and hyperbaric evacuation systems to compression chambers and compression chambers to one another shall ensure their tight and efficient connection.

**7.2** Connecting flanges, hatches, sealing and closing devices of the lockout 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.

In such case, account shall be taken, among other things, for additional inertia forces arising in the mating device and arrangements for fixing the diving bells and lock-out submersibles to the deck under rolling, pitching and heaving of the support ship of the ship's diving system at sea states according to design specifications of the ship's diving system.

**7.3** The mating systems 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.

**7.4** The mating system of the lock-out submersibles, diving bells and compression chambers shall incorporate an interlocking device.

**7.5** The interlocking device shall prevent from actuating the closing device at increased pressure in the transfer lock.

The movement of the trolley of the diving bell, lock-out submersible and hyperbaric evacuation system, or operation of the main lifting winch shall be also prevented until the pressure becomes equal to the atmospheric one and the lock of the closing device of their mating connection is released.

**7.6** The mating systems of a hyperbaric evacuation system shall be designed to be capable of easily disconnected when the support ship has heel of up to 20 ° and trim of up to 10 ° in either direction.

**7.7** If a hydraulically or electrical driven device is used for connection, there shall be provided manual operation capability or a redundant back-up device capable of being used in case of the main driven device failure.

**7.8** Lock-out submersible, diving bell, hyperbaric evacuation system, as well as compression chamber or transfer trunks fitted with mating devices, shall be equipped with valves, measuring and other instruments necessary for the monitoring and control of the internal environment of the compartments being connected from the control station of the ship's diving system.

**7.9** The structure, technical characteristics and methods of strength calculations of the ship's diving system's mating devices shall be agreed with the Register.

## **8 EMERGENCY RELEASE DEVICES OF THE SUPPORT WIRE ROPE AND UMBILICAL**

**8.1** Diving bells arranged for emergency ascent by free surfacing shall have emergency cutting/release devices for the support wire rope(s) and umbilical.

**8.2** The emergency cutting/release devices for the support wire rope(s) and umbilical shall comply with the applicable requirements of [Chapter 6](#).

## **9 LIFTING LUGS, CROSSBEAMS AND LIFTING GEAR OF MANNED SUBMERSIBLES AND DIVING BELLS**

**9.1** The structural strength of lifting lugs, crossbeams and lifting gear of the manned submersibles and diving bells shall be determined based on the action of the design load, which shall not be less than threefold weight of the manned submersible or operating weight of diving bell in air.

**9.2** When the design load referred to in [9.1](#) is acted on the lifting lugs, the maximum normal stresses therein shall not exceed 0,7 of the upper yield point of their material.

**9.5** The umbilical securing device on the hull of the diving bell shall be strength tested by a tensile force 2,2 times the design tensile force.

**9.6** Submersibles shall be equipped with a necessary number of lifting points. The minimum number of lifting points and their location shall be confirmed based on technical background submitted by designer in the technical design documentation for the manned submersibles and shall be approved by RS. Every such point shall be capable of lifting the submersible to the surface in case of emergency and be designed with a safety factor 6 times the design load. At least one of these points shall remain available even in case of a heavy damage of the manned submersible. Design and location of these alternative points shall ensure the possibility to lift the submersible even if the manned submersible's internal spaces are flooded.

**9.7** Lifting points shall have vivid identification painting and marking with its load capacity indicated.



## **10 LIFE-SAVING APPLIANCES, SIGNAL AND EMERGENCY SIGNAL MEANS**

**10.1** Manned submersible shall be equipped with life-saving appliances, signal and emergency signal means.

**10.2** Life-saving appliances of manned submersibles include life jackets and immersion suits.

**10.3** Life-saving appliances shall comply with the international and national requirements applicable to these types of appliances.

**10.4** Life jackets shall be provided in the compartments of the passenger submersibles. Inflatable life jackets shall be preferred. The number of life jackets shall correspond to the number of crew members and passengers plus one spare life jacket.

**10.5** The manned submersible's embarkation and disembarkation stations for passengers and crew members shall be equipped with lifebuoys or equivalent means.

**10.6** The list of signal means used by manned 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. Signal shapes is not required for the manned submersibles.

**10.7** It shall be agreed with the Register if a manned submersibles or a diving bells shall be equipped with an ascending emergency signal means to indicate their submerged position in emergency condition.

**10.8** The ascending emergency signal means shall be installed on the hull of the manned submersible or diving bell and shall be listened thereto by a wire rope.

**10.9** 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 the limiting heel and trim angles, which are likely to occur in operation of the manned submersibles or diving bells.

**10.10** 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 [6.2 — 6.8](#).

**10.11** The length of rope of the ascending emergency signal means shall be by 10 — 15 % 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.

**10.12** 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 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 h.

**10.13** 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.

**10.14** 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 [10.13](#) is permitted.

**10.15** Electrical position indicating devices and emergency communication means shall be supplied from both main and emergency power sources. Non-electrical position indicating devices shall be capable of being activated without any power supply.

**10.16** Hyperbaric evacuation systems designed for operation on the surface shall be equipped with a radar reflector and a flashing light or an emergency position indicating radio beacon (EPIRB) intended to indicate position in case of emergency situation when afloat. A position indicating device shall be equipped with an autonomous power source to enable operation for at least 72 h. Alternatively, the position indicating device shall be designed in such a way that it can be supplied from the evacuation system's electric power source.

**10.17** Hyperbaric evacuation systems designed for underwater operation shall be equipped with an emergency position indicating device (acoustic beacon-transponder). Position indicating device shall be suitable for use with the 3D sonar station, which shall be kept on board of the diving ship/offshore unit. The equipment shall provide operation according to Section 2.12.5 of IMO resolution A.831(19) "Code of Safety for Diving Systems". A position indicating device shall be equipped with an autonomous power source to enable operation for at least 72 h. Alternatively, the position indicating device shall be designed in such a way that it can be supplied from the evacuation system's electric power source.

**10.18** Manned submersibles and diving bells shall be equipped with first-aid outfits.

## **11 HYPERBARIC EVACUATION SYSTEMS**

**11.1** Saturation diving systems shall be equipped with systems for hyperbaric evacuation of divers in case of an accident of saturation diving system's support ship.

**11.2** The following hyperbaric evacuation systems and rescue modes can be used in the saturation diving system:

hyperbaric self-propelled lifeboats;

hyperbaric evacuation compression chambers capable of being towed and unloaded to the attendant ship;

transfer of diving bell or lock-out submersible with divers to another ship;

passage of divers from one diving bell to another one in water under pressure.

**11.3** Hyperbaric evacuation system shall have sufficient capacity to ensure evacuation of all divers under pressure in case of need to abandon the ship.

**11.4** Hyperbaric evacuation systems on the saturation diving system support ship shall not be located in class 0 or 1 hazardous zones.

**11.5** Towed hyperbaric evacuation systems shall be equipped with accessible point for attachment of towing arrangement with the dimensions corresponding to the expected operating conditions. The towing arrangement attachment points shall be located to exclude the possibility of hyperbaric evacuation system capsizing when being towed.

**11.6** If the towing arrangement is on the hyperbaric evacuation system, its dimensions, strength and the weight shall correspond to the expected conditions. Towing halyard attachment systems, if any, shall be secured on hyperbaric evacuation system and, as far as practicable, shall not hinder its launching.

**11.7** Hyperbaric evacuation systems shall be equipped with the corresponding facilities for detachment on deck.

**11.8** Hyperbaric evacuation systems shall be equipped with appropriate hatches for safe passage to and from compression chambers of the diving system. Mating systems shall be quickly disconnectable to ensure fast launch of the hyperbaric evacuation system on water in emergency situation and shall correspond to the functional requirements. At the same time, the appropriate facilities shall be provided to prevent accidental separation of hyperbaric evacuation system to compression chamber mating system under pressure. The appropriate facilities shall be provided to protect mating flange of the hyperbaric evacuation system manhole from damages that may be caused by launching/lifting and towing.

**11.9** Design of trunks/hatches for passage of divers from compression chamber to hyperbaric evacuation system shall correspond to the functional requirements and requirements of these Rules. It is necessary to provide special facilities for admission of unconscious divers into the hyperbaric evacuation system.

**11.10** Hyperbaric evacuation system shall be equipped with appropriate devices enabling visual observation of the personnel in the hyperbaric compartment of the hyperbaric evacuation system. If viewports are installed, they shall be arranged in a way to minimize the risk of their damage and have structural protection against external mechanical damages.

**11.11** The casing of hyperbaric chamber of hyperbaric evacuation system shall be equipped with a lock for delivery of food, water, medicines and other life-support facilities.

**11.12** If a saturation diving system is installed on a drilling platform or industrial complex where hydrocarbon emission is possible, the hyperbaric evacuation system shall be made as a self-propelling hyperbaric lifeboat capable of moving through a petroleum products spillage area. Here, propulsion systems, steering equipment and control systems shall comply with the requirements of the corresponding section of the Rules.

**11.13** Hyperbaric compartments of hyperbaric evacuation system shall have seats and corresponding appliances for protecting divers during launch/ recovery and when afloat. At least one seat with seat belts shall be provided for each diver.

**11.14** The external hull of hyperbaric lifeboat, propulsion system and related equipment and arrangements shall comply with the applicable requirements for lifeboats specified in IMO resolutions MSC.48(66) and MSC.81(70) "International Life-Saving Appliances (LSA) Code".

**11.15** The hyperbaric compartment of hyperbaric evacuation system shall be equipped with life-support facilities/systems independent from the systems of the saturation diving system; those facilities/systems shall ensure the following:

increase of gas pressure in the hyperbaric compartment to the maximum operating pressure in the compression chamber of the saturation diving system;

maintaining set pressure values during diver's decompression;

monitoring gas composition in the compartment;

life support in hyperbaric compartment of hyperbaric evacuation system for at least 72 h by use of own oxygen reserves and means for removal of carbon dioxide from the breathing gas mixture at CO<sub>2</sub> partial pressure not exceeding 0,005 at;

life support of divers in emergency conditions by use of emergency stationary breathing system with individual face masks.

**11.16** Emergency life-support system shall ensure supply of the appropriate breathing gas mixtures to individual mask of the fixed breathing system. The capacity of this system shall be sufficient to ensure breathing of all divers through the masks if the atmosphere of compartment is dirty. The capacity of the system shall be calculated on the basis of respiratory minute volume of 12 l/min at rest and 22,5 l/min at light work at the atmospheric pressure. The design of the system shall ensure that partial pressure CO<sub>2</sub> is not exceed 0,015 at in the inhaled gas. Emergency life support system shall be independent from the main life support system. Fixed breathing system's masks shall be supplied with breathing gases from hyperbaric evacuation system's source. Gas mixtures shall be additionally supplied from sources on the support ship.

**11.17** Onboard standby life support system of hyperbaric evacuation system shall comprise two independent distribution systems to supply oxygen to hyperbaric evacuation system's compartment. Oxygen shall be stored in at least two storages with independent entries to the chambers. The entries shall be arranged in way to minimize the possibility of failure of both entries as a result of a single accident. Equipment supplying oxygen to onboard standby life support system shall be equipped with a regulator to maintain partial pressure of oxygen inside the hyperbaric evacuation system within proper limits.

**11.18** For decompression of divers, the hyperbaric evacuation system shall be fitted with equipment and gases in necessary amounts.

**11.19** Besides the hyperbaric evacuation system controls installed outside, inside the hyperbaric chambers there shall be controls for all necessary systems and life support devices to control the supply of breathing gas mixture from hyperbaric compartment and maintain due atmosphere in the hyperbaric evacuation system compartment under all the working depths. As far as practicable, these controls shall be accessible for the systems control without need for the operator to remove the seat belt at his standard place.

**11.20** The hyperbaric evacuation system shall have appropriate autonomous life support system instruments to monitor oxygen and carbon dioxide content in the hyperbaric compartment and the pressure in the gas supply system's gas bottles with a set pressure accuracy. Gas monitoring devices shall be capable of autonomously operating for at least 72 h.

**11.21** Hyperbaric evacuation system shall be equipped with emergency diver heating facilities capable of operating at the maximum working depth for at least 72 h. (Such measures

as passive heat insulation, heating of diver's breathing gas by active or regenerative method, heating of divers by means of heated suits, etc. are considered acceptable).

**11.22** Before launching, the hyperbaric evacuation systems shall be provided with sufficient supplies of food, water, first medical aids, seasickness bags, paper towels and all necessary operating instructions for systems and devices of the hyperbaric evacuation system. The area of operations and expected environmental conditions shall be taken into account.

**11.23** Arrangements for collection and discharge of human waste shall be provided in the hyperbaric compartment of hyperbaric evacuation system. Such facilities shall be suitable for use for at least 72 h. Flush toilets where wastes are expelled outside shall be equipped with the appropriate interlocks to prevent flushing until their use is not over.

**11.24** The hyperbaric evacuation system shall have unions for emergency supply of hot and cold water and breathing gases into the compartment. The unions shall be located outside the pressure hull of the hyperbaric evacuation system in an easily accessible place. The connections shall be clearly and permanently marked and suitably protected.

**11.25** Life-support systems and facilities shall be stationary installed on board the hyperbaric evacuation system. The possibility of using mobile life-support facilities shall be agreed with the Register.

**11.26** It shall be possible to connect umbilical to emergency unions and connectors of the hyperbaric evacuation system to have connection with external life support systems. For towed hyperbaric evacuation systems, the umbilical shall be longer than the towing cable to ensure safe towing in any operating conditions. The umbilical shall be capable of supplying breathing gases, hot/cold water, power supply, communication, etc.

**11.27** Operational instructions for life-support equipment shall be stored in the hyperbaric evacuation system.

**11.28** Hyperbaric evacuation systems installed on support ships with fire-protected lifeboats shall also be provided with adequate fire protection means.

**11.29** In hyperbaric evacuation systems designed to pass through fires, the breathing gas bottles, piping and other essential equipment shall be adequately protected. Heat insulation, if installed, shall be non-toxic and suitable for fire protection.

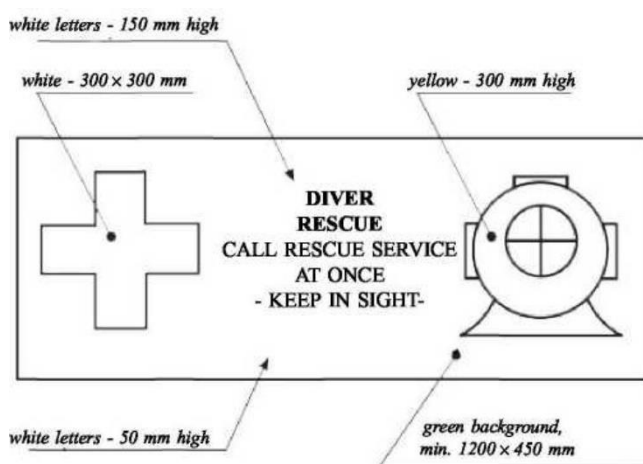


Fig. 11.2.27

**11.30** Onboard electric power source of the hyperbaric evacuation system shall supply power to all consumers, including emergency life-support, communication and illumination systems for at least 72 h.

**11.31** Hyperbaric evacuation systems shall be coloured orange colour and provided with light reflectors to assist in their location during night hours.

**11.32** Hyperbaric evacuation systems shall be marked with at least three identical marks shown below. One of these markings shall be on top of the hyperbaric evacuation system and be clearly visible from air when hyperbaric evacuation system is afloat. The other two markings shall be mounted vertically on both sides as high as possible to be visible when the hyperbaric evacuation system is afloat.

**11.33** The following most essential devices, marking and information on the hyperbaric evacuation system shall be easily accessible and clearly visible:

- towing arrangements (for towed hyperbaric evacuation systems);
- all external connections, particularly for the provision of emergency gases, hot/cold water, communication, etc.;
- maximum weight of fully loaded hyperbaric evacuation system in air, lifting points;
- name and port of registry of a diving ship;
- emergency phone number and fax number;
- instructions on safe lifting of the hyperbaric evacuation system.

**11.34** The following warning inscriptions, which shall be clearly visible when the hyperbaric evacuation system is afloat, shall be permanently displayed in two separate locations of the hyperbaric evacuation system:

- "Unless specialized diving assistance is available:
  - do not touch any valves or other controls;
  - do not tow, unless danger is imminent;
  - do not try to get the personnel out;
  - do not connect gases, air, water or any other life-support facilities;
  - do not try to transfer food, drinks or medicine to personnel in the hyperbaric evacuation system;
- do not open any hatches"

**11.35** Fully equipped hyperbaric evacuation systems shall undergo the following initial tests in the presence of the RS representative:

- .1** functional tests of life-support systems, pipelines, electrical equipment, radio equipment, propulsion plants, etc. at the maximum permissible operating pressure in the hyperbaric compartment;
- .2** launching tests of fully loaded hyperbaric evacuation system in water using standard handling systems installed on the support ship;
- .3** determining deadweight and measurement of lightweight displacement of the hyperbaric evacuation system. Positions, quantities and dimensions of all the items from the table of weights and relation of forces shall be physically tested upon completion of construction and outfit. Fully equipped hyperbaric evacuation system shall be weighted. Measured weights shall be compared with full tabular weights with corrections for any weights of external objects that could be loaded onboard the hyperbaric evacuation system for the tests;
- .4** new hyperbaric evacuation systems shall undergo inclining test on surface;
- .5** towed hyperbaric evacuation systems shall undergo tow testing at maximum design speed to make sure that capsizing will not occur.

**11.36** If lifeboats of saturation diving system's support ship are flame-proof, these requirements shall be also applicable to the hyperbaric evacuation system.

**11.37** Hyperbaric evacuation system shall be equipped with a two-way telephone communication system for communication with divers. If helium breathing gas mixtures are used, speech unscramblers shall be provided.

**11.38** The communication tapping code signs in Russian or English shall be placed inside and outside the hyperbaric evacuation system for communication with divers in hyperbaric compartment.

**11.39** Hyperbaric evacuation system installed in ship's diving system on ships and drilling units, which envisage evacuation of divers afloat through fire, shall have fireproof design and own external water-spraying system.

**11.40** Reservoir with flame arrester onboard the hyperbaric evacuation system shall have facilities to monitor the quantity of fire suppression agent and variations of its pressure. Besides, each compartment inside the hyperbaric evacuation system shall be equipped with mobile hyperbaric fire extinguisher approved for use at the maximum operating pressure.

## **12 LAUNCHING APPLIANCES FOR HYPERBARIC EVACUATION SYSTEMS**

**12.1** Saturation diving system's evacuation systems shall have an appliance for safe launching of the hyperbaric evacuation system from the support ship. 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.

**12.2** In the event of failure of the electrical power supply to the launching appliance during lifting and launching of the hyperbaric evacuation system, a braking system shall be automatically engaged. A manual release of the brake shall be provided in the braking system.

**12.3** The launching appliance shall be designed so as to ensure easy disconnection of the hyperbaric evacuation system from the deck compression chamber, as well as its transportation and lowering into water at the same permissible angles of heel and trim as for other survival craft.

**12.4** When disconnection of hyperbaric evacuation system engages an actuator dependent on a power source is used in its operation, provision shall be made for standby disconnection method, e.g. manual or with the use of stored mechanical power.

**12.5** Once the hyperbaric evacuation system is launched into water, easy disconnection shall be provided from running or hoisting wire ropes.

**12.6** For the cases when hyperbaric evacuation system is lifted from the sea or transferred from one ship to another in the open sea, provision shall be made for the appropriate equipment to allow for the added water mass effect, presence of bilge water, dynamic loads due to motions at sea, and other factors arising in the process of lifting or transferring the hyperbaric evacuation system to the ship. Clearly visible instructions for proper use of the hyperbaric evacuation system with indication of its mass shall be displayed nearby the handling system.

**12.7** Handling systems of the hyperbaric evacuation system shall comply with the applicable requirements of Part XII of these Rules. Where the hyperbaric evacuation system is designed as a hyperbaric lifeboat, it shall comply with the applicable requirements of IMO resolution A.692(17) "Guidelines and Specifications for Hyperbaric Evacuation Systems" and IMO resolutions MSC.48(66) and MSC.81(70) "International Life-Saving Appliances (LSA) Code".

**12.8** Generally, each handling system of the hyperbaric evacuation system shall be actuated either by the stored mechanical energy or by gravity. After lowering the hyperbaric evacuation system on water by means of handling systems with wire rope systems, the release mechanisms shall ensure easy disconnection. Wire ropes shall have protection against rotation and shall be manufactured of corrosion-resistant steel wire rope. Length of halyards shall be sufficient for launch of the hyperbaric evacuation system in water at the minimum draft of the support ship and at unfavourable conditions of heel of up to 10 deg. and trim of up to 5 deg. in either direction.

**12.9** Evacuation system shall be equipped with hoisting appliances enabling to lift the system using a standard ship's crane.



### **13 ACCESS AND PROTECTIVE MEANS IN PASSENGER SUBMERSIBLES**

**13.1** For protection of passengers and crew on the passenger submersibles, provision shall be made for appropriate functional appliances and safety means, such as handrails, non-skid coatings, etc., with regard to all operating conditions likely to occur.

**13.2** 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 their compartments, passenger embarkation places, effect of waves, protection against appendages of the passenger submersible and the carrier ships, if applicable.

**13.3** Transparent and shatterproof protective screen shall be installed from the inner side of all glasses of passenger submersible's viewports accessible for passengers in standard operating conditions. Where impracticable or impossible, other measures shall be taken to prevent damages of the glasses by passengers.

