RUSSIAN MARITIME REGISTER OF SHIPPING

Version: 01.07.2025

RULES

FOR THE CLASSIFICATION AND CONSTRUCTION OF NUCLEAR SHIPS AND NUCLEAR SUPPORT VESSELS

PART VI

NUCLEAR STEAM SUPPLY SYSTEMS

ND No. 2-020101-169-E

St. Petersburg

RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF NUCLEAR SHIPS AND NUCLEAR SUPPORT VESSELS (PART VI)

The present version of Part VI "Nuclear Steam Supply Systems" of the Rules for the Classification and Construction of Nuclear Ships and Nuclear Support Vessels of Russian Maritime Register of Shipping (RS, the Register) has been approved in accordance with the established approval procedure and comes into force on 1 July 2025.

The present version is based on the version dated 15 December 2022 and Rule Change Notice No. 25-72214 taking into account the amendments and additions developed immediately before publication (refer to the Revision History).

REVISION HISTORY[1]

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

[1] With the exception of amendments and additions introduced by Rule Change Notices (RCN), as well as of misprints and omissions.

1 GENERAL

1.1 This Part sets down requirements for ship two-circuit NSSS with pressurized water reactors. Requirements for ship's NSSS with other reactors on board shall be set by the Register.

1.2 The Register may also apply the requirements of this Part in accordance with provision in force to equipment other than that specified in 2.3.

1.3 Definitions and explanations relating to adopted abbreviations and terms are given in Part I "Classification".

2 SCOPE OF TECHNICAL SUPERVISION

2.1 SSS and its equipment shall be subject to technical supervision by the Register at design, manufacturing and testing stages as well as during construction and testing, operation and repair of the ship.

2.2 The scope, frequence of surveys carried out by the Register as well as procedure for issuing documents by the Register are specified in Part I "Classification" of the Rules for Classification and Construction of Sea-Going Ships[1], Rules for the Classification Surveys of Ships in Service[2] and the Rules for the Classification and Construction of Nuclear Ships and Nuclear Support Vessels[3] as well as the Guidelines on Technical Supervision of Ships in Service[4].

2.3 The SSS machinery, equipment and systems subject to the Register technical supervision are given below:

.1 reactors (cases, covers with their fasteners, piping attachments, removable and non-removable parts, safety devices and valves, supporting structures);

.2 cores (fuel elements, burnable poisons, displacers, working and permanent neutron sources and their assemblies);

.3 arrangements for control, testing and suppression of chain reactor (rods, protective liners, drives and actuators, ionization chambers with suspensions, thermocouples and resistance thermometers, level gauges);

.4 machinery (pumps, compressors, fans);

.5 safety valves and devices, valves and fittings of the equipment, machinery and systems;

.6 pressure vessels and units (metal-water shielding tanks, SG, pressure compensators, hydraulic chambers, ion-exchange and electromagnetic filters, heat exchangers and refrigerators, drainage containers, gas and air tanks, hydropneumatic cylinders);

.7 systems:

primary coolant circulating system;
primary coolant purification system;
primary coolant make-up system;
residual heat removal system;
core emergency cooling system;
primary coolant sampling system;
deaeration system;
primary water drainage, storage and distribution system;
pressure compensation system;
HPG system;
secondary coolant (from SG to the secondary circuit);
fresh water cooling system (equipment and protection system);
sea water cooling system (equipment);
ventilation system for the SSS spaces and controlled area spaces;
sorbent storage and handling system;
explosive mixture removal and hydrogen content monitoring system;
automatic equipment operating water and fitting control system;

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[1] Hereinafter referred to as "the Rules for the Classification".
[2] Hereinafter referred to as "the Rules for the Classification Surveys".
[3] Hereinafter referred to as "these Rules".
[4] Hereinafter referred to as "the Guidelines on Technical Supervision".

.8 reactor CPS and arrangements;
.9 reactor control and alarm systems and arrangements;
.10 control, protection, monitoring and alarm arrangements for the SSS systems and devices;
.11 survey facilities;
.12 facilities for handling and repair of the SSS machinery;
.13 SGU (integrated cases, covers with their fasteners, SG cassettes, primary circulating pumps, valve chests, piping attachments, internal removable and non-removable parts, safety devices and valves, supporting structures).