## **14 PRODUCTION MODULES OF SHIP'S DIVING SYSTEMS AND MANNED SUBMERSIBLES**

**14.1** Design type of a container used as production module to accommodate components of manned submersibles, ship's diving systems and their mechanisms, tools, spares, etc. on the carrier ship shall comply with all applicable requirements considering its functional purpose as a modular element of manned submersibles and ship's diving systems. When a container production module is installed on the carrier ship, such module shall be considered by the Register as ship's space of a corresponding category, depending on its location onboard, and it shall not be considered as a product listed in the Nomenclature of Items of the Register Technical Supervision. The requirements of Part VII "Offshore Containers" of the Rules for the Manufacture of Containers may also be applied to such product in case the specified container is considered as offshore, i.e. handled in open seas.

**14.2** Production modules as components of mobile ship's diving systems and manned submersibles installed on deck of support ships shall comply with the following requirements:

**.1** modules of ship's diving systems and manned submersibles shall be installed on the corresponding foundations or attachments that prevent them from displacement relative to the deck and to each other. Reliability of the foundations and attachments shall be verified by calculations taking into

account all the operating conditions of ship's diving system, manned submersible and the support ship;

**.2** modules of manned submersible and ship's diving system shall be grounded to the support ship's hull.

**.3** cables, hoses and pipelines connecting the communication lines of mobile ship's diving system modules with each other or with the carrier ship: shall not be arranged on the deck under conditions that may cause their damage and shall have a mechanical protection;

shall be well secured and laid with a slack; shall have technological plugs and proper marking of all the mating parts.

**.4** provision shall be made on the deck of support ship for proper illumination of modules and overboard space where manned submersible, diving bell or diving stage are lowered in water.

**14.3** Technological modules of manned submersibles and ship's diving systems shall meet the requirements of the RS rules to support ship's spaces.

**PART IV. BUOYANCY, STABILITY AND UNSINKABILITY**

**1 GENERAL**

**1.1 APPLICATION**

The requirements of this Part apply to 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 for the Classification and Other Activity Relating to Manned Submersibles and Ship's Diving Systems of these Rules.

**1.2.2** In addition, the following definitions have been adopted.

**Reballasting of the manned submersible** means an operation to be performed in order to bring the residual buoyancy, trim and heel to the specified (design) values.

**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.

### **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 review and approval are set out in the General Regulations for the Classification and Other Activity for the Manned Submersibles and Ship's Diving Systems and in Part I "Classification" of these Rules.

**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 unsinkability of the submersibles and diving 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 Stability Booklet 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 Stability Booklet.

## 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 % 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

$$F_1 \geq (1,4 - 2,8h_{3\%max}/L)h_{3\%max} \quad (2.1.3.2)$$

where  $h_{3\%max}$  = the maximum specified height with 3 % of probability of exceeding level at the limiting sea state permitted, proceeding from the operating conditions of the manned submersible, in m;  
 $L$  = submersible length, m, to be taken equal to the maximum of a series of values calculated for all  $h_{3\%} \leq h_{3\%max}$  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, free operating conditions of which provide for opening of free 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 manned submersibles, free operating conditions of which provide for opening of free hatch cover only on board the support ship, free height of hatch coaming (edges), from free standpoint of flooding prevention, is not specified;

**.6** when some other pressure hull structures (e.g. hinged semispherical bulkheads in free manned submersibles of "Mantis" type, etc.) are used as access hatch in free manned submersibles referred to in [2.1.3.5](#), the height of free hull upper edge above free waterline in still water is specified for reasons of ease of 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.

**2.1.5** Manned submersibles shall be so designed to ensure control of their buoyancy and retaining of fixed depth in the range of submergence operational depths under normal operating conditions.

## **2.2 BUOYANCY IN SUBMERGED POSITION**

**2.2.1** The emergency buoyancy reserve of the manned submersible dependent on the mass of jettisonable ballast and equipment shall ensure emergency 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.

For self-sustained submersibles, several alternative methods of emergency surfacing recognized by the Register based on the given risk analysis shall be provided. The emergency surfacing system shall duly function under all expected heel and trim conditions and shall meet to the following condition:

the surfacing speed shall be equal to the normal surfacing speed and the jettisonable weight may include jettisonable cargo, umbilical, cargo ropes and hull appendages.

**2.2.2** The positive buoyancy of diving bells is achieved by the jettisoning of emergency ballast. The value of buoyancy of diving bells shall be enough for the diving bell to ascend from any operating depth.

**2.2.3** After the ballast weights are jettisoned, the ascending diving bell with full payload shall have a positive buoyancy and sufficient stability to retain the upright position. For determining buoyancy and stability of diving bells, use the methods adopted for manned submersibles. The design substantiation shall be submitted to the Register confirming that after the jettisoning solid ballast the diving bell or manned submersible can ascend to the surface and will stay in a steady surface position.

**2.2.4** During design of jettisonable ballast of manned submersible, the maximum value of the following shall be used:

**.1** weight of water volume in all the tanks, if they are intended for pumping out excluding planned water residue;

**.2** weight of water volume of the largest pressure vessel or apparatus positioned outboard and taking external pressure excluding inner content;

**.3** weight of water volume in the largest main ballast tank.

**2.2.5** Self-propelled manned submersibles shall be equipped with facilities for trimming them in submergence and for compensating the changes in load and buoyancy.

**2.2.6** 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.



### 3 STABILITY

#### 3.1 REQUIREMENTS FOR INITIAL STABILITY OF MANNED SUBMERSIBLES, DIVING BELLS AND EVACUATION SYSTEMS OF SHIP'S DIVING SYSTEM IN SURFACE AND SUBMERGED POSITIONS

**3.1.1** The class of manned submersibles is assigned only subject to verification of appropriate intact stability corresponding to operating conditions.

In the maximum loaded condition, under rolling and under the most unfavourable designed sea state, every manned submersible shall have sufficient intact stability on the surface so that the submersible couldn't take in water through any hatch which may be opened in surface position.

**3.1.2** 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.

**3.1.3** 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.

**3.1.4** The minimum permissible value of the initial transverse metacentric height of the manned submersible when in surface position, in m, shall be determined by the formula

$$h_{\min}^{\text{perm}} \geq 0,05 + 0,9 \times 10^{-3} D \quad (3.1.4)$$

where  $D$  = submersible displacement, in t

**3.1.5** The minimum permissible value of the initial transverse metacentric height of the manned submersible when in submerged position, in m, shall be determined by the formula

$$h_{\min}^{\text{perm}} \geq 0,065 + 0,75 \times 10^{-3} D. \quad (3.1.5)$$

**3.1.6** For towed manned submersibles and evacuation systems of ship's diving systems 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.

**3.1.7** The initial metacentric height of the diving bell and evacuation system of ship's diving system 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.

**3.2.3** Movement of passengers and crew over the submersible (including that during embarkation and disembarkation) possible in operation shall not cause trim or heel exceeding:

**.1** in surface position – an angle equal to one half the flooding angle, at which the access hatch coaming edge immerses;

**.2** 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.

**3.2.4** Experimental determination of stability of the passenger submersible shall be performed both in surface and submerged positions.

#### **4 REQUIREMENTS FOR THE STABILITY BOOKLET**

**4.1** Every manned submersible shall be provided with Stability Booklet approved by the Register compiled in accordance with the instructions specified in [Appendix 3](#).

**5 ADDITIONAL REQUIREMENTS FOR BUOYANCY, STABILITY AND EMERGENCY  
SURFACING OF PASSENGER SUBMERSIBLES**

**5.1** The design of a passenger submersible shall ensure its safe and controlled surfacing/submergence within the entire range of operating depths.

**5.2** During surfacing and submergence and in the submerged and surface positions, the passenger submersible shall retain trim and stability, at which normal (non-emergency) operation is possible.

**5.3** The passenger submersible, at any combinations of cargo jettisoning, shall have a positive stability in order to ensure safe evacuation of passengers in accordance with the contingency plan. The efficient reserve of stability shall be confirmed during tests.

**5.4** The passenger submersible shall be capable of emergency surfacing in case where drainage of pressure tanks and ballast tanks is impossible.

## **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** The reballasting shall be carried out in the presence of Register's surveyor in compliance with this Instruction and relevant requirements for manned submersible specified in Appendix 11 to Chapter 2 of Part V "Technical Supervision during Construction of Ships" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

**1.3** Instructions for reballasting process is 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 instructions 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 wind speed shall not exceed 3,5 m/s. 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 exceed 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 metacentric 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;  
 $\Delta h$  = 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. Determination of stability shall be performed in the presence of the RS surveyor in accordance with these Instructions and applicable requirements for manned submersibles specified in Appendix 11 to Chapter 2 of Part V "Technical Supervision during Construction of Ships" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

**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.

**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 % (5 % when stability of the passenger submersible is determined experimentally in surface position);

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                                 | $\bar{x}$    | $\bar{x}_0$                        | $\bar{x}_1$ | $\bar{x}_2$ | $\bar{x}_3$ | $\bar{x}_4$ |                                     |                                     |   |                                     |

**.2** the error for the mid-position of the long plumb line does not exceed that determined by the formula



$$\delta = \sqrt{[(\bar{x}_0 - x)^2 + (\bar{x}_2 - x)^2 + (\bar{x}_4 - x)^2]/3} \leq 0,03d - 1,5$$

where  $x = 1/3(\bar{x}_0 + \bar{x}_2 + \bar{x}_4)$ ;  $d = \bar{x}_1 - \bar{x}_3 - (\bar{x}_4 - x)/2$ ;

**.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

$$\epsilon_h = \sqrt{\delta_i^2 + \delta_3^2 + \delta^2/d} \leq 0,03$$

where  $\delta_i = 1/[4(n-1)(n-2)]$ ;  $\sum_{k=1}^{k=n-1} [\delta_{ik} + \delta_{i(k+1)}]^2 \geq 1$   
 $i = 1; 3$ ;  
 $i$  = number of observation;  
 $k$  = ordinal number of the plumb line deviation measurement;  
 $n$  = number of measurements for one reading.

The values of  $\delta_{ik}$  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.

## **INSTRUCTIONS FOR DRAWING UP THE STABILITY BOOKLET**

1. These Instructions contains only general provisions as to the purpose and contents of the Stability Booklet since 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 with the Register and shall correspond to the relevant requirements for manned submersible specified in Appendix 1 to Chapter 4 of Part IV "Stability" of the Rules for the Classification and Construction of Sea-Going Ships.

2. Each manned submersible shall be provided with the Stability Booklet 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 Stability Booklet shall be complied with regard to the experimental stability determination data. Furthermore, the Stability Booklet shall contain references to documents, on the basis of which it was drawn up.

4. It is recommended that the Stability Booklet 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 Stability Booklet for a form to make notes by the Surveyors to the Register on extension of the validity of the Stability Booklet or on the need for its updating.

6. A provision shall be made in the Stability Booklet 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 Stability Booklet 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 this 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 ship's diving systems, manned submersibles and spaces of the support ships, which are intended for sitting the manned submersibles and ship's diving systems and their ancillary gear and for control of underwater operations performed using these arrangements.

**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 support ship spaces for ship's diving systems and manned submersibles specified 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 for the Classification and Other Activity Relating to Manned Submersibles and Ship's Diving Systems 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 has been additionally 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 for the classification, survey during manufacture and construction of fire protection for ship's diving systems and manned submersibles, as well as the requirements for the technical documentation to be submitted to the Register for review and approval are specified in the General Regulations on Classification and Other Activity for the Manned Submersibles and Ship's Diving Systems and in Part I "Classification" of these Rules.

**1.3.1** The scope of surveys carried out by the Register in the process of construction of the manned submersible, ship's diving system and support ship shall be established in compliance with 13.2, Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea Going Ships and this Part.

**1.3.2** The fixed fire-extinguishing systems of the manned submersible and ship's diving system compartments shall be functionally tested in the presence of the RS representative at a maximum working pressure of the gas medium.

## 2 STRUCTURAL FIRE PROTECTION

**2.1** Structural fire protection of the support ship spaces intended for sitting, control and communication of the manned submersibles and ship's diving systems, as well as for placement of their 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.

**2.2.** General arrangement of the ship's diving system and manned submersible shall be such as to reduce fire and smoke hazard in their manned compartments in case of fire on board the ship. Sources of ignition and fire loads in the installation area for ship's diving systems and manned submersibles, gas storage facility spaces and control stations of ship's diving systems and manned submersibles shall be minimized.

**2.3** Control stations and spaces for arrangement of equipment of vital importance of fixed ship's diving systems shall be separated from adjacent ship spaces by A-60 divisions.

**2.4** Structural fire protection of spaces in the container modules of mobile ship's diving systems shall comply with the requirements of Section 2, Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships.

**2.5** Structural members and equipment in the manned submersible, compression chamber and diving bell compartments shall be manufactured of non-combustible materials. The combustibility of materials shall be tested in accordance with the International Code for Application of Fire Test Procedures (FTP Code).

**2.6** Non-metallic materials used for construction of the structural members and equipment located inside the diving bell, diving compartment of the lockout submersibles and compression chambers shall have the value of the limiting oxygen concentration ( $C_{loc}$ ) meeting the following condition:

$$C_{loc} \geq 1,05C_{vc}$$

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.

**2.7** Members and materials for the manned submersible, compression chamber and diving bell compartments shall be selected with regard to minimum hazard of electrostatic charges. Synthetic-based cloth materials shall not be generally used for the internal outfitting 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  $10^8 \Omega/m$ , is considered to be suitable for avoiding building-up of static electricity.

**2.8** 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.

**2.9** Electric heaters in the manned submersible and compression chamber compartments shall be provided with means of preventing heat stress.

**2.10** Oxygen and other gases from storage bottles (groups of bottles) shall be vented to a safe location.

**2.11** The hyperbaric evacuation system shall be located in the safety area, as far as possible from vent openings of engine rooms, exhausts and other spaces with fire risk.

**2.12** The boundaries of the ship in area of the hyperbaric evacuation system installation shall be designed as class A-60 divisions.

**2.13** The oxygen bottles may be arranged in well-ventilated ship spaces or on the upper deck at a safe distance from combustible materials. The oxygen storage spaces shall be separated from adjacent spaces with A-60 bulkheads and division and provide for a prompt personnel evacuation in case of any hazard.

### 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** pressure water-spraying system shall provide the water discharge rate not less than 0,5 l/s per 1 m<sup>2</sup> 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** 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

$$V_c = 5V_\delta \quad (3.1.2)$$

where  $V_\delta$  = interior volume of the compression chamber compartments, in m<sup>3</sup>.

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.

**.3** supply of inert gas to the compression chamber shall be also continued after the safety valve opening. Special group of bottles shall be provided for smothering. Technical background and the relevant calculations shall be provided to confirm the application of smothering systems in compression chambers with working pressure of above 1 MPa;

**.4** carbon dioxide or sea water shall not be used as an extinguishing medium in compression chamber and manned submersible compartments;

**.5** fire-fighting system shall ensure distributing the extinguishing medium evenly in each compartment of the manned submersible pressure hull.

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  | $0,5 \geq \Delta P/t \geq 0,3$                                | 0,5  |
| 0,3–0,6  | $0,7 \geq \Delta P/t \geq 0,5$                                | 1,0  |
| 0,6–1,0  | $1,0 \geq \Delta P/t \geq 0,7$                                | 1,5  |

Provision shall be made for proper arrangements to prevent accidental actuation of the fire-fighting system;

**.6** fire-fighting system of the compression chamber compartments shall be capable of being actuated manually. Provision shall be made for arrangements capable of actuating the system both from the inside and outside of the compression chamber compartments. Provision shall be made for suitable safety devices to prevent accidental actuation. Actuation of the fire fighting system shall not lead to an unacceptable pressure increase or drop in the compression chamber compartments;

**.7** fire-fighting system shall be capable of being recharged without need to depressurize the compression chamber compartments. Provision shall be made for a controlled consumption of the extinguishing medium reserves in the system at prompt stop of ignition upon its actuation.

**3.2** The fire fighting systems 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 requirements specified in [3.2.1](#) and [3.2.2](#).

**3.2.1** Enclosed spaces of the support ship intended for control, communication and siting of the manned submersibles and ship's diving systems as well as for placement of the ancillary gear of the manned submersibles and ship's diving systems, shall be provided with one of the fixed fire-extinguishing systems depending on the purpose of the specific space, according to 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 listed in 1.5.1.2 and 1.5.1.5 of the Part specified. For protection of control and communication spaces of the manned submersibles and deep diving systems only water-based fire-extinguishing systems are allowed.

**3.2.2** When pressure vessels, including compression chambers, diving bell and manned submersibles are located in the enclosed spaces, the manually activated water-spraying system with a delivery rate of water discharge not less than 10 l/min per 1 m<sup>2</sup> of the horizontal projected area of these pressure vessels shall be provided to cool and protect such pressure vessels in the event of external fire. Where pressure vessels are located on open decks, fire hoses may be considered as the means ensuring necessary protection.

**3.3** Hyperbaric evacuation and ship's diving systems installed on the open deck shall be protected by ship's fire detection systems (water spraying and water fire main systems).

#### **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 and 4.2, Part VI "Fire Protection" of the Rules for the Classification and Construction of Sea-Going Ships.

**4.2** Provision shall be made for manual and automatic activation of fire or smoke detection and alarm system in manned submersible compartments and ship's diving system spaces with audible and visual alarm transmitted to the submersible and ship's diving system control panel.

**4.3** 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.

**4.4** Saturation diving system's compression chamber compartments may be equipped with automatic fire detection alarm with audible and visual alarm transmitted to the saturation diving system control panel.

**4.5** In ship's spaces where a fire hazardous oxygen concentration may exceed 23 % or reduced down to hazardous levels (helium storage space), provision shall be made for automatic fixed oxygen gas analyzers capable of giving audible high/low oxygen concentration alarm in the secured spaces with signal transmission to the ship's main control station (navigation bridge), diving operation control station or compression chamber decompression control station. Personnel at control stations may be also provided with portable indicating gas analyzers.

**4.6** In spaces intended for storage and servicing of acid accumulator batteries of manned submersibles and ship's diving systems, hydrogen gas analyzers also capable of providing the audible alarm shall be recommended.

**4.7** The number and location of gas analyzers in protected spaces shall be based on volumes of protected spaces, operating modes and capacity of ventilation systems.

## **5 FIRE FIGHTING OUTFIT**

**5.1** For the support ship's spaces intended for the manned submersible and ship's diving system control stations on the support ship, provision shall be made for self-contained breathing apparatus capable of functioning at least 30 min for respiratory protection of the personnel. The number of such apparatuses shall correspond to the number of normal attending personnel of the ship's diving systems and manned submersibles on board the support ship. The breathing apparatus masks shall be designed to enable efficient communication.

**5.2** For respiratory protection of the personnel in the manned submersible, diving bell and compression chamber compartments, provision shall be made for emergency fixed breathing systems with breathing masks (half-masks) or self-breathing apparatuses capable of functioning over the entire range of working pressures for a period required for ventilation of compartments and emergency surfacing of the manned submersible or diving bell from the operating diving depth with retrieval thereof aboard the support ship. The number of masks/breathing apparatuses in each compartment shall correspond to that of the specified crew members of the manned submersible and divers in the compression chamber and diving bell. In addition, provision shall be made for one spare breathing mask and breathing apparatus.

**5.3** In spaces specified in [3.2](#), portable fire extinguishers shall be provided in compliance 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. Fire extinguishers shall be readily accessible.

Portable fire extinguishers in spaces for manned submersibles and ship's diving systems shall be of the same type with regard to IMO resolution A.951(23) and be arranged at all spaces where ship's diving systems are located so that one portable fire extinguisher shall be available for use within a distance not exceeding 10 m from any location.

One portable fire extinguisher shall be located in the ship's diving system control station and at the entrance to all other ship's diving system spaces.

**5.4** In ship's diving system spaces on support ship, spare charges or spare fire extinguishers shall be provided at a rate of 100 % for the first 10 extinguishers and 50 % of the remaining fire extinguishers.

**5.5** 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.

**5.6** Fire extinguishers in compression chambers and hyperbaric evacuation systems shall be suitable for electrical fire extinguishing with voltage of up to 24 V. According to the atmospheric content inside the compartment, the air or breathing gas mixture may be used as a gas to produce overpressure in the extinguishing medium reservoir.

## **6 ADDITIONAL REQUIREMENTS FOR PASSENGER SUBMERSIBLES**

**6.1** Each passenger cabin shall be provided with an emergency breathing system or self contained breathing apparatuses capable of functioning for 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 apparatuses in each passenger cabin shall correspond to the number of passenger seats plus one spare apparatus.

**6.2** Service passenger compartments of passenger submersibles shall be provided with appropriate fire-fighting means. Such means may be fixed firefighting 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 and potential building-up of pressure.

## **PART VI. MACHINERY INSTALLATIONS, MECHANICAL EQUIPMENT AND SYSTEMS**

### **1 GENERAL**

#### **1.1 APPLICATION**

**1.1.1** The requirements of this 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 these 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 are given in the General Regulations for the Classification and Other Activity Relating to Manned Submersibles and Ship's Diving Systems. 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.

### **1.3 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 for the Classification and Other Activity for the Manned Submersibles and Ship's Diving Systems 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**

**2.1.1** Machinery installations and equipment of the manned submersibles and ship's diving system generally include the components of propulsion plants of self-sustained manned submersibles, pumps and actuators of hydraulic systems, water supply system pumps, winches and reels, compressor plants, refrigerating plants of conditioning units, etc. Machinery installations, equipment, fittings and instruments 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 specified critical operating conditions, except machinery and equipment, the operability of which is not 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 for the Classification and Other Activity Relating to Manned Submersibles and Ship's Diving Systems.

**2.1.4** Essential components and systems exposed to the environment shall be suitable for operation at temperatures from - 30 °C up to +50 °C 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 and equipment external to the pressure hull of the manned submersibles and diving bells shall be protected against mechanical damages and entry of foreign objects to prevent injuries to attending personnel or divers.

**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 working hydrostatic 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 or mobile containers. Siting of the ship's diving system components on open decks shall be agreed with the Register.

**2.1.11** Siting of the ship's diving system on the support ship shall allow easy servicing and using of instrumentation, 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 specified in [2.1.14](#) with the ship's spaces of common purpose is generally prohibited. Possibility of intercommunication between the above spaces shall be agreed with the Register.

**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** 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.

**2.1.18** The design of actuating elements of manipulators of the manned submersibles and diving bells shall generally provide for their forced detachment in an emergency situation to create positive buoyancy of the manned submersibles.

**2.1.19** Data on capacity of all pumps, compressors and pressure relief safety devices shall be included in the technical documentation submitted to the Register for review.

## **2.2 COMPRESSOR PLANTS**

**2.2.1** Compressor plants for preparation of compressed air, transfer of oxygen, preparation of artificial breathing gas mixture, transfer of helium and helium breathing gas mixtures may be used in life support systems for manned submersibles and ship's diving systems and breathing gas mixture recovery systems and diver's closed-loop gas supply systems. Compressor plants shall be certified according to their purpose and operating conditions.

**2.2.2** 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. Electric motors and electrical equipment of electrically driven compressors shall comply with applicable requirements of Chapter 10, Part XI of the "Electrical Equipment" of the Rules for the Classification and Construction of Sea Going Ships and Part VII "Electrical Equipment" of these Rules.

**2.2.3** The number of the compressors and bottles for storage of prepared compressed air or gas shall be determined from the required capacity for preparation of compressed gases for operation of manned submersibles and ship's diving systems. The capacity of the compressors shall exceed by 10 — 15 % the gas flow rate required to supply all the consumers having regard to the use of the reserves of air or breathing mixture in bottles. As a rule, at least two compressors of the same purpose shall be included in each gas system.

**2.2.4** In gas supply systems of manned submersibles and ship's diving system, the compressors whose delivery pressure exceeds the design pressure of the system (as a rule, not exceeding 15 %) may be used. Provision shall be made for suitable safety devices to prevent overpressure in the systems above the permissible value.

**2.2.5** Diving air compressor plants on the discharge line shall be provided with devices for compressed air cooling, drying and removal of noxious substances to permissible sanitary regulations and standards applicable to diving breathing air, for example, EN 12021. The purifying and drying devices of the compressed air shall be fitted on the discharge line of the compressor before its storage bottles.

**2.2.6** Pressurized components of compressor stages shall be subject to hydraulic and pneumatic pressure tests according to the requirements of Chapter 1.3, Part IX "Machinery" and Chapter 1.7, Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification and Construction of Sea-Going Ships as well as functional and operational tests to determine moisture content and possible contaminations in the compressed air shall be performed, and control, monitoring and safety devices shall be checked.

**2.2.7** The compressors of systems of manned submersibles and ship's diving systems shall be suitable for use on board the support ship under relevant environmental conditions and correspond to the design capacity, gas type and design pressure of the system with regard to the requirements specified in [2.2.4](#).

**2.2.8** Air compressors shall be fitted on the support ship so as to prevent ingress of fuel vapors, oil vapours and exhaust gases at their suctions.

**2.2.9** Where the compressor is used in the direct breathing gas supply system, provision shall be made for a device for compensation of pressure fluctuations and sines in the system during its operation.

**2.2.10** Oxygen compressors shall be fitted in separate spaces complying with the requirements of Chapter 4.5, Part VI of these Rules.

**2.2.11** Liquid-cooling systems of compressors shall be designed to prevent exceeding the specified pressure of the cooling liquid.

**2.1.12** Oil-free piston compressors shall be provided at each stage with a device which initiates an alarm in case the compression temperature is exceeded and disconnects the drive motor.

**2.2.13** Diaphragm compressors shall be provided at each stage with a diaphragm rupture indicator which disconnects the compressors in case of damage of its drive or diaphragm.

**2.2.14** Compressors shall be provided with accessories and tools as required for their operation.

**2.2.15** For manufacture of compressors, materials and products complying with their operating conditions shall be used. Materials and products shall be selected with due regard to composition of the transferred gas medium. During certification, documentary evidences of quality of materials used for manufacture of pressurized components of compressors shall be submitted.

**2.2.16** Moving parts of compressors shall be surrounded by suitable guards. Safety valves and devices shall be capable of venting gas to a location safe for attending personnel.

**2.2.17** Compressors shall be supplied with nameplates generally containing the name of manufacturer, model, serial number, date of manufacture, maximum output rated pressure, rated capacity, rated drive power, speed.

### **3 HEAT EXCHANGERS AND PRESSURE VESSELS**

#### **3.1 GENERAL**

**3.1.1** Heat exchangers, pressure vessels, and fixed 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** Drawings, calculations and characteristics of pressure vessels and heat exchanges shall be submitted to the Register for review and approval. They shall be manufactured, installed and tested in accordance with the approved documentation in the presence of the RS representative.

**3.1.3** The application of pressure vessels manufactured from glass reinforced plastic on manned submersibles and ship's diving systems shall be agreed with the Register.

### 3.2 PRESSURE VESSELS

**3.2.1** Pressure vessels and gas bottles on open deck shall be protected from mechanical damages and solar radiation.

**3.2.2** Pressure vessels and gas bottles shall be installed at a distance not less than 1 m from heat emission sources.

**3.2.3** Bottles shall be so secured as to preclude displacement thereof at any admissible heels and trims of the support ship.

**3.2.4** Each bottle or group of bottles (except for the cases specified in 6.4.4.7, 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.

Bottles for the storage of gases combined in groups with no individual isolating valves with total value of  $pV < 100$  may have a common overpressure relief device, pressure gauge and shut-off valve

where

$p$  = design pressure, in atm;

$V$  = total volume of bottles, in m<sup>3</sup>.

Application of bursting disks or fusible plugs is not allowed.

**3.2.5** Bottles for the storage of gases, gas mixtures or their heads shall be painted in colours specified in [Table 3.1.6](#). Moreover, each bottle shall bear on its cylindrical portion the chemical formula and name of gas or gas mixture stored therein.

Table 3.1.6

| Gas (gas mixture)               | Chemical symbol   | Colour of bottles (or heads) and pipelines |
|---------------------------------|---|--|
| Oxygen                          | O <sub>2</sub>  | White                                      |
| Helium                          | He  | Brown                                      |
| Air<br>Nitrox                   | -<br>(O <sub>2</sub> + N <sub>2</sub> )                           | White and black                            |
| Nitrogen                        | N <sub>2</sub>  | Black                                      |
| Helium-oxygen mixture<br>Trimix | (He + O <sub>2</sub> )<br>(He + O <sub>2</sub> + N <sub>2</sub> ) | White and brown<br>White, brown, black     |
| Carbon dioxide                  | CO <sub>2</sub>   | Grey                                       |

**3.2.6** Bottles with oxygen shall be stowed in upright position on the ship's deck or in a special enclosed room. This room shall be located outside the machinery spaces and as far as possible from accommodation spaces, control stations, and spaces where readily ignitable materials are stored.

**3.2.7** For storage of different breathing gas mixtures separate groups of bottles shall be provided. 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 mixtures and vice versa.

**3.2.8** 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. Once installed, vessels shall be tested for tightness by working pressure normally used for operation.

**3.2.9** Capacity of bottles or group of bottles installed inside the pressure hull of the manned submersible 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 volume oxygen content in this case shall not exceed 23 %.

**3.2.10** 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 hull of the manned submersible.

**3.2.11** Pressure vessels that may contain water or condensate when operated shall be provided with drainage devices.

### **3.3 HEAT EXCHANGERS**

**3.3.1** Heat exchangers are generally used in conditioning units and plants of manned submersibles and ship's diving systems for heating, cooling and drying of breathing gas mixtures, and in compressor cooling systems and other mechanical equipment.

**3.3.2** Breathing mixture heaters and coolers shall have devices for the discharge of gas mixture and drainage.

**3.3.3** 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 %.

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 diving compartments 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 shall prevent building-up of pressure exceeding the operating pressure by more than 10 %. 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.

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 lockout 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 diving compartment of the lock-out submersible and be constantly open and sealed. The safety valve shall be protected from mechanical damage and catching. The effects of sea water backpressure acting on the outlet side of the safety device shall be taken into account.

**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 by a pressure equal to the operating pressure for gases and gas mixtures and to  $1,25P_{op}$  for liquid media.

**3.4.7** All pipes entering the compression chamber and diving compartment of the manned 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 drops. The external pipeline of the breathing gas mixture conditioning and purification system shall be provided with a quick-closing valve, which actuates automatically upon pressure drop not more than the last decompression stage's pressure drop. Installation of closing fittings on one side only shall be agreed with the Register.

**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 or lock-out submersible hull and intended for reduction of pressure, drainage, connection of pressure gauge shall be made of non corrosive materials and be protected against mechanical damages. Flooding valve shall be installed 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** Ball valves fitted on hulls and essential systems of manned submersibles and ship's diving systems capable of being operated upon pressure drop shall be provided with arrangements for their reliable locking in open/closed position. The essential ball valves without control position locking arrangements shall be used only if possible unauthorized opening of these valves is excluded. Use of plug type tapered cocks is not permitted.

**3.4.12** 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.

**3.4.13** Outlets of safety devices of pressure vessels and systems fitted within pressure hulls of manned submersibles shall be led overboard directly or through a special tank. In this case, the tank shall be equipped with a pressure gauge and check valve.

**3.4.14** While installing safety valves in medium- and low-pressure system, the safety device shall be arranged as close as possible to the reducing valve. The capacity of safety valves shall be sufficient to maintain the system pressure of not more than 110 % of the design pressure.

**3.4.15** Regulating devices of pressure regulators shall be capable of providing more than one complete rotation in order to be switched from the fully closed to the fully open position.

### **3.5 SPECIAL REQUIREMENTS FOR COMPRESSION CHAMBERS**

**3.5.1** Compression chambers in the ship's diving systems shall comply with requirements of these Rules and applicable requirements of national standards imposed on this equipment.

**3.5.2** The ship's diving systems intended for diving operations at depths more than 12 m shall, as a minimum, include either one compression chamber with two separate compartments or several interconnected chambers combined in a single compression system so designed as to permit the personnel to move between pressurized compartments (compression chambers) and go outside while one or several compartments (compression chambers) remains pressurized. Covers of transfer hatches of these compression chambers shall be designed so that locking mechanisms can be operated from both sides.

**3.5.3** The compression chamber 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 constant pressure.

**3.5.4** The locks shall be designed to prevent accidental opening under pressure and suitable 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 transfer (lock-out) compartments of the compression chambers shall be designed to provide the safe transfer of the persons under pressure to the diving bell and back. Lock-out compartments shall be designed to prevent their accidental opening. Locking arrangements shall be capable of being locked in the closed position and of preventing their accidental opening. Pressure inside the lock-out compartment shall be indicated by a pressure gauge attached outside directly near the external cover.

**3.5.7** The compression chamber shall provide a suitable living environment and facilities for the persons who use it, having regard to the type and duration of the diving operation. They shall be designed and equipped so that the internal illumination intensity in compartments and noise level of the manned areas do not exceed the applicable sanitary norms.

**3.5.8** The equipment of compression chamber compartments shall be suitable for operation under high pressure atmosphere. Under these conditions, they shall not produce toxic or irritating gaseous substances. This requirement applies also to protective coatings, paints and outfitting components used inside compartments.

**3.5.9** The compression chamber shall be designed to provide complete protection against unauthorized increase or decrease of operating pressure while using its systems and devices.

**3.5.10** Gas mixture outlets in compression chambers, diving bell and lockout submersible compartments shall be equipped with protective arrangements to prevent suction of foreign objects.

**3.5.11** All compression chamber gas system inlets intended for gas distribution, e.g. pressure supply, discharge and equalization shall be equipped with suitable non-return valves according to the gas flow direction. All compression chamber gas systems shall be provided with manual pressure relief arrangements.

**3.5.12** Pipelines not intended for gas distribution, e.g. sounding or sampling pipes shall have a minimum internal diameter not exceeding 5 mm.

**3.5.13** Inlet and outlet fluid piping of compression chambers shall be provided with non return valves fitted downstream in the vicinity of shut-off valves.

**3.5.14** Compression chambers intended for therapeutic recompression and decompression of divers in bounce diving systems at depths of up to 60 m shall also meet the following requirements:

- .1 diameter of the recompression chamber shall be at least 1,2 m;
- .2 main compartment shall be designed to accommodate at least one person in lying position and one person in sitting position. The airlock shall accommodate at least two persons during airlock transfer operations;
- .3 number of seats in the compression chamber compartment shall correspond to the number of people for which it is designed as intended;
- .4 volume of main compartments of the compression chambers except for internal outfitting shall be at least 0,5 m<sup>3</sup> per person inside therein;
- .5 compression chamber compartments shall be provided with compressed air forced ventilation system. The compression chamber gas supply system shall ensure air exchange rate of 30 l/min per person at the operating pressure;
- .6 main compartment shall be provided with individual breathing masks of oxygen fixed breathing system to provide for oxygen recompression and decompression of divers in number corresponding to that of the regular personnel. The gas exhaled from masks shall be vented outside the compression chamber. The masks shall be provided with inhaled and exhaled air regulators capable of automatic or manual adjustment of inhale and exhale resistance. Pressure regulators shall be fitted external to the compression chamber on the oxygen supply line and on the discharge line;
- .7 breathing air and oxygen shall be supplied in the compression chamber compartments through different piping;
- .8 compression chamber living compartment shall be provided with adjustable heating means;
- .9 main compartment shall be provided with an airlock for passing medicines and food. The airlock shall be at least 200 mm in diameter and at least 300 mm long;
- .10 provision shall be made for installation of an additional check pressure gauge external to the compression chamber main compartment;
- .11 compression chamber may be equipped with the closed-loop life support system which includes arrangements for removal of carbon dioxide from the gas medium, oxygen metering system and gas analyzers of breathing medium to measure oxygen and carbon dioxide content;
- .12 controls and indicators intended for airlock and main compartment of the compression chamber shall be combined on a single control panel. They shall be clearly marked and arranged according to their function and be lighted;
- .13 pressure gauges intended for monitoring pressure in the airlock and main compartment of the compression chamber shall have accuracy class of at least 0,25 and provide adequately accurate pressure reduction during decompression;
- .14 compression chamber control panel shall, as a minimum, have indicators displaying the following:
  - pressure in compressed air bottles or at the outlet of pressure regulator on the line for air supply to compression chamber compartments;
  - pressure in oxygen bottles at the outlet of pressure regulator and on the line for oxygen supply to oxygen metering system and individual breathing masks in the compression chamber;
  - temperature and air humidity in the compression chamber compartment;
  - volumetric concentration and/or partial pressure of oxygen and carbon dioxide in the compression chamber compartment;
  - second hand clock independent of mains power;

**.15** compression chamber panel shall, as a minimum, be equipped with the following controls:

- air inlet and discharge valves;
- valves for helium or breathing gas mixture supply to the airlock (if applicable);
- valve for equalizing pressure between the compartment and airlock;
- valves of compression chamber compartment oxygen metering system (if applicable);
- switches for power supply to fans of units for removal of carbon dioxide from the gas medium (if applicable);
- switches of compression chamber compartment lighting system;
- controls of communication equipment and gas analyzers;
- valves for oxygen/breathing gas mixture supply to masks of the fixed breathing system.

**3.5.15** Compression chambers in the saturation diving system shall additionally comply with the following requirements:

**.1** they shall be so equipped to maintain the suitable breathing atmosphere for divers inside compartments throughout the occupation period;

**.2** compression chamber systems and conditioning means shall be capable of automatically maintaining the temperature inside living compartments

under steady-state conditions within 27 – 36 °C with accuracy of up to ± 1 °C and relative humidity of at least 50 % (to be specified according to the operating pressure in the compression chamber);

**.3** compression chambers shall be so designed and equipped to maintain the gas medium uniform in composition, temperature, humidity and mobility, as far as possible, inside compartments in steady-state conditions. Air or gas mixture discharge from the compression chambers shall be arranged at the bottom of the compartment. Compression chamber compartments shall be free of trapped and non-ventilated zones;

**.4** compression chambers shall be equipped with sanitary compartments or enclosures where the flush toilet, hand washer and shower complying with requirements of [Chapter 4.3](#) shall be provided. The sanitary compartments (enclosures) shall be provided with a protective filter against ingress of harmful odors from sewage system into the compartment;

**.5** external diameter of living compartments of saturation diving system compression chambers shall be at least 2200 mm. The compartments of these compression chambers shall be so arranged as to allow most divers to stand upright and stretch out comfortably on their bunks;

**.6** living compartments shall be provided with one berth for each normally accommodated diver. The sizes of berths shall comply with the appropriate ergonomic requirements;

**.7** compartments or compression chambers used as transfer/lock-out chambers shall have internal dimensions sufficient for concurrent transfer of at least two persons through the airlock and a volume of at least 3 m<sup>3</sup>;

**.8** each living compartment of compression chambers shall be equipped with self-containing breathing masks of the compression chamber's emergency fixed breathing system in the number corresponding to the number of divers for which it is designed. One spare mask shall be additionally provided. The masks shall be arranged near berths for breathing;

**.9** The transfer compartments of diving bells of saturation diving systems shall also be provided with masks of emergency life support system in the number corresponding to a maximum number of divers in a diving bell. One spare mask shall be additionally provided. Other compartments shall be provided with at least two masks each;

**.10** components of equipment in compression chamber compartments shall be so arranged and installed to minimize diver's injuries and provide a sufficient space for motions.

In addition, the compression chamber equipment shall not impede observation of divers in the manned areas from viewports or using CCTV equipment;

**.11** external insulation of compression chambers shall be protected against damage and suitable for operating conditions in the area of compression chamber installation.

### **3.6 SPECIAL REQUIREMENTS FOR DIVING BELLS, HALF-BELLS AND DIVING STAGES**

**3.6.1** Diving bells, half-bells and diving stages shall be designed to provide for safe transfer of regular divers with equipment and outfit during their diving, underwater operations and recovery.

**3.6.2** Diving bells shall be so equipped to provide structural protection against unauthorized pressure variation within the compartment during diving.

**3.6.3** Outside the diving bell, provision shall be made for unions for connecting emergency hot water and breathing gas mixture supply hoses, as well as a connector for power supply and connection of emergency communication capable of being mated in sea water. Unions and connectors shall be clearly marked and protected against mechanical damage, and be readily accessible near cargo handling appliance for emergency slinging. Connection dimensions of unions shall comply with the requirements specified in Section 9, Part III "Equipment, Arrangements and Outfit" of these Rules.

**3.6.4** Diving bells shall be equipped with an unconscious diver recovery appliance.

**3.6.5** Provision shall be made for a seat equipped with safety harnesses for divers in the diving bell.

**3.6.6** Diving bells shall be provided with viewports. Viewports shall be protected against mechanical damage.

**3.6.7** Each diving bell shall be provided with interior and exterior lighting arrangements. Exterior lighting fixtures shall provide 360-degrees of lighting capacity and shall be connected so that a failure of one lighting fixture will not cause failure of the others.

**3.6.8** Two video cameras are recommended to be provided in the diving bell. One camera shall be installed in the upper part of the bell and directed vertically towards its access hatch, while the other shall be directed towards the panel with gas supply valves and gas analyzer.

**3.6.9** The diving bell shall be provided with at least one mechanical depth gauge.

**3.6.10** The diving bell shall be equipped with a flooding system to facilitate entry and exit of divers. The gas bleeding system shall not allow the water level in the bell to be above the electrical equipment when the diving bell is in upright position. The flooded volume shall not exceed 40 % of the internal bell volume. The exhaust gas system shall be so arranged that the diver intending to facilitate his entry by partial flooding of the bell may control this system from the lower part of the compartment inside the bell. This system shall be equipped with a spring-loaded valve capable of closing at valve handle release and protected against accidental opening.

**3.6.11** The diving bell shall be equipped with a valve for draining the diving bell when the hatch is closed by increasing inner pressure, also in case of diving bell inclination from the upright position. The extent of the assumed inclination shall be considered separately in each particular case. This requirement is normally fulfilled by using a flexible hose fitted to the drain pipe.

**3.6.12** Saturation diving bell shall be additionally provided with the following:

- .1** telephone communication means with helium speech unscrambler;
- .2** emergency sonar communication station;
- .3** automatic gas analyzers which shall automatically measure and display in the diving bell the content (and/or partial pressure) of oxygen and carbon dioxide, and transmit their readings to the control station on the support ship through umbilical;
- .4** ship's emergency power supply capable of supplying power to emergency consumers for at least 24 h including emergency lighting, emergency life support systems, communication means and gas analyzers;

**.5** medical lock generally provided at the top of the diving bell ensuring the passage of life support means, medicines, etc. to the emergency bell being afloat or after being surfaced;

**.6** individual masks of the emergency fixed breathing system in the number corresponding to the number of divers. One spare mask shall be additionally provided. The masks shall be capable of being switched between the main and emergency sources of the breathing gas mixture supply in the diving bell;

**.7** arrangements for heating divers in diving outfit and gas medium in the diving bell. Provision shall be made for adequate arrangements to prevent overheating of divers. Diver heating arrangements shall be powered independently from those of the diving bell.

**.8** emergency arrangements for removal of carbon dioxide from diving bell atmosphere and for heating divers (preventing heat losses) within at least 24 h. These arrangements shall be independent from umbilical.