3 GENERAL REQUIREMENTS

3.1 When the ship is fitted with two SSS, each shall operate independently and provide the NPP operation regardless of the other SSS.

3.2 The SSS equipment shall be secured to prevent its displacement in case of variation in ship's position up to and including capsizing.

3.3 Components and systems of safety classes 1 and 2 shall be located within the collision protection.

3.4 The core emergency cooling system, residual heat removal system and reactor protection system shall be tested for capability of performing their intended functions. The operating reactor shall be tested without temporary deactivation of safety functions and failure in the system operation.

3.5 Liquid and gas systems as well as pressure vessels shall be provided with the arrangements required for the following purposes:

.1 filling systems and vessels after initial installation, modernization or repairs;
.2 initial pressure test;
.3 overpressure protection;
.4 periodical examinations and pressure tests;
.5 system isolation;
.6 survey procedure;
.7 monitoring of thermodynamic parameters.

3.6 Automatically controlled systems critical for the SSS operation and safety shall be also equipped with the manual local or remote controls.

3.7 The reactor safety systems shall be capable of automatic activation as soon as events requiring quick response start.

Automatically activated systems shall be capable of keeping reactor plant in safe condition for at least 30 min without operator's assistance.

Safety systems may be controlled manually, provided that operator's error does not impair normal operation of these systems and does not impede proper actuation of protection means.

3.8 All safety systems shall meet a single failure concept. These systems are given below:

.1 SSS automatic and remote control, protection, monitoring and alarm system (in terms of safety functions);
.2 residual heat removal system;
.3 core emergency cooling system;
.4 containment isolation arrangements;
.5 primary pressure rise prevention system;
.6 containment pressure reduction system.

3.9 Activation time for stand-by equipment shall eliminate probability of accident in the installation.

The adequacy of the accepted redundancy for equipment shall be explained in the SSS design.

3.10 The SSS systems and piping shall be properly secured under normal and emergency conditions. Structure of piping fasteners shall be as such to allow their thermal expansion, where necessary. The distance between piping, systems and fastening surface shall be as such to ensure their proper maintenance and repair.

3.11 SSS shall be capable of operating at decreased power in case of deactivation of parts of the SG/steam generating sections, pumps and other SSS equipment as well as parts of the pumps, heat exchangers and other equipment of steam-turbine unit.

3.12 Primary coolant shall properly circulate to provide proper reactor cooling at any power as stipulated by operating conditions.

3.13 The SSS equipment shall meet requirements regarding cleanliness of its cavities and surfaces approved by the Register. Prior to assembly, in the course of assembly and workshop tests, onboard installation, testing and operation, parts, the SSS assemblies and items shall be properly cleaned.

3.14 Equipment to maintain coolant purity and quality at the required level during the SSS operation as per design standards shall be provided.

3.15 Filtering elements/substances in filters with radioactive working fluids shall be replaced by reliable shutdown of filters by means of double valves from the system under operating pressure.

3.16 The ship shall be fitted with water preparation equipment for SSS. The quality of water shall meet the standards as specified for this SSS.

3.17 The ship shall be provided with equipment to maintain the primary pressure at a required level and its make-up as well as other auxiliary equipment for the SSS safe normal operation in all operation modes.

3.18 It is required to envisage effective means for piping leak tightness continuous monitoring for each SG and effective means for deactivation of SG/steam generating sections in case of vapor and feed-water.

3.19 The SSS equipment shall be designed to withstand vibrations as per standards approved by the Register.

3.20 The list and amount of spare parts for the SSS machinery and equipment shall be based on delivery specifications or supplier's specifications approved by the Register.

3.21 The list and justification for selecting emergency parameters of the installation at which reactor is stopped, shall be given in the SSS design.

3.22 Systems and devices with possible formation of explosive mixture in hazardous concentrations shall be fitted with effective removal system or concentration reduction system.