**3.6.13** Diving bells shall be equipped with gas supply and distribution systems providing the following:

**.1** supply of breathing gases to working divers both from surface supply and ship's emergency gas supply system of the diving bell;

**.2** breathing gas supply to a working diver independently from its supply to the other one;

**.3** gas mixture main supply to the standby diver outside the diving bell independently from its supply to working divers. The main supply of the breathing gas to the standby diver may be carried out from the surface or ship's emergency life support system of the diving bell. The supply shall be adequate to allow the diver to exit from the bell and hoist the diver in distress to the diving bell;

**.4** diving bell ventilation with air or breathing gas mixture through simultaneous gas supply from the surface and its discharge to water with no interruption of breathing gas supply to any diver.

**3.6.16** The diving bells with positive buoyancy shall be equipped with the emergency ballast jettison systems to disconnect the devices acting as an emergency ballast from the bell, umbilical release arrangements, cargo and guide ropes for surfacing. Umbilical and wire rope disconnection systems shall be protected against accidental actuation. The ballast jettison systems shall be capable of actuating by at least two confirmed actions and be independent from power supply.

**3.6.17** The diving bells with positive buoyancy shall have an adequate buoyancy reserve and adequate stability in the surface condition to maintain their upright position when surfacing in the bulk of water. Time required for the diving bell to surface shall not exceed the design operation time of the diving bell emergency life support system.

**3.6.18** The diving bells with negative buoyancy shall be provided with emergency recovery arrangements. The application of the diving bell with negative buoyancy shall be confirmed by necessary calculations and technical background.

**3.6.19** Diving half-bells may be used as part of bounce diving systems, generally for diving at depths of up to 60 m using breathing air. The use of half-bells for saturation diving shall be agreed with the Register.

**3.6.20** Half-bells shall comprise an upper part designed as a tight half shell where a gas space for diver breathing, life support system devices and controls are to be located, and an open lower part with the platforms for divers in standing or sitting position.

**3.6.21** Half bells shall produce a gas cushion of compressed air or breathing mixture (depending on depth but with no saturation achieved) with possible controlled decompression while surfacing the half-bell.

**3.6.22** Divers inside the half-bell shall be properly protected against mechanical impacts during diving and recovery.

**3.6.23** Provision shall be made for breathing air or gas mixture supply to divers inside the half-bell through umbilical, hot water supply to the water heating system and power supply from the support ship. Provision shall be made to maintain communication with divers. The half bell shall be provided with umbilical winding and storage arrangements.

**3.6.24** The half-bells shall be provided with a self-contained ship's emergency breathing system which shall supply breathing gases to divers through hoses and to the enclosed upper space, as well as to emergency breathing masks (if any) at all depths up to the maximum operating depth.

**3.6.25** Emergency reserves of the half-bell breathing mixture shall enable breathing of divers at a rated diving depths for 2 h. The capacity of the emergency life support system shall exceed the following two values:

.1 for breathing gas supply to each diver inside the half-bell for 15 min when they are outside the half-bell;

.2 for supplying divers with breathing gases during recovery of the half-bell.

**3.6.26** The upper part of the half-bell where a gas space is located shall be provided with arrangements for blowing-out by means of the breathing mixture used.

**3.6.27** The following shall be also provided on the half-bell:

.1 arrangements to hoist the unconscious diver inside and secure him so that his head is in the gas cushion;

.2 internal handrails used by the divers as a support;

.3 door or chain to prevent divers from falling out during diving and recovery;

.4 seats for each diver;

.5 depth gauge certified by a competent organization;

.6 main and emergency internal lighting allowing the divers to operate the controls and monitor instrument readings.

**3.6.28** The hose of the pneumatic depth gauge displaying the diving depth in the control station on the support ship shall be secured on the half-bell.

**3.6.29** Half-bells shall be equipped with an additional lifting point designed for receipt of a total dry (in air) weight of the half-bell including weight of divers with diving outfit and additional equipment. The additional lifting point shall be located in line with the half-bell center of gravity.

**3.6.30** The half-bell umbilical shall be reliably secured to the diving bell by means of a strong structural components or strain relief coupling to prevent connections from breaking loads.

**3.6.31** The diver gas supply lines shall be so arranged that a failure in one line does not affect the supply of the breathing gas to the other diver, and purging of the enclosed upper section of the half-bell does not impede the supply of the breathing gas to any diver.

**3.6.32** The requirements for half-bells may be also applied to diving stages (as applicable).

**3.6.33** The diving stage shall be designed to provide the following:

.1 non-skid platforms of at least 800×800 mm per diver, openings (slots) for free passage of water and coamings 150 mm high (coaming shall not be fitted from the guard rail opening side);

.2 guard rails of 1900×2000 mm high opened from one side (flexible guards are not allowed);

.3 diving stage slinging arrangement preventing spontaneous disconnection from handling wire rope, twisting and chaffing in operation;

.4 sufficient number of handrails for divers designed to prevent injuries to diver hands at accidental striking of the stage against the support ship side or underwater objects;

.5 seat for each diver;



- .6** helmet slinging arrangement allowing a diver to carry out slinging on his own;
- .7** stable position of the stage during diving, recovery and operation at an operating depth.

## **4 SYSTEMS AND PIPING**

### **4.1 GENERAL**

**4.1.1** Materials used in the manufacture of pipelines, their connections 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** Flexible connections, fittings and pipes shall be of the approved design type and delivered with the RS certificates. 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 hull.

**4.1.4** Pipes located in places where they can be subject to mechanical damage shall be safety 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 safety 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. protective gratings).

**4.1.12** 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.

**4.1.13** The systems providing the operation of the ship's diving systems shall be generally separated from other systems of the support ship.

**4.1.14** Oxygen piping shall be laid, as far as practicable, apart from other systems and shall not be laid close to the pipelines and equipment containing fuel or oil, and to the hot surfaces.

**4.1.15** 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.

**4.1.16** 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.

**4.1.17** Piping penetrating pressure hulls of manned submersibles, diving bells and compression chambers shall be provided with valves according to the requirements specified

in [4.1.18 — 4.1.30](#). Pipes and fittings which connect penetrations in the shell with these valves shall be as short as possible.

**4.1.18** Breathing gas piping shall be laid as far as possible from cable runs, as practicable.

**4.1.19** Provision shall be made for arrangements for complete draining of all liquid media piping.

**4.1.20** Piping systems which may be exposed to pressure exceeding their design pressure shall be provided with safety devices.

**4.1.21** Pipelines, fittings and penetrations exposed to sea water or atmosphere containing sea water shall be corrosion-resistant.

**4.1.22** Pipe material and flexible connections in the systems of manned submersibles and ship's diving system shall have the tensile strength 4 times the maximum allowable operating pressure in the systems. The use of flexible hoses in the life support systems for manned submersibles, ship's diving systems except for cables and hoses shall be minimized.

**4.1.23** The use of clamps and similar fasteners in pressurized systems or systems of vital importance is not permitted.

**4.1.24** All welded pipe connections of the systems for manned submersibles, ship's diving systems shall be subject to non-destructive testing according to the requirements specified in Chapter 3, Part XIV "Welding" of the Rules for the Classification and Construction of Sea-Going Ships.

**4.1.25** Only piping connections of the approved type may be used in the systems for manned submersibles, ship's diving systems. The application of other connections/fittings shall be considered particularly in each case. Mechanical piping connections shall be designed for a rated operating pressure which is more or equal to maximum permissible operating pressure of the piping system where they are used. The breaking strength of connections shall be at least 4 times the permissible pressure of the piping system. The pipe connections are preferred to be executed using welded butt joints with full penetration.

**4.1.26** All piping exposed to internal pressure shall be subject to strength tests by test pressure equal to 1,5 times the maximum operating pressure. Piping systems exposed to external pressure during submersion shall be additionally subjected to tests at a nominal submergence pressure.

**4.1.27** The piping connections of manned submersibles and ship's diving systems shall be performed by the RS certified welders using approved welding procedures and welding consumables.

**4.1.28** All systems shall be equipped with manual pressure relief arrangements.

**4.1.29** Filters in the gas systems with regulators shall be fitted on pressurized piping sections. Filters and automatic pressure regulators shall be so arranged as to provide their switching off with no interruption of gas supply to consumers.

**4.1.30** In the systems of ship's diving systems flexible hoses shall not be used instead of fixed piping. Short sections of hoses (up to 2 m long) may be used where necessary to provide relative displacements between moving gears of diving bell handling system and fixed piping systems. Where the use of fixed piping is not reasonable, in some system assemblies, sections of approved hoses up to 5 m may be used. In these cases, hose fasteners shall be arranged at the interval of 1 m throughout the hose length.

## **4.2 SUBMERGENCE AND SURFACING SYSTEMS**

**4.2.1** Submergence and surfacing systems for manned submersibles shall ensure surfacing, submergence and trim control in normal and emergency conditions.

**4.2.2** The vent valves of ballast tanks in the manned submersibles shall be closed automatically in the event of failure of their actuators.

**4.2.3** 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.

**4.2.4** The compensating tanks shall be equipped with water level gauges.

**4.2.5** 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.

**4.2.6** 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.

**4.2.7** Ballast tanks of manned submersibles exposed to internal and external pressure shall comply with the relevant requirements of the Register. Provision shall be made for two independent draining arrangements for ballast tanks. One of these arrangements shall be generally independent of electric power supply. Where both arrangements operate from power supply, their application shall be considered on the case-by-case basis.

**4.2.8** The emergency surfacing system for manned submersibles shall ensure positive buoyancy sufficient for surfacing from the maximum operating depth. The system shall be actuated by two confirmed manual actions and be independent from electric power supply. The emergency surfacing system shall duly function under all expected heel and trim conditions.

**4.2.9** Air supply pipelines for blowing out compensating tanks in the manned submersibles shall have not less than two isolating valves.

### **4.3 LIFE SUPPORT SYSTEMS**

**4.3.1** The manned submersibles and ship's diving systems shall be provided with necessary life support systems to maintain normal living environment for the manned submersible crew, as well as divers in compartments of compression chambers, diving bells, lock-out submersibles and hyperbaric evacuation system and during underwater operations with diving outfit.

**4.3.2** Life support systems for manned submersibles and ship's diving systems shall be designed, manufactured and tested under the RS technical supervision according to these Rules. Operating characteristics of life support systems (capacity, working period, etc.) shall be confirmed by calculations performed according to the design conditions as agreed by the customer and competent organization.

**4.3.3** The following may be generally included in main life support systems and arrangements for manned submersibles, ship's diving systems, compression chambers, diving bells and evacuation systems:

- .1** gas supply systems including compressed diving air system, gas and gas mixture (oxygen, helium, breathing gas mixture, etc.) systems and gas recovery system;
- .2** systems and means of regeneration of the gas medium and removal of carbon dioxide from the gas medium;
- .3** systems and means of gas medium conditioning;
- .4** systems for heating the diving bell and divers under water;
- .5** fixed emergency breathing systems;
- .6** compression chamber sewage systems;
- .7** compression chamber domestic water supply system.

**4.3.4** The gas supply systems shall ensure necessary preparation, storage and consumption of an adequate amount of compressed air, gases and gas mixtures for operation of manned submersibles and ship's diving systems at operating pressure under normal and emergency conditions.

**4.3.5** Provision shall be made for the required amounts of gases and breathing gas mixtures based on relevant calculations for their operating conditions in gas supply systems for manned submersibles and ship's diving systems. While calculating gas amounts, their operating losses shall be taken into account including when using life support systems like airlock transfer systems, sanitary systems, gas analysis systems, etc.

**4.3.6** For ship's diving systems, provision shall be made for fixed gas storage bottles or area on board the ship for the storage of transportable groups (containers) of gas bottles. Emergency amounts of gases and breathing gas mixtures shall be stored in separate gas bottles (groups of bottles) which shall not be used during normal operation,

**4.3.7** The total capacity of bottles for the storage of amounts of gases and emergency breathing gas mixtures for ship's diving systems shall, as a minimum provide the following:

- .1** for bounce diving systems – two-fold pressure increase in compression chamber compartments, diving bell and transfer compartments up to maximum operating depth, as well as for air ventilation of compartments if there are no closed-loop life support systems in the compression chambers;
- .2** for saturation diving systems – design amounts of gases for diving at a maximum depth, as well as one-fold pressure increase in the largest compression chamber compartments up to a maximum level;
- .3** oxygen amount for maintaining the partial oxygen pressure in the compression chamber compartments and for using in the fixed emergency breathing systems within the following time:  
24 h – for bounce diving systems;

48 h – for saturation diving systems;  
(minimum amount of oxygen shall be specified based on 2 nm<sup>3</sup> per diver for bounce diving systems or 4 nm<sup>3</sup> per diver for saturation diving systems);

**.4** two emergency submergences of diving bells at the maximum depth.

**4.3.8** The sections of life support system pipelines shall be tested upon manufacturer by hydraulic pressure equal to 1,5 times the maximum permissible operating pressure. Upon testing and before installation, the sections of life support system pipelines shall be properly cleaned.

**4.3.9** Once installed on board the ship, the assembled life support systems 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 % of the test pressure per day when testing the life support system together with hyperbaric compartment

**4.3.10** Filters, automatic pressure regulators and other equipment of life support systems which require maintenance shall be so connected to enable isolating them without interruption of the system operation.

**4.2.11** Where flexible connections (detachable pipelines) are used for gas and breathing gas mixture supply, isolating valves and pressure gauges shall be fitted at their connections, and in case of gas and breathing gas mixture supply for charging bottles of the manned submersibles, diving bells and hyperbaric evacuation systems, valves for pressure relief in the detachable pipeline shall be fitted too. In such a case, a separate detachable pipeline with unique connection sizes shall be provided for each gas.

**4.2.12** Gas booster compressors shall be used for the transfer of gases and breathing mixtures. Oxygen compressors shall not be used for the transfer of breathing mixtures or air. A non-return or stop-check valve shall be fitted on the delivery pipeline of each booster compressor.

**4.3.13** The gas distribution, supply and discharge gas systems for compression chambers, diving bells, hyperbaric evacuation systems and lockout submersibles shall be designed for a specified maximum gas flow capacity determined by operating conditions of diver compression and decompression.

**4.3.14** The space for the storage of helium bottles is recommended to contain a gas analyzer, which operates at the oxygen content below 20 % by volume.

**4.3.15** Gas jet silencers are recommended to be fitted at inlet and outlet pipes of gas supply systems for manned submersibles and ship's diving systems in order to reduce noise in the manned compartments.

**4.3.16** Pipelines containing breathing gas mixtures or pressurized oxygen shall not be laid through accommodation spaces, engine rooms or other spaces with fire risk.

**4.3.17** The system supplying breathing gas to the standby diver's hose shall be independent from the main system that supplies gas to the working diver's hose.

**4.3.18** The gas supply system shall be so arranged that the purging of the compartment of a diving bell or lock-out submersible airlock shall not be linked with the supply of breathing gas to any diver.

**4.3.19** Low pressure gas systems fed from high pressure systems shall be equipped with pressure relief safety valves. The total pressure relief capacity of a safety device shall be sufficient to maintain the pressure inside the system not exceeding 110 % of the design pressure. The pressure relief arrangement shall be fitted as close as possible to the reducing valve.

**4.3.20** The oxygen shall be stored and distributed in the piping system intended exclusively for oxygen systems. The requirements to systems intended for handling gas mixtures with oxygen content of more than 23 % shall be the same as those to oxygen systems.

All components and materials of this system shall be of type and purpose suitable for oxygen and be carefully cleaned and degreased prior to commissioning. The maximum permissible pressure for oxygen stored in ship's fixed bottles shall be agreed with the Register. Leaks are not allowed in oxygen systems.

**4.3.21** As far as practicable, pressure in storage bottles and oxygen supply lines shall be reduced down to the minimum values which are still sufficient for normal gas supply to manned submersibles and ship's diving systems.

**4.3.22** Hoses used in oxygen systems shall be suitable for handling oxygen. The oxygen supply piping connections shall be fire resistant

**4.3.23** The diving bell oxygen system designed for metered oxygen supply to the bell shall be supplied from two independent bottles via independent inlets in the bell. Those inlets shall be so arranged to minimize the possibility of failure of both inlets as a result of a single accident. The oxygen supply arrangement shall be equipped with a metering unit to maintain the oxygen partial pressure within permissible limits and preventing unauthorized increase in oxygen content inside the compartment above the permissible level.

**4.3.24** The metered oxygen for saturation diving system compartments may be supplied directly to the compression chamber compartment, either through a dedicated gas distributor arranged under ceiling along the axis of the compression chamber and suitable for uniform distribution of the injected dose over the compartment, or be injected in the gas flow of the conditioning system in small doses for uniform mixing with the main gas. The oxygen supply upstream of charcoal filters is not allowed.

**4.3.25** Each manned compartment of manned submersibles, compression chambers, hyperbaric evacuation system, diving bell or lock-out submersible shall be equipped with breathing gas mixture regeneration and purifying system. Such a system shall safety maintain the CO<sub>2</sub> partial pressure inside compartments under operating conditions. The equipment of the system may be installed either inside the compartments or outside the compression chambers and be connected thereto by pipelines. For deep saturation diving systems, the system shall be independent for each compartment of the compression chamber and shall be duplicated.

**4.3.26** 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.

**4.3.27** In order to produce and maintain the required humidity, temperature, flowability and composition of the gas medium in the manned compartments of manned submersibles, compression chamber, diving bell and hyperbaric evacuation system, conditioning systems and arrangements shall be used. The purpose, components and characteristics of conditioning arrangements for compartments of manned submersibles and ship's diving systems shall be based on the purpose and conditions of using these compartments.

**4.3.28** In recompression and compression chambers intended for bounce dives, the following regeneration and conditioning means may be used:

**.1** periodic forced ventilation of compression chamber compartments during compression/recompression with compressed air at constant pressure, to provide oxygen enrichment, removing carbon dioxide and reduction of temperature and humidity;

**.2** ventilation arrangements inside compartments – fans of units for removal of carbon dioxide from the gas medium of the compression chamber (scrubbers). Where necessary, filters for removal of moisture and harmful substances may be also connected to these fans provided that their capacity specified in datasheets is maintained;

**.3** electric, steam or water heaters for the gas medium. These heaters may be used both for heating of gas medium directly inside the compartment and for heating the compressed

chamber hull. Provision shall be made for arrangements to provide electrical safety and restrict the temperature of the supplied thermal liquid.

**4.3.29** The compression chamber compartments for deep saturation diving systems may be equipped with the following regeneration and conditioning arrangements:

- .1** systems and arrangements specified in [4.3.24](#);
- .2** combined closed-loop breathing gas mixture conditioning and purification system for compressed chambers whose components may be arranged both outside and inside the compartments of saturation compression chambers;
- .3** additional breathing gas mixture heating units arranged inside the compression chamber compartments as additional means of breathing gas mixture thermal and humidity conditioning.

**4.3.30** The units of combined breathing gas mixture conditioning and purification systems are generally provided outside the saturation compression chambers in pressure hulls. Pressure hulls of units and pipelines shall be equal in strength with the compression chamber hull. For saturation compression chambers, regeneration and purification units are generally combined with conditioning units via pipelines into a single system with a common gas medium flow booster. This system may include gas medium flow boosters (fans), carbon dioxide absorbers, filters for removal of dust and harmful substances from the breathing gas mixture, antibacterial filters, gas medium dehydrators and heaters, breathing gas mixture automatic temperature and humidity control systems, gas distributors, pipe silencers, pipelines, regulating and isolating valves. Pipelines laid between units and compartments of compression chambers shall have an adequate flow rate capacity for designed gas exchange rate between medium purification and conditioning means and the controlled compartment. The flow rate is based on the compartment volume, type of gas medium, pressure and number of divers inside the compartment.

**4.3.31** The combined conditioning and purifying system for saturation compression chamber shall be closed for each manned compartment. The system's capacity shall be sufficient for emergency serving two adjacent compartments (two compression chambers) concurrently with the nominal number of divers inside the compartments. The system shall be capable of being controlled from the compression chamber control station. Intake and discharge pipes of the system are recommended to be arranged in opposite sections of the compartment, and the intake pipe shall be arranged in the lower part and near the sanitary enclosure wall (if any).

**4.3.32** Additional gas medium heat treatment units to be fitted in living compartments of the saturation compressed chamber shall operate as a standby conditioner generally connected for thermal and humidity conditioning of the helium breathing mixture at last decompression stages in the compression chamber.

**4.3.33** Covers of pressure hulls of pressurized carbon dioxide absorbers outside the compression chambers shall be equipped with locking mechanisms and safety devices (mechanical locks are preferred) to prevent accidental opening of covers under pressure and pressure increase in hulls of CO<sub>2</sub> absorbers should they be not fully closed.

**4.3.34** Corrosion-resistant non-toxic materials shall be used for structures of CO<sub>2</sub> removal systems. The materials shall be compatible with CO<sub>2</sub> removal agents.

**4.3.35** The carbon dioxide absorption cartridges and units shall be designed to be easy recharged without specific tools.

**4.3.36** The diving bells shall be provided with the main and emergency breathing gas mixture regeneration system capable of maintaining the permissible partial pressure of CO<sub>2</sub> in the diving bell for 24 h in case of emergency.



**4.3.37** For bounce compression chambers and recompression chambers (when operated with air), emergency removal of CO<sub>2</sub> may be carried out through forced ventilation provided that permissible noise levels are not exceeded.

**4.3.38** In the manned submersible compartments under atmospheric pressure, the life support system shall maintain an oxygen content in the air for breathing in the range from 18 to 23 % by volume, and CO<sub>2</sub> content below 0,5 % by volume under normal conditions and below 1 % by volume under emergency conditions.

**4.3.39** Where gas bottles are provided in the compartment of manned submersibles, their volume shall be so restricted that the total pressure of their contents shall not exceed the compartment pressure by more than 1 atm and does not increase oxygen content above 23 %. Where the design pressure increase exceed 1 atm or oxygen content exceeds 23 % by volume, the bottles shall be stored external to hull of the manned submersible or its manned compartment

**4.3.40** When calculating the necessary capacity of the main and emergency life support system in the maimed submersibles, the oxygen consumption shall be assumed to be equal to 28,3 l/hr per person, and the rate of CO<sub>2</sub> formation - equal to 0,0523 kg/hr per person.

**4.3.41** During operation of regeneration systems for manned submersibles and ship's diving systems at least the following parameters of gas medium in compartments shall be monitored:

- .1 oxygen content;
- .2 carbon dioxide content;
- .3 gas medium pressure;
- .4 gas medium temperature;
- .5 gas medium relative humidity;
- .6 helium content (for saturation diving system, if required).

**4.3.42** The gas supply systems shall be provided with means for sampling air and breathing gas mixture from bottles (group of bottles) to perform analyses for harmful substances according to the effective sanitary standards.

**4.3.43** The ship's deep diving systems may include plants (systems) for dynamic preparing breathing gas mixtures based on helium, oxygen and nitrogen in different combinations and percentage for further direct supply for diver breathing or filling intermediate reservoirs for the storage of breathing gas mixture. These plants shall operate automatically by means of: automatic control, indication and safety systems.

**4.3.44** The deep saturation diving system may include closed-loop gas supply systems for divers in the diving bell and with diving outfit. The system shall ensure circulation of breathing gas mixture between divers and support ship with regeneration and automatic maintenance of specified parameters of composition, temperature and humidity of: breathing gas mixture. The breathing gas mixture supplied to divers is normally heated in the diving bell by means of diving bell and diver heating system. In this case, the partial pressure of CO<sub>2</sub> in the purified breathing gas mixture shall not exceed 1 kPa.

**4.3.45** The closed-loop diver gas supply system shall generally include an intermediate receiver (a group of bottles) with such a volume that the partial pressure tolerances remain maintained within the first hour after receiving signals from gas analyzers that the breathing gas mixture is beyond the permissible range of oxygen or carbon dioxide content. In such a case, the audio-visual alarm signal shall be given to the ship's diving system control station. The control system shall maintain the gas mixture composition in terms of oxygen partial pressure with accuracy within +/- 0,03 bar. The oxygen control system shall be independent and be capable of automatically stopping the breathing gas mixture supply if: the composition tolerances are exceeded. In such a case, the breathing gas mixture shall be supplied to divers from alternative sources. In case of equipment failures, provision shall be made for

arrangements to prevent pressure drops inside diving outfits by more than  $\pm 6,0$  kPa relative to the common pressure in the breathing gas mixture to outfit supply line.

**4.3.46** The life support systems for ship's diving systems may include heating systems for divers with diving outfits. Water heating systems based on hot water boilers or electrical water heaters are generally used. The application of heating systems for divers with diving outfits shall be agreed with the Register.

**4.3.47** The heating systems shall be equipped with means to control and monitor flow rate and temperature of water supplied for diver heating and have a capacity sufficient to maintain the comfortable temperature of divers with diving outfit when in water and in the diving bell.

**4.3.48** The heating system for deep diving systems shall be fully redundant as regards to power supply systems, electric heaters and supply pumps.

**4.3.49** Non-redundant water heating plants shall not be used for dives which require diver decompression in cold water.

**4.3.50** The deep saturation diving system may include the used helium breathing mixture collection and recovery systems. The recovery system shall collect breathing gas mixtures discharged from compression chambers (during decompression), diving bell and gas systems, remove moisture, carbon dioxide and harmful substances from them, and then supply them to groups of bottles for recovered breathing gas mixture for subsequent reuse.

**4.3.51** The deep saturation diving system may include plants and systems for recovery/extraction of pure helium from recovered breathing gas mixtures. The plant shall remove nitrogen and oxygen impurities from the breathing gas mixture and extract a pure helium for further use in preparation of breathing gas mixture.

**4.3.52** Life support systems of compression chambers (hyperbaric compartments) of hyperbaric evacuation systems shall additionally meet the following requirements:

**.1** in addition to the controls intended for supplying breathing mixtures and maintaining their parameters, fitted externally, provision shall be made for the same controls fitted inside the pressure hull;

**.2** oxygen supply to the hyperbaric evacuation system compression chambers shall be controlled from the control panels and effected through two independent distribution systems;

**.3** hyperbaric evacuation systems intended for evacuation of divers with decompression carried out simultaneously shall be provided with life support systems including the systems for oxygen supply to the fixed breathing system masks;

**.4** evacuation compression chambers shall be equipped with connections for external supply of hot and cold water and breathing gas mixture; these connections shall be arranged on the outside in a readily accessible place:

3/4" for hot and cold water;

1/4" for breathing gas 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 at high temperatures in the event of fire on board the ship carrying ship's diving system shall be suitably insulated.

**4.3.53** The saturation compression chamber sanitary systems shall include sewage and domestic fresh water systems. A shower and a toilet in the saturation compression chamber shall be located in a separate compartment or an enclosure separated from the living compartment.

**4.3.54** The sewage system shall collect water drains from toilet, washbasin and shower into a separate sewage holding tank under pressure equal to the operating pressure in the compression chamber. As a rule, an individual sewage holding tank capable of being drained when full shall be provided for each compression chamber. The sewage tank filling level shall

be remotely monitored from the compression chamber control station. The arrangements for removal of bacteria and harmful odours from the breathing gas mixture shall be fitted on the ventilation pipeline of the sewage tank.

The system shall include the jet flush toilet. The flush toilets shall be equipped with the following:

- .1 locking arrangement to prevent flushing when a person is sitting on the toilet seat;
- .2 spacers on the toilet seat to avoid tight contact between the toilet and a sitting person;
- .3 flushing water under pressure at least equal to the maximum operating pressure in the compression chamber;
- .4 arrangement for actuation of the flushing system by two confirmed manual actions.

**4.3.55** To remove human wastes from the bounce compression chambers and recompression chambers, there may be used the composting toilets or special purpose tanks or bags, all capable of being transferred outside through airlocks from the manned compartments as they are filled (used).

**4.3.56** The saturation compression chamber fresh water systems shall generally include cold and hot water tanks under operating pressure equal to the maximum operating pressure in the compression chamber, water heaters, supply pumps, as well as shower and washbasin with appropriate fittings located in the sanitary compartment (enclosure) of the compression chamber.

**4.3.57** Where the water is supplied to the compression chamber under pressure difference between the water tank and compression chamber compartment, the breathing gas mixture corresponding to the medium in the compression chamber shall be used as a gas medium in the tank. Provision shall be made to prevent pressure loss in the compression chamber compartment while using the domestic water supply system.

#### **4.4 EMERGENCY LIFE-SUPPORT SYSTEM**

**4.4.1** All manned compartments of manned submersibles, compression chambers, diving bells and hyperbaric evacuation system shall be provided with emergency life support systems and arrangements independent from main life support systems. As a rule, emergency life support systems include the following:

**.1** respiratory protection equipment (RPE) in compartments in case of smoke or unacceptable deterioration of the gas medium composition in the compartment. These means include self-contained breathing apparatuses or fixed breathing systems with isolating masks (half-masks) with dedicated groups of bottles with purified compressed air or ready-to-use breathing gas mixtures. The bottles are generally arranged external to pressure hulls;

**.2** arrangements and systems for emergency removal of carbon dioxide from the gas medium in the compartment. These arrangements may include carbon dioxide absorbers inside compartments operating from independent power supplies, passive carbon dioxide absorption means like absorption cartridges, substances, etc.;

**.3** emergency oxygen sources as individual groups of bottles with emergency amounts of oxygen and systems for controlled metered supply of oxygen to the compartments. The application of solid sources of chemically bonded oxygen in form of standardized cartridges or pellets with actuation devices shall be agreed with the Register.

**4.4.2** For compartments of tethered manned submersibles and diving bells, emergency life support systems shall be provided to enable the personnel to remain therein in emergency situations for a period not less than 24 h over the entire range of operating conditions.

**4.4.3** Operating characteristics of emergency life support systems (capacity, working period, etc.) shall be confirmed by calculations performed according to the design conditions as agreed by the customer and competent organization.

**4.4.4** For compartments of self-sustained manned submersibles and hyperbaric evacuation systems, emergency life support systems shall be provided to enable the personnel to remain therein in emergency situations for a period not less than 72 h over the entire range of operating conditions. For the lock-out submersibles, a reduction in the minimum operating period of the emergency life support system to 24 h is permitted.

**4.4.5** The systems of emergency fixed breathing systems for living compartments of saturation diving system compression chambers shall include several groups of bottles with emergency breathing mixtures of various compositions which correspond to breathing gas mixtures that may be used within operating range of pressures inside the compression chamber compartments.

**4.4.6** The emergency breathing mixture shall be supplied to masks through a separate pipeline ensuring the required gas flow rate. The fixed breathing system shall supply the emergency gas over the entire range of operating pressures in the manned compartment.

**4.4.7** Where emergency life support systems with open-circuit masks (exhale beyond the compression chamber) are used in the compression chamber compartments, appropriate pressure regulators to protect masks against unacceptable pressure drops shall be fitted on the gas supply line and exhale line outside the compression chamber.

**4.4.8** The number of masks of emergency fixed breathing systems in the manned compartments of manned submersibles, in living and decompression compartments of compression chambers, in diving bells and hyperbaric evacuation system shall correspond to the number of operators or divers in this compartment. One spare mask shall be additionally provided. In ingress/egress compartments, the number of masks shall correspond to the maximum number of divers simultaneously passing from the compartment into diving bell, and one spare mask shall be additionally provided. Provision shall be made for at least two masks

in auxiliary compartments (lock-out, transfer compartments). Breathing masks in living compartments of compression chambers for breathing shall be arranged near each berth.

**4.4.9** The fixed breathing system masks shall be permanently connected or be capable of being easily connected to manifolds for supply and discharge of the breathing gas via quick-release connectors. To prevent incorrect connection of masks to manifolds, quick-release connections on the gas hoses connected shall be of various design and be properly marked.

**4.4.10** The breathing masks used in emergency fixed breathing systems shall be suitable for use during operation of these systems.

**4.4.11** The gas mixture amounts for fixed breathing systems of compression chambers, diving bells, hyperbaric evacuation systems, and compartments of lock-out submersibles shall be sufficient for breathing for a period required to complete the most long-lasting decompression sequence from all the possible design ones.

**4.4.12** Emergency life support arrangements and systems for diving bells, lock-out compartments of lock-out submersibles and divers with diving outfit shall be independent from main life support systems.

**4.4.13** Where the divers are provided with the breathing gas mixture through umbilical, the amounts of the breathing gas mixture for the emergency breathing system of diving bells and lock-out submersibles shall exceed the maximum of the following three values:

**.1** amounts required for breathing of a maximum number of divers in the diving bell and additionally one diver for 150 % time required for surfacing from the maximum operating depth but at least 2 h. The amounts are based on lung ventilation rate (at the atmospheric pressure) of 12 l/min per diver without physical exercise or 22,5 l/min in case of light exercise at higher pressure;

**.2** amount sufficient to provide each diver with diving outfit with the breathing gas for at least 15 min during operation outside the diving bell. The amounts shall be determined based on a respiratory minute volume of at least 45 l/min per diver for operation outside the bell in severe conditions, and 62,5 l/min per standby diver for extremely severe conditions (at the atmospheric pressure);

**.3** amount of the breathing gas mixture sufficient for draining water from the diving bell (lock-out compartment of the lock-out submersibles) when filled up to 40 % at the maximum operating depth.

**4.4.14** The amounts of the breathing gas mixture for the emergency life support system on board the lock-out submersibles with divers wearing self-contained breathing apparatus shall exceed the maximum of the following two values:

**.1** amounts required for breathing of a maximum number of divers in the lock-out submersible and additionally one diver for 150 % time required for surfacing from the maximum operating depth but at least 2 h. The amounts are based on lung ventilation rate (at the atmospheric pressure) of 12 l/min per diver without physical exercise or 22,5 l/min in case of light exercise at higher pressure;

**.2** amount of the breathing gas mixture sufficient for draining water from the lock-out compartment of the lock-out submersibles when filled up to 40 % at a maximum operating depth.

**4.4.15** The diving bell shall be provided with the emergency breathing gas mixture so that in case of failure in the diving bell's umbilical, the emergency amounts of the breathing gas mixture shall be manually or automatically supplied to divers without being discharged into the damaged umbilical. The fixed breathing system masks in the diving bell shall supply breathing gases both from the emergency source on the surface and ship's emergency life support system (diving masks and helmets may be also used as self-containing breathing means of emergency fixed breathing system).

**4.4.16** The half-bells may be provided with emergency breathing gas mixtures in amounts and composition corresponding to the diving depth and conditions. Where different breathing gas mixtures are used in the half-bell during bounce dives at appropriate phases of decompression, the system shall be capable of preventing errors when these mixtures are supplied to divers.

The emergency arrangements for emergency removal of carbon dioxide of the breathing gas mixture in compartments of manned submersibles and ship's diving systems shall be capable of removal of carbon dioxide from the gas medium in case of failure in the main life support systems for a period sufficient for remedying the fault or surfacing the personnel or completion of diver decompression. In such a case, the partial pressure of carbon dioxide in the emergency compartment shall not exceed the permissible values.

#### **4.5 VENTILATION AND AIR CONDITIONING**

**4.5.1** The spaces on the support ship for manned submersibles and ship's diving systems intended for receipt and transfer, gas storage and preparation of breathing gas mixture shall be 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 and safety devices used in the systems of the manned submersibles and ship's diving systems shall be of the RS approved type for appropriate operating conditions.

**4.6.2** Fittings used in the systems of the manned submersibles and ship's diving systems shall have position indicators: "open" and "closed". All essential valves, fittings and controls shall be marked with permanent identification number resistant to sea water.

**4.6.3** Fittings with the class corresponding to operating parameters of the medium used in the system may be used in the systems of the manned submersibles and ship's diving systems.

**4.6.4** Where reducing valves are used, safety valves and pressure gauges shall be fitted at the low-pressure side. The discharge capacity of the reducing 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** Casings with covers of gas fitting used in life support systems of the manned submersibles and ship's diving systems shall be tested for strength by a pressure equal to  $1,5P_{op}$ . 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 in all operating modes for the manned submersibles and ship's diving systems.

**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 %.

**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 safety valves shall enable their adjustment and operational testing.

**4.6.11** Safety valves of the manned submersibles and ship's diving systems installed on open decks shall be protected from atmospheric precipitation.

**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 pressure hull.

**4.6.13** The slow opening valves, e.g. needle valves providing for a smooth transition from the fully open to the fully closed position shall be used as control valves in the oxygen systems.

**4.6.14** The valves shall be so designed that their covers and spindles are secured against possible detachment

**4.6.15** Valves and safety devices of the systems shall be made of corrosion resistant material.

**4.6.16** The sea water backpressure effects shall be taken into account in the setting of safety valves operating under water.



#### **4.7 DIVING HOSES**

**4.7.1** Diving hoses are generally include gas supply hoses for diving bells and divers with diving outfit, hot water hose for heating diving bells and divers, hoses of pneumatic depth gauges.

**4.7.2** Diving hoses shall comply with the following requirements:

**.1** to enable their use in sea water at temperatures from  $-2$  to  $+50$  °C and at ambient air temperature from  $-55$  to  $+55$  °C;

**.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 % 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.

**4.7.3** The design of detachable and non-detachable connections intended for connecting the hoses shall ensure tightness and prevent any accidental damage and spontaneous disconnection of hoses.

**4.7.4** Hoses shall be fracture resistant and have corrosion-resistant fittings designed for rated parameters of the medium conveyed.

**4.7.5** Diving hoses may be included in umbilicals which connect the diving ship with the diving bell (half-bell), and in umbilicals of diving outfits. According to their purpose, the umbilicals of the manned submersibles, diving bells and divers may contain various control and communication cables, gas and hydraulic hoses, as well as power cables and components.

**4.7.6** The weight of diving bells and umbilicals shall be taken up by a strong strength component of the umbilical which shall be its structural component and shall not impose load on its constituent diving hoses and cables.

**4.7.7** The points of umbilical connections to connectors and cable penetrators shall not be exposed to unacceptable loads and fracture.

## **4.8 CONTROL STATIONS AND PANELS**

**4.8.1** For safe and efficient operation, the manned submersibles and ship's diving systems shall be equipped with centralized control stations continuously manned during operations, as well as local control stations for control of some most essential machinery, systems and devices that depending on their purpose may be continuously or temporarily manned.

**4.8.2** The following specially equipped control stations shall, as a minimum, be included in the ship's diving systems on board the support ship:

**.1** compression chamber control and support station to control and monitor technical means and life support systems of the ship's diving systems and diver actions inside the compartments in order to ensure their normal vital activity under pressurized gas medium at all stages of diving operations;

**.2** diving operation control station to control technical means and systems of the ship's diving systems, as well as to monitor diver actions under water, while diving from the support ship, diving bells (half-bells) or stages.

**4.8.3** During underwater operations, the diving operation control station shall generally operate as a central control station of the ship's diving system; while at the decompression stage, the compression chamber control and support station shall operate as a central control station of the ship's diving system.

**4.8.4** For bounce diving systems, the functions of compression chamber control station and diving operation control station may be combined. For saturation diving systems, the diving operation control station shall be generally separated from other control stations.

**4.8.5** The number of local control stations for the ship's diving systems depends on the type of the ship's diving system, as well as extent of automation and centralization of the control and monitoring processes. Some most essential local control stations may be arranged on the central control stations, e.g. gas supply stations for diving bells and divers, physiologist station, control station for diving bell handling systems, etc.

**4.8.6** Control stations for mobile lock-out submersibles and ship's diving systems may be arranged in spaces equipped in containers, and they shall comply with general requirements for stations for lock-out submersibles and ship's diving systems.

**4.8.7** Control stations for mobile lock-out submersibles and ship's diving systems shall be designed to minimize exposure to external factors impeding the control (audio-visual interference, restricted access to working areas, etc).

**4.8.8** The ship's diving system control stations shall provide comfortable environment for operators in any specified conditions. The air intake by the ventilation system of the control station space shall be from the non-hazardous area. Provision shall be made for main and independent emergency lighting means for spaces, panels and control boards on stations.

**4.8.9** Control stations shall be equipped with fire detection and fire alarm systems, fire protection means and means for control of fire extinguishing system in accordance with the requirements of these Rules.

**4.8.10** Control stations for handling of the manned submersibles and diving bells shall be located in safe areas of the support ship and have independent exits to the open deck. Release of gas mixtures in hazardous quantities from compression chambers, systems or bottles shall take place in the control station spaces.

**4.8.11** Control stations for handling of the manned submersibles, diving bells and hyperbaric evacuation system shall have access to their launching area and area of their mating to the ingress/egress compartment of the compression chamber. A clear view of these areas shall be provided from control station.

**4.8.12** Control stations (panels) for self-contained manned submersibles (lock-out submersibles) shall, as a minimum, be equipped with the following:

- .1 tachometers and instruments showing the sense of rotation of propulsors;
  - .2 indicators showing amount of water in compensating tanks;
  - .3 signalling instruments and devices to monitoring and alarm for pressure and gas medium composition in the manned compartments;
  - .4 instruments to monitor current, voltage, insulation resistance of electric circuit and accumulator battery capacity (if required);
  - .5 machinery equipment indicators;
  - .6 fire detection alarms;
  - .7 ballast tank level indicators (if any);
  - .8 jettisoned ballast indicators;
  - .9 pressure gauges for bottles (group of bottles) with compressed air, oxygen, breathing gas mixture, etc.;
  - .10 navigation, radio equipment and communication systems;
  - .11 internal (intercompartment) communication systems;
  - .12 electric consumer power supply controls;
  - .13 pressure regulators in the lock-out compartment of lock-out submersibles;
  - .14 oxygen metered supply arrangements;
  - .15 arrangements to control and monitor of gas supply to diving outfits (for lock-out submersibles);
  - .16 arrangement for compartment temperature control;
  - .17 arrangements for increase and relief pressure from compartments (for lock out submersibles) from internal and external sources;
  - .18 arrangements to monitor the pressure of breathing mixture supply to masks of emergency fixed breathing system;
  - .19 diver communication means (for lock-out submersibles).
- 4.8.13** The diving operation control station shall, as a minimum, be equipped with the following:
- .1 gas supply panel (board) equipped with the following:
    - arrangements for controlled supply of compressed air and breathing gas mixture to the diving bell and diving outfits;
    - arrangements for controlled supply of breathing gas mixture to the diving compartment of lock-out submersible and hyperbaric evacuation system (on board the support ship);
    - pressure gauges and flow regulators in groups of bottles with gases and gas mixtures;
    - switchers from operational breathing gas mixture supply to emergency breathing gas mixture supply;
    - pressure equalizers between diving bells, lock-out submersibles, hyperbaric evacuation systems, transfer devices and compression chamber compartment;
  - .2 control panels for handling systems of diving bells, lock-out submersibles, hyperbaric evacuation systems equipped according to the requirements of Chapter X "Shipboard Handling Systems of Manned Submersibles and Ship's Diving System" of these Rules;
  - .3 arrangements to monitor pressure, temperature, oxygen and carbon dioxide content in the atmosphere of diving bells, ingress/egress compartment of the compression chamber and transfer trunk of the diving bell;
  - .4 pneumatic depth gauges to monitor the submersion depth of the diving bell, stage and each diver;
  - .5 arrangements to monitor temperature and flow rate of hot water from the water heating system to the diving bells and divers;
  - .6 diving bell/half-bell main external and internal lighting controls;
  - .7 arrangements for main and emergency communication and audio recording voice exchange with diving bell operators and divers under water and with ingress/egress

compartment (compression chamber), as well as means for loud speaking communication with the compression chamber control station, local stations of ship's diving systems, main control station and navigation bridge (dynamic positioning station) and shipboard cargo crane (if used for diving operations);

**.8** means for displaying ship's position during operation of dynamic positioning system to maintain its position at the operational areas (recommended for deep diving system);

**.9** means for video monitoring and video recording of diver actions under water, in diving bells, in compression chambers (for deep diving system), at the area of diver/diving bell/stage launching on the ship's deck, as well as of operation of ship's diving system machinery in unmanned spaces (where necessary, as agreed upon with the customer);

**.10** alarm systems of machinery equipment of the facility for mating diving bells, lock-out submersibles, hyperbaric evacuation systems with the compression chamber;

**.11** fire alarms in spaces of ship's diving systems and compression chamber compartments (if any);

**.12** marine chronometer;

**.13** control panel (board) of the diving bell and diver closed-loop gas supply control and monitoring system (for saturation diving system) equipped with the following:

pressure gauges in gasholder and on suction and discharge lines of the compressor/compressors;

instruments for continuous measurement of carbon dioxide and oxygen content, temperature and humidity of the gas medium supplied to the diving bell through umbilical;

oxygen metering control arrangements;

system emergency protection actuation indicators;

test gas mixture supply devices for calibration of gas analyzers.