3.23 Regulatory documents on welding of the SSS structures and equipment and welded joint quality check shall be approved by the Register.

3.24 The SSS equipment subject to the Register technical supervision shall be load tested on the manufacturer's test bench according to the procedures approved by the Register upon completion of its manufacture, assembly, adjustment and running-in and prior to its installation on board the ship.

3.25 Prototypes of the equipment shall be tested according to the procedures which provide testing for reliability, long-term operability and compliance with operating conditions.

3.26 SSS and its equipment installed on board the ship shall be subject to mooring and sea trials according to the procedures approved by the Register.

4 SSS COMPARTMENT

4.1 The SSS compartment shall be located in such a way as to minimize probability of the SSS damage in case of the nuclear ship collision with another ship or in case of grounding and stranding.

It is recommended that SSS be located in the middle of the ship.

Transverse distance from the shell plating to the SSS shielding barrier is specified in 2.3.4, Part III "Hull" and the height of double bottom in area of the reactor compartment is specified in 2.1.5, Part III "Hull".

4.2 SSS and its components containing radioactive substances shall be enclosed in containment (refer to 2.2, Part III "Hull").

4.3 Passages of the pipelines and electric cables through containment shall be minimized. These passages shall withstand conditions resulting in containment at SC1 — SC4.

Layout and structure of these passages shall allow their surveys and local leakage tests.

4.4 The pipelines passing through the containment of the nuclear ship shall be fitted with double shut-off valves located as close to the containment as possible. They shall automatically cut off the containment and be provided with remote control. Containment cut-off means as the safety system shall comply with a single failure criterion.

4.5 Containment shall be provided with facilities for automatic external and internal pressure balancing in case of the ship flooding. Design of these facilities shall be approved by the Register.

4.6 Special facilities shall be provided for periodical inspections and tests of the containment in service to determine integral leakage.

4.7 In addition to hatch for fuel loading, the special hatch shall be provided for the personnel access to equipment in the containment. This hatch shall maintain gas tightness of the containment at SC1 — SC4.

Containment shall be also provided with escape manhole.

5 REACTOR CORE

5.1 Reactor core shall provide continuous effective reactor operation in the specified operating and transient modes as well as interrupted operation when a number of startups is not less than permissible value per core life.

5.2 Core components and structure shall be designed as to prevent reactor uncontrolled runaway and nuclear accident in all operating and emergency states of the plant and ship.

5.3 The core shall be designed as to provide safe movement of devices for its operation at any permissible powers permitted by the designer in case of reactor startups and stops.

5.4 When designing the core, permissible limits for damages to core components shall be specified and justified.

The core shall be designed as to prevent release of radioactive materials from core components in concentrations exceeding the specified limits during manufacture, testing, storage and operation in the reactor till total exhaust of energy.

5.5 Fuel assemblies as well as core control and protection components shall be designed as to account for material properties, exposure effects, physical and chemical processes, static and dynamic loads for all states of the plant, roll effects of the ship, manufacture tolerances and uncertainties in calculations, effect of deposits on heat-emitting surfaces on heat removal efficiency.

5.6 The structure, shape and dimensions of the core and its components shall allow for their effective cooling at SC1 — SC4.

5.7 There shall be safety margins for abnormal conditions of coolant consumption due to loss of power of circulating pumps or for other reasons.

5.8 To detect damages of core components, means for permanent monitoring of the primary coolant radioactivity shall be provided.

5.9 When estimating core thermal loads, the appropriate inaccuracy in calculations shall be taken into account. Thermal margins shall be selected as operating restrictions. Estimated heat transfer values at limiting transient processes shall be verified experimentally.

5.10 The calculated distributions of coolant flow through fuel assemblies shall be provided. The calculations shall account for variation in coolant flow and heat transfer with the roll of the ship. Safety factors envisaged in calculations shall account for inaccuracy of similar calculations.

5.11 Calculation results and/or test data confirming availability or non-availability of vibration in the core and its supports due to coolant hydraulic flows shall be presented.

6 REACTOR

6.1 The reactor shall ensure effective and stable operation under operating conditions stipulated by the design at all design loads.