**4.8.14** Compression chamber control and support station which shall be equipped with the following:

**.1** panels (boards) of the control and monitoring system for gas supply systems of each compartment of all compression chambers equipped with the following:

instruments for direct monitoring of pressure in compression chamber compartments;

arrangements for controlled supply of air, helium and breathing gas mixture to compression chamber compartments during compression, for controlled pressure relief in compartments during decompression and pressure by-pass between compartments;

air lock transfer system control;

arrangements for monitoring pressure in all storage bottles for compressed air, helium and breathing gas mixture, as well as pressure downstream of reducers on gas supply lines;

automatic and manual controls of oxygen metered flow to compression chamber compartments;

arrangements for monitoring breathing gas mixture of oxygen supply to masks of the fixed breathing system in each individual compartment;

**.2** means for control and monitoring of sewage, domestic water supply and fire main systems of compartments;

**.3** panels (boards) of arrangements and systems for continuous gas monitoring of atmospheric content in compression chamber compartments equipped with the following:

oxygen percentage/partial pressure gauges;

carbon dioxide partial pressure gauges;

helium percentage gauges (for saturation compression chamber);

calibration and operability test instruments for gas analyzers;

**.4** means for control and monitoring of gas medium flow boosters of compression chamber air conditioning systems as well as controls of gas medium scrubbers and breathing gas mixture additional heat treatment units inside the compartment;

**.5** means for control and monitoring of temperature and relative humidity inside compression chamber compartments (where applicable);

**.6** indicators on actuation of compression chamber life support system warning alarms;

**.7** fire detection and alarm systems in compression chamber compartments (where applicable) and in spaces of ship's diving systems;

**.8** marine chronometer with stopwatch;

**.9** arrangements for main and emergency communication with compression chamber compartments, diving operation control station, local control stations of ship's diving systems, as well as with main control station and navigation bridge of the support ship. For saturation compression chambers, arrangements for audio recording voice exchange with divers in compression chambers are recommended;

**.10** controls of compression chamber compartment main and emergency lighting;

**.11** arrangements for monitoring the pressure of breathing mixture or oxygen supply to masks of emergency fixed breathing system;

**.12** video monitoring means of diver actions inside compression chambers, as well as of operation of machinery of ship's diving system in unmanned spaces. (For saturation compression chambers, arrangements for video recording of diver actions in compression chamber compartments are recommended);

**.13** means for broadcasting of entertainment programs to compressed chamber compartments (as required for saturation compression chambers);

**.14** oxygen content alarms in ship's spaces with oxygen equipment of ship's diving systems and hydrogen content alarms in accumulator battery spaces (where necessary).

**4.8.15** The application of automated computer-based systems for control, monitoring and recording of parameters of ship's diving system life support systems shall be agreed with the Register.

**4.8.16** The loud speaking communication system shall be used as a main communication arrangement between all control stations of ship's diving system on board the support ship. In addition to that, provision shall be made for a telephone communication as an emergency communication between main control stations (navigation bridge), diving operation control station and compression chamber control station.

**4.8.17** Breathing gas mixtures shall be supplied to gas supply panels via two independent mains.

**4.8.18** The gas supply control panels shall be capable of supplying gases or breathing gas mixtures separately to consumers.

**4.8.19** The main controls on panels shall be readily accessible and shall have marking and distinctive painting. On life support system control panels, it is recommended to use mimic diagrams jointly with the controls permitting control of the system equipment and closing fittings. For panels with a large number of controls, it is recommended to use levers, tumbler switches and handwheels of different shapes.

**4.8.20** Visible and audible alarm devices shall be generally provided in the control panels of systems and devices of the manned submersibles and ship's diving systems to indicate malfunctions and hazardous variation of gas medium parameters in the manned compartments.

**4.8.21** When using electronic instruments for metering gas pressure supplied to compression chambers, diving bells (lock-out submersibles) and divers, the panels shall be additionally provided with direct pressure meters (pressure and depth gauges).

**4.8.22** Control and monitoring devices on panels and boards of the manned submersibles and ship's diving systems shall be combined in functional groups.

## **4.9 INSTRUMENTATION**

**4.9.1** The manned submersibles and ship's diving systems shall have instrumentation to ensure safety of diving operations and monitor parameters of the systems and equipment applied.

**4.9.2** Instrumentation used in the manned submersibles and ship's diving systems shall correspond to their purpose and operating conditions as well as comply with the requirements of national legislation for instrumentation.

**4.9.3** Instrumentation shall be subject to periodic metrological checking (calibration) for accuracy of readings and monitoring of limit settings. Checking and sealing (branding) of pressure gauges shall be carried out not less than once per year by the competent bodies recognized by the Register.

**4.9.4** Indicating gauges and indicators shall be so arranged and marked to be easily and unambiguously read.

**4.9.5** 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.

**4.9.6** Compression chamber compartments may be equipped with clocks, pressure and temperature gauges, and gas analyzers capable of being read from inside of the compression chamber.

**4.9.7** Provision shall be made for alternative measurement methods for instruments ensuring safety of personnel in the manned submersibles and ship's diving systems (depth of submergence, pressure and content of gas medium in compartments, etc.). The components of redundant instrumentation shall be agreed upon with RS on the case-by-case basis.

**4.9.8** The pressure gauges of diving bells and compression chambers shall be installed so that to allow readings of several instruments to be compared.

Pressure gauges in compartments and depth gauges in the manned submersibles and ship's diving systems shall have arrangements for their cutoff and connection of the checking devices.

**4.9.9** Pressure gauges measuring gas medium supply to the compression chambers and diving bells and directly to a diver shall be of type 1 precision class.

**4.9.10** The instrumentation accuracy for measuring pressure in compression chambers, diving bells and near divers in the bounce diving system shall be equal at least 1 % of scale over the entire measurement range. In the saturation diving system, the pressure measurement accuracy shall be equal to  $\pm 0,3$  % of the full scale, and for range of depths (pressures in compression chamber) from 0 to 30 mH<sub>2</sub>O) at least  $\pm 0,25$  %. The depth gauge scales shall have a scale reserve at least 20 % of the rated depth of submergence.

**4.9.11** Pressures inside and outside the diving bells for divers shall be measured by mechanical instrumentation fitted inside the diving bell.

**4.9.12** Gas analyzers used in compartments of the manned submersibles, compression chambers, diving bell, diving compartment of lock-out submersibles, in hyperbaric evacuation systems and closed-loop diver gas supply systems shall be suitable for operating conditions and be of the approved type. Operating fluctuations in temperature, humidity and pressure in compartments of the manned submersibles and ship's diving systems shall not affect the permissible measurement accuracy of gas analyzers.

**4.9.13** Provision shall be made for additional self-contained rapid oxygen and carbon dioxide analyzers in the manned submersibles with atmospheric pressure in compartments, in addition to fixed gas analyzers.

**4.9.14** For diving systems intended for operation near Floating Production Storage and Offloading Units (FPSOs), arrangements for monitoring the content of hydrocarbon gases and H<sub>2</sub>S in the diving bell atmosphere are recommended.

**4.9.15** Gas analyzers of the diving bell and lock-out compartment of the lock-out submersible shall operate from independent power supply for at least 24 h.

**4.9.16** Provision shall be made for suitable calibration gas mixtures for operation check of accuracy of gas analyzers of the manned submersibles and ship's diving systems.

**4.9.17** Electronic instruments of the manned submersibles and ship's diving systems shall comply with applicable requirements of Section 2, Part XV "Automation" of the Rules for the Classification and Construction of Sea-Going Ships.

**4.9.18** Pressure gauges for oxygen or breathing gas mixture with oxygen content exceeding 23 % shall be marked to indicate that they are free of oil and grease.

## **PART VII. ELECTRICAL EQUIPMENT**

### **1 GENERAL**

#### **1.1 APPLICATION**

**1.1.1** The requirements of this 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 Relating to Manned Submersibles and Ship's Diving Systems 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 Relating to Manned Submersibles and Ship's Diving Systems 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 other electrical equipment of the life support system;

**.4** electric drives of the arrangements for emergency release of ballast and other outboard equipment of the manned submersibles and diving bells to be jettisoned in case of emergency surfacing;

**.5** electric systems and devices for monitoring and alarm (actual and limiting values) for submergence depth, overpressure in the diving bell and compression chambers, pressure, composition 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 specified 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 specified 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](#) shall be subject to survey during manufacture.

**1.3.6** The electrical equipment of the manned submersibles and ship's diving systems installed in dangerous areas as well as designed for ensuring hydrocarbon production operations shall be surveyed (with respect to its safety) by a competent authority whose documents are recognized by the Register, irrespective whether or not this equipment is subject to survey according to the requirements of 1.3.3.1, Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships.

**1.3.7** All electrical equipment installed on the manned submersibles and ship's diving systems shall be type approved by the Register.

## **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 diving bells. 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 and their 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 diving bells, 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 diving bells, or it would be possible to supply such services from the support ship's electric power plant. The electric power plant shall be located on board the ship outside the room with support equipment of the tethered manned submersibles and diving bells.

**2.1.3** The emergency source of electrical power for the tethered manned submersibles and diving bells may be the support ship's emergency power source if 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 recovery of the tethered manned submersible or diving bell aboard the support ship, the following equipment of the tethered manned submersibles (diving bells):

- .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 emergency heating systems of the manned submersibles (diving bells) 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 diving bell shall be provided with an emergency accumulator battery installed directly on the manned submersible and diving bell, of a capacity sufficient for power supply, without reduction of voltage at its terminals lower than 0,9 times the rated voltage of the following electrical consumers supporting vital activity of the crew within 24 h:

- .1 emergency lighting;
- .2 emergency communication means;
- .3 life support system units;
- .4 environmental monitoring devices;
- .5 main control systems;
- .6 alarm device to indicate submergence to design depth (if its operation depends on the electrical power);
- .7 surfacing position indicators and flashing lights;
- .8 ballast release devices at emergency surfacing.

## **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 shall be accumulator batteries. Other electrical power sources with equivalent properties and safe in operation under the project concerned may be used.

**2.2.2** The main source of electrical power of the manned submersibles shall have the power (capacity) sufficient to supply all the necessary equipment for the period of normal voyage and in addition thereto, it shall have the power/capacity reserve to provide supply of electrical power, for a time period consistent with the emergency rescue plan but not less than 24 h, to the following consumers:

- .1 emergency lighting;
- .2 communication equipment;
- .3 life support systems;
- .4 environmental monitoring devices;
- .5 main control systems;
- .6 alarm devices to indicate submergence to design depth (if its operation depends on electrical power);
- .7 surfacing position indicators and flashing lights.

**2.2.3** 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 for 72 h without reduction of voltage below 0,9 of the rated one of the following consumers:

- .1 electrical consumers of the life support system;
- .2 emergency communication;
- .3 emergency lighting;
- .4 ballast release;
- .5 surfacing position indicators and signaling means.

For the diving self-sustained manned submersibles, it is allowed to reduce the operating time of emergency consumers, but it shall not be less than that specified in [2.1.4](#).

**2.2.4** 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.

**2.2.5** 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 [2.2.2](#), 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.

### **2.3 ELECTRICAL POWER SOURCES OF SHIP'S DIVING SYSTEMS**

**2.3.1** Electrical systems and installations providing main power supply to consumers of ship's diving systems shall be supplied with power from the main and emergency electrical power sources.

Where the generators of the diving ship are used as the main electrical power source for the ship's diving system, provision shall be made for its supply both from main and from emergency generators.

**2.3.2** All electrical equipment essential for the safety of divers and diving operations shall have main and standby power sources. The capacity of the emergency electrical power source shall be sufficient to supply electrical power to all consumers having emergency functions for safe completion of diving operations.

**2.3.3** The ship's emergency electrical power source may be used as an emergency source provided that it has an adequate capacity for supplying ship's diving systems and emergency consumers.

## **2.4 ELECTRICAL POWER DISTRIBUTION AND ALLOWABLE VOLTAGE**

**2.4.1** The following systems of electrical power distribution may be used on the manned submersibles and ship's diving systems:

- .1** direct current (DC);
- .2** single-phase two-wire isolated mains;
- .3** three-phase three-wire isolated mains.

Only isolated systems of electrical power distribution are allowed in the electrical installations of the manned submersibles and ship's diving systems. Systems with earthed neutral wire shall not be used on the manned submersibles.

**2.4.2** Each isolated system of electrical power distribution with the nominal voltage above 50 V AC and 110 V DC shall have devices for monitoring and alarm to indicate an inadmissible reduction of the insulation resistance.

A change-over arrangement or a separate device for each network of isolated systems for measuring and indicating insulation resistance shall be installed on the main and emergency switchboards. In any case, the hull leakage current due to the operation of the measuring device shall not exceed 30 mA.

Audible and visual alarms to warn of inadmissible decrease in the insulation resistance shall be provided on the control panel of the ship's diving systems and manned submersibles.

**2.4.3** The nominal voltage at the terminals of power sources and electrical 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.

**2.4.4** The consumers of ship's diving systems may be supplied with main power directly from specified sections of the ship's main switchboard or its own main power switchboard.

**2.4.5** The power switchboards of ship's diving systems shall be supplied by two different feeders laid in widely separated routes from different sections of the main switchboard (switchboards).

**2.4.6** Electric drives of all machinery and equipment of the manned submersibles and ship's diving systems shall have means for centralized emergency switch-off. Such means shall be located in permanently attended control station (control station of the ship's diving systems).

**2.4.7** Standby control cables for a single circuit shall be laid through different cable penetrations in the pressure hull of the manned submersibles and ship's diving systems (gastight seals of a type approved by the Register capable of withstanding hydrostatic pressure equal to the test pressure of the pressure hull of the manned submersibles, ship's diving systems) and shall be installed at the maximum possible distance from each other.

**2.4.8** The following consumers shall be supplied through separate circuits:

- .1** handling and transportation platforms for the manned submersibles and diving bells;
- .2** lighting systems for decompression chambers and diving bells;
- .3** electrical consumers of systems of life support devices;
- .4** communication systems.

**2.4.9** Ammeters shall be installed in the circuits of essential consumers rated at 20 A and over. Ammeters shall be provided on the main switchboards or on switchboards in control stations.

## **2.5 POWER SUPPLY OF ESSENTIAL SERVICES**

**2.5.1** 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 distribution switchboards of the tethered manned submersible, diving bell and compression chambers of the ship's diving system.

**2.5.2** 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 and ships diving systems:

- .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.

**2.5.3** The emergency source of electrical power for the essential services of the ship's diving systems shall be an independent accumulator battery.

**2.5.4** The emergency accumulator battery power source on board the support ship shall ensure concurrent supply of at least the following components of the ship's diving system equipment:

- .1 emergency lighting systems in decompression chambers and control stations of the ship's diving systems, and on areas when operations are performed;
- .2 systems for emergency communication with compression chambers and between compression chamber compartments;
- .3 life support systems, arrangements and devices of compression chambers;
- .4 central control station as well as necessary check systems and alarm systems.

## **2.6 DISTRIBUTION GEAR AND PROTECTIVE DEVICES**

**2.6.1** Circuit breakers shall be used for protection of electrical equipment against overloads and short circuit in electric mains of the manned submersibles and ship's diving systems.

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.

**2.6.2** Each outgoing circuit in a switchboard shall be provided with an appropriate circuit breaker to disconnect all poles and phases. Circuit breakers of power consumers of tethered manned submersibles, compression chambers and diving bells shall be fitted in the control station of the ship's diving system.

**2.6.3** Provision shall be made for audible and visual alarms to warn of inadmissible decrease in the insulation resistance. The insulation resistance shall be continuously monitored. The indicator shall be located on the control panel of the ship's diving system or manned submersible. The alarm indicator which actuates from the system for insulation resistance monitoring of diving bell electric equipment shall be also recommended in the diving bell.



## **2.7 ELECTRIC DRIVES OF MACHINERY AND EQUIPMENT**

**2.7.1** Electric drives of all 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 on the support ship.

**2.7.2** Provision shall be made for arrangements preventing the generation and accumulation of moisture and condensate in casings of electric propulsion motors of the manned submersibles. These arrangements may electric heaters, air dryers, etc.

**2.7.3** All electric drives in the propulsion plant and other essential systems shall be equipped with overload alarm in addition to overload protection of the electric drive. The overload alarm shall actuate at the permanently attended control station (control station of the ship's diving system) early enough before actuation of the electric drive overload protection (25 % of current overload).

**2.7.4** The electric drivers of machinery and equipment for the manned submersibles and ship's diving systems shall be marked with their purpose and brief indication of characteristics.

**2.7.5** Provision shall be made for an automatic power limitation of drive motors for overload protection of the ship's power source.

**2.7.6** The automatic power limitation of drive motors shall protect the ship's power source against total power loss (over-discharging of accumulator batteries).

**2.7.7** Electric drives inside the pressure hull of the manned submersibles, diving bells and compression chambers shall be equipped with overload alarms with alarm signals to control stations. For electric drives in the diving bells, the alarm signals may be provided in diving bells.

**2.7.8** Collector-type electric motors shall not be installed in the compression chamber compartments.

## **2.8 LIGHTING**

**2.8.1** The lighting inside manned compartments and on control stations shall be such as to read all instruments and marking correctly.

**2.8.2** 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 in case of failure in the main lighting. It is allowed to have the same lighting fixtures for the main and emergency lighting.

**2.8.3** Lighting fixtures in compartments of the manned submersibles, diving bells and compression chambers shall be protected against mechanical damages.

**2.8.4** In pressurized compartments of the manned submersibles, compression chambers and diving bells, the lighting fixtures shall be designed to enable replacement of lamps or lighting fixtures under pressure. No switches of the lighting fixtures shall be installed in the compression chambers.

**2.8.5** 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.

**2.8.6** Socket outlets for portable lighting and other portable electrical equipment shall have an electrical or mechanical locking arrangement to protect the plug contacts from being energized when inserted into socket outlet or portable socket and to prevent the withdrawal of the plug while its contacts are live or to de-energize the contacts before withdrawal.

**2.8.7** The illumination inside compression chambers shall be at least 60 lux.

## **2.9 SERVICE TELEPHONE COMMUNICATION AND VIDEO MONITORING**

**2.9.1** The control station of the manned submersibles and ship's diving system on board the support ship shall have a two-way telephone communication with the following:

- .1** divers in the water;
- .2** diving bell operator;
- .3** manned submersible crew;
- .4** each compartment of compression chambers;
- .5** control stations of handling system, machinery and arrangements for supporting manned submersibles and ship's diving systems;
- .6** central control station of support ship;
- .7** control station of the ship's dynamic positioning system and others involved when operating with control stations of the manned submersibles and ship's diving systems;
- .8** hyperbaric evacuation system;
- .9** operator of the deep crane used during underwater diving operations;
- .10** operator of a remotely operated vehicle (ROV) when used for supporting underwater diving operations.

**2.9.2** The control station of the self-sustained manned submersible shall have an independent telephone communication with the diving compartment (for lock-out submersible) 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.

**2.9.3** The tethered manned submersible and diving bell shall be equipped with telephone wire communication with the control station of the manned submersible and ship's diving system on the support ship as a main communication system. The system shall be equipped with self-return switches for reversion of the communication direction.

**2.9.4** To maintain the communication with the diving bell, compartment of the lock-out submersible or compression chamber intended for operation with the use of helium breathing gas mixture, not less than two speech unscramblers shall be installed.

**2.9.5** Provision shall be made to maintain the communication between separate compartments of compression chambers or between compression chambers in the compression system of the ship's diving system including the use of unscramblers when handling helium breathing gas mixtures.

**2.9.6** 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.

**2.9.7** Provision shall be made for emergency arrangements for communication between the control station of the manned submersibles and diving bells, and divers under water and inside compression chambers. For diving bells, such a system may be the automatic sonar communication system.

**2.9.8** Main communication system shall be supplied from two independent power sources, where one source shall be an emergency source. The compression chamber emergency communication system may be duplicated by channels of the main system or include an induction telephone or other means capable of being operative in case of main system operability loss.

**2.9.9** Where there is no visual contact between the personnel at the control station and divers in the diving bells and compression chambers, the emergency system shall be equipped with visual and audible alarm.

**2.9.10** The control stations of the manned submersibles and ship's diving systems are recommended to be provided with means to record all conversations with manned submersible operators as well as with divers in diving bells, compression chambers and during underwater operations.

**2.9.11** Voice communication between the control station and compartments of the manned submersibles, diving bells and compression chambers shall be activated when the tumbler switch on the control panel is switched to the RX position. Each compression chamber compartment shall be provided with at least one telephone-microphone headset.

**2.9.12** The voice communication electrical systems shall be provided with a standby power supply source.

**2.9.13** A microphone and telephone in spaces with increased humidity shall be of appropriate waterproof type.

**2.9.14** A microphone and speakers in diving masks and helmets shall be functionally separated from each other.

**2.9.15** In addition to the communication systems specified above, provision shall be made for tapping communication code signs in the diving bell and compression chambers for urgent emergency communication. These signs shall be placed inside and outside the diving bell, compression chambers and in the main control station of the ship's diving system.

**2.9.16** Self-sustained submersibles shall be equipped with at least one single-channel sonar communication system.

**2.9.17** Voice communication systems shall be provided with volume controls.

**2.9.18** Compression chamber compartments for saturation diving systems may be equipped with radio and video broadcasting equipment.

**2.9.19** Manned submersibles may be provided with underwater CCTV systems and video recording systems with video data display on the control station of the self-sustained or tethered manned submersible on board the support ship.

**2.9.20** Depending on type, the ship's diving systems may be provided with the following video systems:

- .1** for monitoring of divers under water with diving outfit;
- .2** for monitoring of divers in the diving bell and under water with diving outfit;
- .3** for monitoring of divers in the compression chamber;
- .4** for monitoring of operation of supporting machinery and equipment of ship's diving system on board the support ship.

**2.9.21** Saturation compression chambers and medical treatment compression chambers shall be equipped with CCTV system. The number of video cameras and their angle of view shall be selected so that all manned areas inside the compression chamber might be monitored.

**2.9.22** In the ship's diving system, the number of video cameras shall be sufficient for complete monitoring of safe performance of the most essential diving operations and processes. Each video display unit shall clearly indicate what compartment is currently displayed. The images on video display units shall allow for identification of necessary details.

**2.9.23** Video data from video cameras shall be output to video display units of the diving operation control station supervisor. A video recorder is also recommended to be installed in the system. The number of concurrently displayed video images and scope of recorded data shall be determined separately in each particular case.

## **2.10 CABLING**

**2.10.1** Cables and wires for the manned submersibles and ship's diving systems shall be suitable for marine use and be approved by the Register.

**2.10.2** In cabling of the manned submersibles and ship's diving systems 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. All cables shall be shielded with exterior insulation sleeve.

**2.10.3** The umbilical, by means of which the electrical power is supplied to the tethered manned submersible (diving bell), shall have an adequate strength to prevent cable from breaking due to tensioning and jerks in a seaway.

**2.10.4** Cables laid through the pressure hull of the manned submersible, diving bell or compression chamber 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.

**2.10.5** 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.

**2.10.6** Cables external to the manned submersibles and diving bells shall be designed for external high hydrostatic pressure at least equal to the submersion destructive pressure of the pressure hull. The pressure resistance shall be checked through pressure tests of each cable section with mated connectors (if any). Each submersible cable or umbilical shall be tested in the presence of the RS representative.

**2.10.7** Cables of the manned submersibles and ship's diving systems shall be protected against mechanical damages and shall not be exposed to tensile loads during operation. Cables being wound on drums shall be stowed according to permissible bending radii and without mechanical damages.

**2.10.8** Power and control cables, signalling and protection cables shall be well separated. Electric plugs, sockets and receivers shall be of special type preventing incorrect connection of different systems and be fitted with locking arrangements to be locked after connection.

**2.10.9** Insulating braids, protective coverings and cable fillers in cables used in compartments of the manned submersibles, diving bells and compression chambers shall be halogen-free and produce no toxic, hazardous or combustible gases even when overheated. Cables used in compartments of diving bells and compression chambers shall be allowed for application in high pressure gas medium according to operational conditions.

**2.10.10** The disconnected ends of insulated wires shall be protected with sleeves of non combustible materials, e.g. glass fibre.

**2.10.11** Flexible multi-core cables for transmission of electrical power or signals to divers and diving bell shall be made as a dry-core cable i.e. with external insulation to protect insulation of individual wires from ingress of water under operating hydrostatic pressure.

**2.10.12** Electric cables shall be readily accessible for visual inspection, unless laid in pipelines.

**2.10.13** Switchboards shall be so located to minimize the length of cables coming from emergency accumulator batteries to the switchboard. Cables shall be laid to circuit breakers in individual cable ducts.

**2.10.14** Low-voltage cables shall not be laid together with high-voltage cables.

## **2.11 CABLE PENETRATIONS IN THE PRESSURE HULL**

**2.11.1** Cable penetrations in pressure hulls of the manned submersibles, diving bells and compression chambers, plug-and-socket (joints and connectors shall be made tight (i.e. to prevent leakage of liquid or gas medium under test pressure) when operating under specified conditions, when the parts of cable connectors are disconnected and in emergency conditions in case of break or other damage of cables.

**2.11.2** Electrical cable penetrations in the pressure hull shall be designed, manufactured and tested in compliance with the requirements of the national or international standards and have a type approval certificate.

**2.11.3** Electrical conductors in the cable penetrations shall be manufactured of monolithic (non-multicore) material.

**2.11.4** Positive and negative conductors from the same electrical power source shall not be led into the pressure hull through the same penetrator. Conductors running from main and emergency power sources shall also not pass through the same cable penetrator or connection in the pressure hull of the manned submersibles, diving bells and compression chambers. 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.

**2.11.5** The cable penetrations shall not be used for leading any pipelines but common removable plates in the pressure hull to lead in both the cables and the pipelines may be used subject to agreement

**2.11.6** The cable connectors shall have corrosion-resistant cases with protection against accidental disconnection. Cables included in umbilical of the tethered manned submersibles and diving bells shall be so located that the weight of the bell (or capsule) is supported by the strong bearing structural member located in the area where the umbilical is considered as an emergency arrangement for lifting the tethered manned submersible and diving bell up to the water surface.

**2.11.7** Cable glands for which the electric cable is a part of the pressure hull shall be tested assembled with a short cable.

## **2.12 ACCUMULATOR BATTERIES AND CHARGING FACILITIES**

**2.12.1** The accumulator batteries of the manned submersibles and ship's diving systems shall comply with the requirements of Chapter 13, Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships in terms of design, installation method and operational conditions, and be of the RS-approved type.

**2.12.2** Accumulator batteries, which in the process of operation give off explosive substances or substances harmful for human health, shall be located outside the pressure hull of the manned submersibles, diving bells and compression chambers and have pressure compensation devices.

**2.12.3** The design of exhaust gas systems, when submersible accumulators are used, shall be such as to preclude the discharge of compensating liquid to the environment.

**2.12.4** The batteries shall be interconnected by flexible straps.

**2.12.5** For the manned submersibles, arrangements for emergency jettisoning battery containers with accumulator batteries may be used in case of internal fire. Provision shall be made for an emergency power source to supply the jettison arrangements for containers with emergency batteries.

**2.12.6** Charging equipment for accumulator batteries shall be provided with the means for protection against reverse current, overload and short circuits on each non-earthed conductor. Charging facilities shall be of the RS-approved type.

**2.12.7** Circuit protection devices shall be located in a space separate from the battery compartments where accumulator batteries are arranged being a potential source of explosive gases (e.g. gaseous hydrogen). In such case, the cable between the accumulator battery and the protection device shall be as short as possible.

**2.12.8** Where pressure compensation systems are used in submersible accumulator batteries, they shall contain the adequate amount of the compensating fluid under overpressure, temperature and gas volumes for the design depth of submergence. The pressure compensation system shall contain pressure relief arrangements to allow the gases produced by the accumulator battery to be vented overboard. Safety devices shall be free of any obstacles to prevent damage to the accumulator battery or system due to internal pressure of the gas produced. Safety devices shall be designed for the release of expanding gas at a rate corresponding to the emergency surfacing rate of the submersible. Capacity data and performance calculations for safety devices shall be submitted to the Register for review.

**2.12.9** The application of lithium accumulator batteries, their control systems and charging facilities (including lithium-ion, lithium alloy, lithium metal and lithium-polymer) shall be considered separately for each particular case. These batteries are not allowed on passenger submersibles. The lithium batteries shall be of the approved type and comply with the following requirements:

**.1** for the manned submersibles, the lithium batteries shall be located outside the pressure hull in containers which are pressure resistant or with a pressure compensation function. Containers with accumulator batteries shall be mechanically protected against direct impact loads and be located as far as possible from compressed gas bottles and acrylic windows of viewports of the pressure hull, as well as heat sources;

**.2** containers with lithium accumulator batteries for the manned submersibles shall be equipped with temperature detectors with alarms on the control panel. Containers with lithium batteries shall be properly marked and provided with warning signs;

**.3** for lithium accumulator batteries, a control system shall be provided to ensure the following:

voltage and temperature monitoring;

current monitoring in position for charging or discharging;

maintaining balance between the cells within accumulator batteries and between batteries during charging and discharging;

visual and audible alarm on the control panel to indicate that the monitored parameters are beyond the permissible values.

**2.12.10** Provision shall be made for fixed continuous monitoring devices and ventilation systems within spaces for accumulator batteries producing hydrogen. The amount of air supplied and removed by the ventilation system of the battery space of the support ship for the manned submersibles and ship's diving systems shall be calculated so that the lower explosive concentration of the hydrogen-air mixture is not exceeded. Where the gas concentration reaches 35 % of the lower explosive concentration or exceeds this level, the visual and audible alarm shall automatically actuate in the main control station of the manned submersibles and ship's diving systems.

Charging facilities shall be automatically switch off in case of failure in the ventilation system, when the charging facility temperature and permissible fire- and explosive hydrogen concentration are exceeded.

**2.12.11** Charging facilities shall have such nominal voltage that the maximum permissible values of charging currents are not exceeded and the electric consumers' power shall be taken into account. Charging facilities shall

have such nominal voltage that tolerances of restricted and permanent characteristics are retained, accordingly, regardless of external exposure.



## **2.13 DESIGN OF ELECTRICAL EQUIPMENT**

**2.13.1** All electrical systems and equipment of the manned submersibles and ship's diving systems shall be designed and installed to be suitable for operation and operate normally under design conditions to minimize the risk of fire, explosion, electric shock and emission of toxic gases for the crew and passengers and to remain operative under any critical operating conditions: instantaneous heel up to 45 ° and trim up to 30 °, continuous list up to 30° and trim up to 15 °. The electrical equipment shall be capable of trouble-free performance in gas-air medium at a temperature of – 2 °C to + 45 °C and relative humidity of up to 98 % at +35 °C.

**2.13.2** The number of electrical equipment installed inside compression chambers, diving bells and other manned pressure vessels shall be minimized as required for safe operation and monitoring the personnel inside.

**2.13.3** Submerged electrical equipment, as well as the equipment of diving compartments of lock-out submersibles 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 use electrical equipment in tight capsules including those 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 the compensating devices shall be agreed with the Register.

**2.13.4** Materials used for manufacture of electrical equipment for the manned submersibles and ship's diving systems shall be resistant to sea air, oil and fuel vapour effects. In addition, materials used inside the compartments of compression chambers, diving bells, lock-out submersibles, hyperbaric evacuation systems shall not produce harmful gaseous substances and shall be permitted for use under hyperbaric conditions. The structural parts of electrical equipment shall be manufactured of materials ensuring galvanic and electrostatic intrinsic safety.

**2.13.5** Earthing of electrical equipment for the manned submersibles and ship's diving system installed on board the support ship shall comply with the applicable requirements specified in Chapter 2.5, Part XI "Electrical Equipment" of the Rules for the Classification and Construction of Sea-Going Ships.

**2.13.6** Earthing of individual systems in the manned submersibles and diving systems is not allowed. The exception may apply to subsystems where isolating transformers are earthed and high-resistance systems. In way of superstructure or hull of the submersible, in a readily accessible place, provision shall be made for a connection as a connecting plate with a double-end stud bolt M 12 (preferred) to which wires may be connected without any tools. This connection functions as bonding between the recovered submersible and support ship. The area where the protective wire is attached to the hull of the support ship and submersible shall be located at points where they may be easily checked.

**2.13.7** Besides, while earthing the elements of the manned submersibles and ship's diving systems on board the support ship, the following shall be taken into account:

**.1** diving systems shall be equipped with the earthing and grading systems. Provision shall be made for connections for external earthing on all compression chambers including gas storage, etc.;

**.2** enclosures of electrical equipment in water shall be earthed using an earthing conductor included in the feeding cable with at least the same cross-sectional area of the feeding cable core but at least 1 mm<sup>2</sup>. Where it is impracticable, the enclosures installed external to the diving bell may be also equipped with a separate earthed external connection. However, in this case, all earthing (connecting screws and earthing conductor) shall be corrosion resistant. All compression chambers shall be equipped with earthed sockets. Metal

braids of cables may be used for earthing provided that its cross-section is sufficient for this purpose. All pressure vessels for accommodation of people shall be provided with earthing connection devices for external protective earthing of cable sheaths.

**2.13.8** The hulls of diving bells, manned submersibles and compression chambers shall have devices for reliable earthing by connection to the support ship hull. The cross-sectional area of the earthing conductor core shall be at least 16 mm<sup>2</sup>.

**2.13.9** All components of the ship's diving system electrical equipment shall be arranged in cases compatible with their type, installation place and protection rating. The application of electrical equipment enclosures fitted inside decompression chambers and diving bells and operated in water shall be agreed with the Register.

**2.13.10** The electrical equipment used in water shall be agreed with the Register. In any case, measures shall be taken to reduce values of possible short-circuit currents to which divers may be exposed, to safe levels.

**2.13.11** The electrical equipment of the manned submersibles and ship's diving systems shall be designed to exclude possible exposure to electromagnetic and radio frequency interference of electric circuits on instruments and control devices. The circuits shall be screened, where necessary.

**2.13.12** All isolated power systems for the manned submersibles and ship's diving systems including secondary windings of step-down or isolating transformers (converters) shall be equipped with automatic insulation testers capable of switching off the consumers and alarms in case of damage to insulation of these systems. The alarm shall be given in case of a sudden deactivation of the equipment only if such a deactivation may be hazardous for divers. The insulation resistance shall be tested continuously. The indicator shall be arranged on the control panel.

## **2.14 AUTOMATION SYSTEMS AND EQUIPMENT**

**2.14.1** The systems and equipment for automated control, monitoring and signalling of the manned submersibles and ship's diving systems shall comply with the applicable requirements specified in Chapters 1 to 3, Part XV "Automation" of the Rules for the Classification and Construction of Sea-Going Ships and be of the approved type.

**2.14.2** The automation systems shall automatically maintain and monitor operating parameters (in terms of composition and conditions) of the gas medium in compartments of the manned submersibles, compression chambers, diving bells and hyperbaric evacuation systems. The visual and audible alarm shall automatically actuate in the ship's diving system control station in case of unacceptable deviations of operating parameters of the gas medium in compartments and operating media of life support systems.

Provision shall be made for indication of automatic change-over operations in the life support and power supply systems on the control panel.

**2.14.3** The responses of automation equipment shall be matched. For integrated operation of automation systems, delay periods and time constants of constituting units and elements shall be taken into account.

**2.14.4** Measures shall be taken to prevent condensation and moisture accumulation inside electronic units, even when de-energized.

**2.14.5** The systems for automated control of gas composition, pressure, temperature and gas medium mixture in the manned submersibles, compression chambers, diving bells and hyperbaric evacuation systems shall comply with the following requirements:

**.1** failure in the system components shall not cause danger to the safety of the manned submersible crew and divers in the ship's diving system;

**.2** signalling system shall be independent from the automated control system so that a failure in any system may not interrupt operation of the other system;

**.3** provision shall be made for switching to manual control at any time.

**2.14.6** Control instrumentation shall be subject to verification for compliance with operational characteristics according to the established procedure.

## **2.15 ELECTRICAL WATER HEATERS**

**2.15.1** Electrical water heaters may be used in the manned submersibles and ship's diving systems as part of heating systems for diving bells, divers, manned compartments of the manned submersibles and compression chambers, as well as for hot water preparation for compression chamber domestic water supply systems.

**2.15.2** The water heaters and their control systems shall be designed to be capable of switching off if the temperature is exceeded. In such case, the following shall be provided:

- .1** setting and maintaining of specified operating temperatures of the heated water;
- .2** actuation of the thermal protection when maximum temperature is reached;
- .3** operability at temperatures of up to 99 °C;
- .4** water temperature monitoring.

**2.15.3** The water heaters intended for heating sea water in the water heating systems for divers in the ship's diving systems shall be designed to be maintained with washing and removal of scales and repaired with replacement of heating elements.

## **PART VIII. RADIO AND SONAR EQUIPMENT**

### **1 GENERAL**

#### **1.1 APPLICATION**

The requirements of this 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 for the Classification and Other Activity Relating to Manned Submersibles and Ship's Diving Systems 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 "General" 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 stations with digital selective calling (DSC);
- .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 of the Rules, as well as the scope of survey of this equipment shall be agreed with the Register.

#### **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

**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 including 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 submersibles (diving bells) 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 of manned submersibles and diving bells   | Tethered manned submersibles (diving bells) | Self-sustained manned submersibles | Support ship   | Hyperbaric evacuation system |
|-----|---|---|------------------------------------|----------------|------------------------------|
| 1   | Communication sonar systems   | 1 <sup>1</sup>                              | 1                                  | 1              | –                            |
| 2   | VHF radio station with DSC  | –   | 1                                  | –              | 1                            |
| 3   | Emergency sonar beacon with a fixed frequency of 37,5 kHz   | 1   | 1 <sup>2</sup>                     | –              | –                            |
| 4   | Emergency receiver of sonar signals at a fixed frequency of 37,5 kHz  | –   | –                                  | 1 <sup>2</sup> | –                            |
| 5   | Ship's and survival craft search and rescue locating device: radar search or rescue transponder (SART) or AIS search and rescue transmitter | 1 <sup>4</sup>                              | 1 <sup>4</sup>                     |                | 1 <sup>5</sup>               |
| 6   | Two-way VHF radiotelephone apparatus  | –   | –                                  | 2 <sup>6</sup> | –                            |

- <sup>1</sup> To be provided as an emergency communication facility.
- <sup>2</sup> For manned submersibles with operating depth over 500 m and for their support ships, in well-grounded cases, the emergency frequency of 37,5 kHz may be replaced with a frequency of 8-18 kHz.
- <sup>3</sup> Recommended for installation.
- <sup>4</sup> Required under unclear visibility of a manned submersible or diving bell at the support ship radar display station.
- <sup>5</sup> Obligatory for floating self-sustained hyperbaric evacuation systems.
- <sup>6</sup> Quantity shall comply with the requirements of reg. III/6.2.1.1 of SOLAS 74.

## **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**

**3.1.1** The communications sonar system shall provide stable communication in the dual-channel single-band telephony mode between the manned submersible (diving bell) and the support ship at a distance that exceeds at least twice the operating submergence depth.

**3.1.2** 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.

**3.1.3** Communication sonar systems of diving bells for saturation submersions shall include helium speech unscramblers which shall ensure stable communication of diving bell operators with the support ship in helium medium. As an alternative to helium speech unscrambler, it is possible to use a teletype sonar communication channel between the diving bell and the support ship.

### **3.2 VHF RADIO STATION**

**3.2.1** VHF radio station with DSC shall provide stable communication between the manned submersible, diving bell in surface position and the support ship, and shall comply with the requirements of 6.1, Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships.

**3.2.2** Self-sustained manned submersibles when in surface position shall be equipped with at least one dual-channel independent radio station, whose one channel shall be tuned to VHF channel 16 (156,8 MHz) and another one can be used as an "operating channel" for communication between the submersible and its support ship. The communication with the support ship shall be satisfactory at a distance of at least twice the nominal depth of submergence. The communication apparatus shall be equipped with squelches and communication volume controls.

### **3.3 EMERGENCY SONAR BEACON WITH A FIXED FREQUENCY OF 37,5 KHZ**

**3.3.1** 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.

**3.2.2** The beacon shall be operational at a depth of not less than maximum operating depth of manned submersible (diving bell) and shall have a seawater actuated power source.

**3.3.3** Its basic performance parameters shall not be lower than those given in [Table 3.3](#).

Table 3.3

| No. | Basic performance parameters   | Value                           |
|-----|--|---------------------------------|
| 1   | Common emergency response frequency, kHz   | 37,5 ±0,05                      |
| 2   | Individual interrogation frequencies, kHz:   |                                 |
|     | channel A  | 38,5 ±0,05                      |
|     | channel B  | 39,5 ±0,05                      |
| 3   | Minimum output power   | 85 dB/mbar at a distance of 1 m |
| 4   | Minimum operating time of a primary battery for operation with a signal at 85 dB receiver sensitivity, in days | 5                               |

### **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.

**4.2** Hyperbaric evacuation system shall be equipped with emergency radio communication (SHF) and SARTs in compliance with the requirements specified in 2.1.1 of the LSA Code (regs. III/6.2.1.1, III/6.2.2 SOLAS 74) and IMO resolution A.809(19). Hyperbaric evacuation systems shall also be equipped with an emergency position indicating radio beacon (EPIRB).

**4.3** Hyperbaric evacuation systems shall have SHF communication equipment with at least two channels, one of which shall be VHF channel 16 for surface communication. Fixed radio communication aerials shall be installed for operating in any evacuation mode.

## **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 diving bells and hyperbaric evacuation systems.

## **1.2 DEFINITIONS AND EXPLANATIONS**

**1.2.1** Definitions and explanations relating to general terminology of the Rules are given in the General Regulations for the Classification and Other Activity Relating and Ship's Diving Systems 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 for the Classification and Other Activity Relating and Ship's Diving Systems and in Part I "General" and Part V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships.