6.2 The reactor load shall be increased and decreased at a rate to ensure sufficient maneuverability of the ship.

6.3 The reactor, actuating controls, adjusters and protective elements shall be designed to prevent unintended variation in reactivity in the event of roll, heel, capsizing, vibrations, shocks and other prescribed dynamic loads.

6.4 The reactor shall be capable of being switched to subcritical state from any power for all positions of the ship, including capsizing.

6.5 The reactor shall be designed to prevent free drainage of the coolant: all branches on the reactor core shall be arranged at the level above the upper cut of the core.

6.6 The reactor shall meet the applicable nuclear safety requirements in respect of marine reactors as agreed upon with Register.

6.7 The reactor shall be designed to allow for safety handling of the core.

6.8 The reactor shall be designed to allow for visual internal survey and survey by means of remote/non-destructive testing.

7 STEAM GENERATING UNIT

7.1 Steam generating unit (SGU) is intended to generate overheated steam as a part of NSSS. Generation of thermal energy is carried out in the process of controlled self-sustaining nuclear fission chain reaction.

Within SGU, the SG piping system and reactor core are located in one case unlike the block arrangement where the SG piping system is located in a(the) separate SG case(s).

7.2 SGU shall meet the following requirements:

.1 SGU shall provide effective and stable operation under operating conditions stipulated by the design at all design loads;

.2 SGU strength shall be calculated according to the procedures approved by the Register;

.3 technical design documentation and detailed design documentation on SGU shall be approved by the Register;

.4 SGU load shall be increased and decreased at a rate to ensure requirements of operating model;

.5 SGU, actuating controls, adjusters and protective elements shall be designed to prevent unintended variation in reactivity in the event of roll, heel, capsizing, vibrations, shocks and other prescribed dynamic loads;

.6 SGU shall be capable of switching the reactor core to subcritical state from any power for all positions of the ship, including capsizing;

.7 SGU shall be designed to prevent free drainage of the coolant below the upper boundary of the core: all branches on the SGU case shall be arranged above the upper boundary of the core;

.8 SGU shall meet the nuclear safety requirements in respect of marine reactors as agreed upon with the Register;

.9 SGU shall be designed to allow for safety handling of the core;

.10 SGU equipment under pressure of the primary, secondary and tertiary circuits shall be adapted for hydraulic tests;

.11 SGU shall be designed to allow for visual internal survey and survey by means of remote/non-destructive testing according to the SGU operational documentation;

.12 SGU components separating boundaries of the primary and secondary circuits, the secondary circuit and atmosphere shall be tightly connected. Sealing procedures for main connectors shall be approved by the Register. Structure, welding and testing of welded joints of the SG cassettes, integrated case, SGU case shall be performed according to the welding provisions and regulations for testing of welded joints approved by the Register. All welded joints shall be subjected to non-destructive testing;

.13 SG shall be divided into at least two SG piping systems as independently operated and deactivated in case of steam and feed water;

.14 SG piping systems shall be designed as to provide replacement and/or repair of non-tight components. The SG cassettes shall be replaced upon opening-up of the cover of the reactor main connector. Repair (modules' shutdown) of non-tight components shall be provided without opening-up of the cover of the reactor main connector at shutdown cooled reactor under atmospheric pressure of the primary and secondary circuits.