**1.3.2** The following equipment shall be subject to the RS survey during manufacture, installation and in operation of manned submersibles and ship's diving systems:

- .1 course indicators;
- .2 logs;
- .3 echo sounders;
- .4 depth indicators;
- .5 sonars;
- .6 automated navigational systems;
- .7 GNSS receivers;
- .8 navigation lights.

**1.3.3** Technical requirements for navigational instruments and devices, their location and installation in the manned submersibles, ship's diving bells and hyperbaric lifeboats, which are not mentioned in this Part of the Rules, as well as the scope of survey of these devices shall be agreed with the Register.

**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 review 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, SHIP'S DIVING SYSTEMS AND SUPPORT SHIP**

### **2.1 GENERAL**

**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 and hyperbaric evacuation systems shall be provided with means and/or procedures to ensure their detection and independent navigational safety. Self-sustained manned submersibles shall have equipment to display surrounding underwater and surface situation for navigational safety.

**2.1.3** The navigational equipment of the support ship shall be capable of fixing the submerged and surface positions of the manned submersible and diving bell.

**2.1.4** Navigational equipment of self-sustained manned submersible and diving bell shall ensure determining diving depths and motion elements of manned submersible in submerged and surface positions (for hyperbaric evacuation system – when in surface position).

**2.1.5** Manned submersibles, diving bells and hyperbaric evacuation systems shall be equipped with emergency flashing lights that shall be visible at a distance of at least 2 nautical miles in all directions.

**2.1.6** All electrically controlled navigational equipment shall be connected to emergency power supply of the manned submersible. Flashing light shall be supply from the emergency accumulator battery ensuring operation time of at least 72 h.

**2.1.7** Self-sustained hyperbaric evacuation systems shall be equipped with radar reflectors.

## 2.2 LIST OF NAVIGATIONAL EQUIPMENT OF MANNED SUBMERSIBLES

**2.2.1** Manned submersibles and hyperbaric evacuation systems shall have navigational equipment as listed in [Table 2.2.1](#).

Table 2.2.1

| No. | Navigational equipment          | Tethered manned submersible/<br>diving bell | Self-sustained<br>manned<br>submersible | Hyperbaric<br>evacuation<br>system |
|-----|---------------------------------|---|---|------------------------------------|
| 1   | Course indicator                | –   | 1                                       | 1                                  |
| 2   | Log                             | –   | 1                                       | 1                                  |
| 3   | Depth indicator                 | 1 <sup>1</sup>                              | 1 <sup>1</sup>                          | –                                  |
| 4   | Echosounder                     | –   | 1                                       | –                                  |
| 5   | Clock                           | 1   | 1                                       | 1                                  |
| 6   | Stopwatch                       | –   | 1                                       | 1                                  |
| 7   | Inclinometer and trim indicator | 1   | 1                                       | 1                                  |
| 8   | Sea current speed indicator     | 1 <sup>2</sup>                              | –                                       | –                                  |
| 9   | Sonar                           | –   | 1                                       | –                                  |
| 10  | Signal means                    | 1   | 1                                       | 1                                  |

<sup>1</sup> Passenger submersibles shall have two independent instruments to record the submergence depth. At least one of these devices shall be direct measurement pressure/depth gauge which can operate in emergency situation. Where both devices are pressure/depth gauges, they shall not be connected to the same submergence pressure hull inlet

<sup>2</sup> Expediency of installation of sea current speed indicators on tethered manned submersibles/diving bells shall be agreed with the Register.

**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  $\pm 1\%$  of operating depth;
- .2** continuous output of information for automated navigational system (for electronic device in automated navigational system);
- .3** sound and light alarm of approaching to the maximum submergence depth at 50 and 10 m and before reaching it as well as alarm of reaching the maximum diving depth (for electronic device or the device in automated navigational system).

### **3.2 SONAR**

**3.2.1** The sonar shall provide:

**.1** overview of navigational situation and detection of obstacles in the direction of movement and in depth over a distance exceeding the stopping distance of the manned submersible after the propulsors 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**

Controls and indicators of the navigational equipment listed in [2.2.2](#) and [Table 2.2.1](#) shall be arranged in the control station of manned submersible, in diving bell, and in control station of ship's diving system. Any deviation from this requirement due to features of a manned submersible, diving bell or ship's diving system shall be agreed with the Register.



## **PART X. SHIPBOARD HANDLING SYSTEMS OF MANNED SUBMERSIBLES AND SHIP'S DIVING SYSTEMS**

### **1 GENERAL**

#### **1.1 APPLICATION**

**1.1.1** The requirements of this 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** This 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 on Classification and Other Activity Relating to Manned Submersibles and Ship's Diving Systems and in Chapter 1.2 of the Rules for the Cargo Handling Gear of Sea-Going Ships

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

**Safe working load of handling system** 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.

**Design sea state** means the sea state increased by 1 as against the design one.

**Tracking** 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** Scope of surveys of handling systems of manned submersibles and ship's diving systems is determined by the requirements of 1.3, Part I "General" of the Rules for the Handling Gear of Sea-Going Ships.

- .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** winches, umbilical reels, electrical and hydraulic drives and other mechanical and electrical equipment recognized by the Register as necessary for safe operation of the handling system.

**1.2.2** Prior to commissioning, the handling systems shall be examined and tested in accordance with Chapter 3.12 "Handling Systems of Manned Submersibles and Ship's Diving Systems" of the Guidelines for Survey of Manned Submersibles and Ship's Diving Systems under Manufacture under Construction and Manufacture of Products.

**1.2.3** Certification and survey documents as well as technical and operating documentation shall be kept by the owner and submitted to the Register during repairs and periodic surveys.

## **1.4 TECHNICAL DOCUMENTATION**

**1.4.1.1** Besides, the following additional documentation shall be submitted:

**.1** Operation Manual for the handling system as a whole and individual mechanisms and systems, including main and emergency electrical, pneumatic and hydraulic power sources. The Operation Manual shall include instructions on operational checks and planned maintenance scheme and specify the expected service life of important components and equipment;

**.2** diagram or logic diagram of work procedure for intended use of the handling system. Circuit diagrams illustrating operation of systems with details on the systems. The diagrams shall schematically show the arrangement of pipelines and include details on controls and power supply;

**.3** information on operating weight of manned submersible and diving bell (stage) with indication of all hydrostatic and dynamic characteristics which shall be taken into account for strength calculations for handling system's parts;

**.4** drawings, specifications and calculations of the systems and devices used for emergency recovery of manned submersible and diving bell (stage) on board the support ship;

**.5** calculations of electrical load in the main and emergency modes of the handling system;

**.6** data on emergency power sources.

## **2 GENERAL TECHNICAL REQUIREMENTS**

**2.1** General technical requirements for handling systems of manned submersible and ship's diving system shall comply with the applicable requirements specified in Chapter 1.5 of the Rules for the Cargo Handling Gear of Sea-Going Ships. By design and arrangement on board the ship, the handling systems of manned submersibles and ship's diving systems may be subdivided into side, stem or moon pool types. Depending on the type of ship's diving system, the handling system of ship's diving system can be used for launching divers in diving bells, in diving stages or from diver's ladders. As a rule, diving bells handling systems are used in ship's deep diving systems for submersions to depths over 60 m. For lower depths, open diving bells (half-bells), diving stages and diver's ladders are used.

**2.2** For submersions in open diving bell and in diving stage, a facility for submersion of the standby diver shall be provided on board the ship. For submersions from the ladder, a facility for recovery of diver in distress on the deck with the help of safety belts shall be provided.

**2.3** Diver's ladder can be used if ship's freeboard is less than 2 m; it shall extend under water at least 2 m deep; it shall have handrails both above and below sea surface and at the deck level to facilitate recovery of divers on the deck.

**2.4** The control of launching the manned submersible or diving bell (diving stages) under normal conditions shall be effected by means of the winch drive and not by means of mechanical brakes.

**2.5** In case of failure of the main handling system, a standby handling system shall be provided to recovery divers on surface and transport them to the compression chamber. The standby handling system shall comply with the same requirements for strength as the main handling system.

**2.6** Emergency recovery of diving bells shall be provided. For this purpose, in the event of failure of the handling winch, each handling system shall be capable of hoisting the manned submersible or diving bell (stage) on the ship after emergency surfacing or emergency lifting them to the sea surface with the use of mooring or other deck machinery. Handling wire ropes shall be well locked during changeover from the handling winch to deck machinery. Recovery in the second diving bell (stage) may be considered an additional emergency recovery method. For bounce ship's diving systems, emergency recovery can be carried out by free surfacing. In such case, all necessary equipment shall be provided on board the ship to transport the divers from water to the compression chamber within 5 min.

**2.7** For 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 upper access hatch of the manned submersible for the exit of the crew.

**2.8** The design of the handling system shall provide uniform tension of all wire ropes on their branches (refer also to [5.1.2](#)). Support wire ropes shall not twist or rub each other or other hoses and cables when objects are under water.

**2.9** The length of umbilical shall be sufficient to lower tethered manned submersible, diving bell (stage), or non-self-propelled submersible to the test diving depth plus 5 %.

**2.10** At bending points of the umbilical, guide rollers or rounded pieces of appropriate diameter shall be installed to prevent hoses and cables from fracture.

**2.11** 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.

**2.12** 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.

**2.13** 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, the ladders and platforms shall ensure operation in any position of the trusses.

**2.14** 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 10° either side and at static trim of 5°. Outreach of the handling system shall be sufficient to provide launching and recovery of the manned submersible or diving bell (stage) without touching the support ship's side above the summer waterline.

**2.15** The handling system shall have a slinging and unslinging device corresponding to the type of the manned submersible (submersible device), for which the handling system concerned is intended.

**2.16** The launching and lifting gear and the guide wire rope gear of manned submersible and diving bell handling system shall have a system for tracking the object in a seaway to take up the slack in wire ropes, with a tracking amplitude of up to 5 m.

**2.17** 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.

**2.18** The handling system control cabins or consoles installed on the upper deck shall be equipped with screen wipers or other effective facilities.

**2.19** Handling equipment shall be equipped with diving bell (half-bell) or stage stabilization devices to stabilize them during launching/recovery and at the depth, e.g. guide wire ropes with weight anchors.

**2.20** Handling systems of manned submersibles and ship's diving system shall have two independent power sources. Two independent pump stations shall be provided for hydraulic drives of handling system. Power sources together with power supply lines and distributor shall be manufactured to exclude failure of one system in case of failure of another one.

**2.21** A-frame handling systems shall be equipped with two hydraulic cylinders. Hydraulic cylinders shall be arranged and installed to guarantee that each one of them can successfully lower and lift manned submersibles and diving bells in case of failure of one of them. The hydraulic cylinders shall be connected to hydraulic system in a way that the failure of one drive does not cause failure of another one.

**2.22** Handling system shall operate smoothly when the cargo winch is switched on/off. Handling system of manned submersible or diving bell shall ensure their installation on the deck or a mating device without impacts.

**2.23** Manned submersibles and diving bells shall be reliably fastened in the place of location on the support ship. The fasteners shall be designed suitable for dynamic loads of the ship moving at the design sea state.

**2.24** Mobile trolleys and bridges of the handling system shall be equipped with mechanical damping stops in the extreme positions.

**2.25** Handling system hydraulic units shall service their own lifting equipment and shall not be used for any other purpose.

**2.26** Hydraulic handling system shall be equipped with limit switches to prevent diving bell or stage displacement beyond a specified zone.

**2.27** Handling moon pools of manned submersible and diving bell handling systems of the moon pool type shall comply with the following requirements:

**.1** moon pool openings are recommended to be arranged as close as possible to support ship's midship frame;

**.2** moon pools shall withstand possible shear forces when manned submersible or diving bell move inside them;

**.3** design of the moon pool sides shall comply with the requirements for the support ship's shell plating;

**.4** corner radii of ship hull openings for the moon pool shall be at least 0,125 of the maximum moon pool width, but not more than 600 mm;

**.5** edges of the moon pool shall be suitably rounded to prevent damage of diving bell umbilical;

**.6** means shall be provided to prevent personnel from into the moon pool.

**2.28** Handling system of mobile ship's diving system shall be designed for the particular support ship type. The use of a mobile ship's diving system with handling system from other ship shall be agreed with the Register.

### **3 DESIGN STANDARDS**

#### **3.1 GENERAL**

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 Gears of Sea-Going Ships, the design loads shall include the following:

**.1** payload including the maximum weight of the manned submersible or diving bell in air or their devices with all the components, including weight of ballast, tools and consumables, total weight of crew members (crew members with average weight of 75 kg each and fully equipped divers of 150 kg each).

In such case, the load acts when lowering and lifting in air and lowering and lifting in water, together with maximum negative buoyancy of rope, flexible cable, stage or diving bell at the maximum diving depth;

**.2** loads due to entrained masses of water, silty clay, etc.;

**.3** dead load of handling system's structures and equipment;

**.4** external loads which can appear during operation (loads resulting from maximum motions of the ship, sea state, wind force, ice accumulation, etc. shall be taken into account as design assumptions corresponding to the designed conditions);

**.5** braking inertial forces of the machinery operating at maximum speed;

**.6** operational dynamic loads in the handling system at design sea state during start/stop, wire rope slacking, and hydrodynamic loads (dynamic loads include the loads resulting from acceleration in vertical, longitudinal and transverse directions, including permissible heel and trim);

**.7** loads from the handling system devices to foundations; such loads shall be taken into account when designing deck foundations, fasteners and hull structures in the place of installation of handling system devices and mechanisms (winches, pulleys, dampers, etc.).

**3.2.3** Calculations shall be based on the assumption that engaging angle of hoist rope shall deviate from perpendicular by 12° in any direction. Manufacturer's calculations shall indicate the maximum hoisting speed of manned submersible and diving bell which shall be agreed with the Register.

### **3.3 ALLOWABLE STRESSES, SAFETY AND STABILITY MARGINS**

**3.3.1** Strength calculations of metal structures, machinery and loose gear of handling system shall be manufactured for static and dynamic loads. Allowable stresses in the calculations shall be taken as follows:

**.1**  $0,4R_{eH}$  – for static load;

**.2**  $0,8R_{eH}$  – for dynamic load

where  $R_{eH}$  – material yield stress.

Where handling system is used for lowering and lifting manned submersible, diving bell, hyperbaric evacuation system and/or stages with personnel, the safety factor shall be at least 2,2. For other lifting facilities which are not used for lifting people, the safety factor shall be at least 1,5. Reduction of safety margins of handling system's components shall be substantiated by the relevant calculations and agreed with the Register.

**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**

**3.4.1** In calculations the handling system machinery, account shall be taken of the requirements of [Chapters 3.2](#) and [3.3](#) of this Part of the Rules, as well as Chapters 1.5 and 2.2 of the Rules for the Cargo Handling Gear of Sea-Going Ships.

**3.4.2** Drives of winches of handling systems of manned submersibles and diving bells shall be calculated in such a way that the maximum torque equal to the maximum pull which is at least 1,5 times the nominal pull of the winch, can be reached during subsequent operation of at least 5 min. Hydraulic cylinders shall be also designed for the pull 1,5 times exceeding the nominal pull. In both cases, the relevant confirmatory calculations shall be submitted.

## **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**

**5.1.1** In addition to the general requirements for machinery mentioned in [Section 2](#), the requirements of this Section and applicable requirements of Part IX "Machinery" of the Rules for the Classification and Construction of Sea-Going Ships and Chapter 1.5 of the Rules for the Cargo-Handling Gear of Sea-Going Ships shall be taken into account when designing the handling system.

**5.1.2** Design of the handling system's machinery 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 (refer also to [2.8](#)) with the possibility of their separate starting. The driving arrangements of winches and reels shall make it possible to generate and change slack in the umbilical.

**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.

**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 systems;
- .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 taking whole length of the used wire rope (umbilical) and 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. In such case, the following requirements shall be complied with:

- .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.

**5.1.14** Winches shall comply with the following applicable requirements:

**.1** cargo winches of the handling system shall be provided by two independent (main and standby) brakes. Main winch brake shall actuate automatically when the winch load drops. Standby winch brake shall be capable of actuating in case of faults of the main winch brake. One of the winch brakes shall be power-independent and shall actuate when the main power source fails by directly effecting the rope drum. All the winch brakes shall be designed for holding the 100 % design load at the upper rope layer;

**.2** strength of the mechanical brake of handling system shall be sufficient to withstand the design load;

**.3** lowering of manned submersibles and diving systems shall be controlled by power drives independent from the winch brakes;

**.4** nominal winch pull shall be provided at the nominal reeling speed up to the upper rope layer,

**.5** when the rope is wound in one layer, the drums shall be provided with helical grooves at least half diameter of the rope wound. When the rope is wound in several layers, smooth drums may be used. In such cases, the winch shall be provided with a rope-coiling trolley;

**.6** if the rope is inclined more than 2° from the winch drum axis, a winding device (rope-coiling trolley) shall be provided. Rope tangling or deformation in the lower layers on the drum are not allowed.

**5.1.15** Diving hose and umbilical reels and guides shall provide a free reeling-on and reeling-out during launching and recovery of divers, diving systems and diving stages.

**5.1.16** During reel design the following shall be taken into account:

**.1** specified operating conditions and structural particulars of the ship;

**.2** loads on the reel from the diving hose (umbilical) including umbilical's own weight and buoyancy (both filled and empty), entrained water weight, dynamic impacts, etc.

**.3** radius of umbilical winding on the reel that shall not be less than the permissible bending radius;

**.4** umbilical route relative to the reel (angle of winding, winch drum orientation, guide sheave pressure, etc.).

**5.1.17** Diving bell umbilical reel shall be fitted with standby power sources and auxiliary drives (arrangements) for emergency hauling the hose (umbilical) if the main drive fails.

**5.1.18** The reel shall operate so that not to exceed diving hose (umbilical). If exceeded, an alarm shall actuate in the diving operation control station.

**5.1.19** The handling system shall be fitted with a mechanical brake which shall activate automatically if the lifting motor stops. If the automatic brake fails, an auxiliary facility shall be provided to preventing the cargo from falling. It may be operated manually and shall have a simple design.

## **5.2 SAFETY DEVICES AND CONTROL DEVICES**

**5.2.1** Handling systems shall be equipped with control systems and devices that ensure their reliable non-continuous operation with smooth acceleration and deceleration, as well as the operational control of the handling system's machinery from the manned submersible and/or ship diving system control stations (panels).

**5.2.2** Handling systems (except for manually driven systems) shall have limit switches for alarming and automatic stopping of the following gear in their extreme positions:

- .1** launching and recovery of derricks and load hooks;
- .2** truss (girder) luffing;
- .3** traveling of bridge-type trusses or load trolleys.

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, whose indications shall be repeated at the diving operation control station.

**5.2.4** Control panels shall be equipped with interlocking devices for simultaneous performing only those commands whose combination does not cause dangerous or unforeseen conditions.

**5.2.5** Control systems of handling systems for manned submersibles and/ or diving bells shall have an emergency stop button.

**5.2.6** Remotely controllable control units shall be equipped with a system to changeover between remote and local manual control. In case of remote control failure, all started operations shall be automatically stopped.

**5.2.7** Control system of handling systems for manned submersibles, diving bells, diving stages shall provide for synchronized operation of winches, reels and piston-type hydraulic cylinders. In case of de-synchronized operation of the handling system's gears, they shall be emergency stopped and alarm to the handling system control stations (panels) shall be given.

## **6 INTERCHANGEABLE COMPONENTS, STEEL WIRE ROPES AND CHAINS**

### **6.1 INTERCHANGEABLE COMPONENTS**

**6.1.1** Interchangeable components shall comply with the requirements of Chapters 9.3 and 11.2 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

$$P/S \geq K$$

where  $P$  = breaking strength of the wire rope as a whole (according to the Register certificate), in N;  
 $S$  = maximum tension in the wire rope branch under a load equal to the safe working load of the handling system, in N;  
 $K$  = 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 <a href="#">item 1</a> by a single wire rope   | 5                 |
| 3   | Guides used for emergency recovery of the objects specified under <a href="#">item 1</a>   | 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 <a href="#">item 4</a>   | 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  $Q$  = the allowable working load corresponding to the safe working load of the handling system, in N;  
 $n$  = the number of wire rope branches;  
 $\eta$  = the efficiency of blocks.

**6.2.11** Steel wire rope shall be well lubricated throughout its length; the lubricant shall penetrate the rope and remain inside. The lubricant shall be applied when no traces of lubricant can be seen between strands.

### 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.

**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.

Table 6.3.1

| No. | Chains  | <i>K</i> not 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                      |

## **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 TESTING OF WELDED JOINTS**

**7.2.1** The total scope of weld testing is determined by the Rules for the Cargo Handling Gear of Sea-Going Ships and Section 3, Part XIV "Welding" of the Rules for the Classification and Construction 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.

**7.2.3** Each transverse butt weld shall be examined by radiography throughout its length. Other welds shall be examined by radiography for not less than 25 % of length; crossings of welds shall be obligatory subjected to radiography. Where intolerable defects are found in the welds, areas at both sides of the defect detected shall be additionally subjected to radiography until satisfactory results are obtained. Additional testing of two new areas shall be performed per each rejected area.

**7.2.4** Areas to be tested, the scope of non-destructive testing (NDT) and testing procedures shall be submitted to the Register together with design drawings of the handling system.

**7.2.5** The NDT results shall be submitted to the RS representative who reserves a right to require additional weld areas to be subjected to NDT.

**7.2.6** Welding procedures and documents confirming qualification of welders shall be submitted to the Register for approval.

Russian Maritime Register of Shipping

**Rules for the Classification and Construction of Manned Submersibles  
and Ship's Diving Systems**

FAI "Russian Maritime Register of Shipping"

8, Dvortsovaya Naberezhnaya,

191186, St. Petersburg,

Russian Federation

[www.rs-class.org/en/](http://www.rs-class.org/en/)