7.3 Generally, composition of the SGU equipment shall include:
.1 integrated case;
.2 SG piping system;
.3 reactor internals, which, depending on the reactor core type, generally, consist:
for cassette-type core: of internal core barrel/basket intended to load the core and of pipe-and-device assembly containing engaging devices which form controls of compensating groups during engagement with absorbers of fuel assemblies;
for channel-type core: of internal unit intended to load the core and containing the controls consisting of the required number of compensating groups;
other internals intended to arrange the coolant loop;
.4 reactor core;
.5 primary circulating pump with a valve chest, fasteners of the primary circulating pump on the hydraulic chamber;
.6 reactor cover;
.7 main connector gasket;
.8 set of control and protection system drives (drives of compensating groups and emergency protection);
.9 set of instrumentation (resistance thermal elements, thermo-electrical converters) to be fitted on the reactor cover;
.10 assembly components and parts, SGU assemblies, including those designed to secure SGU to the metal-water shielding tank and to form biological shielding (protection ring).
7.4 Upon manufacture, SGU with all the components (or their dummies) and accessories shall undergo test assembly at the firm (manufacturer):
.1 instead of the SGU components such as fuel assemblies of the reactor core, primary circulating pump with the valve chest, standard instrumentation on the reactor cover, during test assembly their dummies may be used;
.2 during test assembly, the following shall be performed:
check of the integral reactor assemblability;
alignment and adjustment of internal centering elements;
check of free movement of movable parts of compensating groups actuators. For fuel assemblies of the cassette-type reactor core the check shall be performed using absorber simulators as a part of dummy fuel assemblies; it shall also be checked whether the engage/disengage operations of the absorbing rods are performed when forming the actuators of compensating groups;
.3 during test assembly technological brass or bronze fasteners may be used instead of the standard austenitic steel fasteners.
7.5 Pressure tests of the SGU equipment during manufacture and installation:
.1 upon manufacture at the firm (manufacturer), SGU case (with the SG cassettes) shall be subjected to:
hydraulic pressure and tightness tests by the primary cavity;
hydraulic or pneumatic pressure and tightness tests by the secondary cavities.
Upon agreement with the Register, in a justified case (e.g. impossible subsequent drainage of the secondary cavities of the SG cassettes at the firm (manufacturer), impossible pneumatic testing at the firm (manufacturer)), the pressure and tightness tests of the secondary cavities may be conducted (upon agreement) at the builder by conducting hydraulic pressure and tightness tests of the secondary circuit, with additional non-destructive testing of welded joints of the SG cassettes with the integrated case at the firm (manufacturer);
.2 upon manufacture at the firm (manufacturer), the SG cassettes shall be subjected to hydraulic pressure and tightness tests in the primary cavity;

.3 upon manufacture at the firm (manufacturer), the reactor cover shall be subjected to:
hydraulic pressure and tightness tests from outside and in the pressure cavities of the primary circuit;
hydraulic tests for strength and tightness of supports cooling system by the tertiary circuit;
pneumatic tests for tightness of a pebble bed cavity;
.4 upon manufacture at the firm (manufacturer), the primary circulating pumps shall be subjected to hydraulic pressure and tightness tests on the primary and tertiary circuits;
.5 upon manufacture at the firm (manufacturer), the drives of compensating groups shall be subjected to hydraulic pressure and tightness tests in the primary cavity;
.6 upon manufacture at the firm (manufacturer), the emergency protection drives shall be hydraulically tested for strength and tightness of the cavity exposed to the primary circuit pressure during safety depressurization of sleeves of emergency protection rods;
.7 upon installation and assembly of SGU with NSSS, SGU shall be subjected to hydraulic pressure and tightness tests on the primary, secondary and tertiary circuits;
.8 components (including welds) of SGU equipment which are subject to gas or vacuum tightness shall be checked for tightness during manufacture and (or) installation by methods corresponding to the specified leak-tightness class. Checking of tightness by the hydraulic method using luminescent indicator coating may be combined with hydraulic tests for strength and tightness.
7.6 Materials used to manufacture SGU equipment:
.1 the materials to be applied during manufacture of the SGU equipment shall be approved by the Register and manufactured under the Register technical supervision;
.2 base metal and welding consumables of integrated case shall have a set of physical and chemical, mechanical and processing properties for: radiation resistance, brittle-to-ductile transition temperature, resistance to thermal embrittlement, strength, ductility, workability during melting, forging, heat treatment and welding, development in industrial production, providing specified service life under safe operation taking into account the following operating factors: pressure, temperature, radiation exposure, mechanical, static, thermal, cyclic, vibration and impact loads, including a technological cycle of manufacturing;
.3 basic metal and welding consumables of the SGU internals shall have a set of physical and chemical, mechanical and processing properties for: corrosion resistance in the primary, secondary and tertiary media, including resistance to intergranular corrosion and cracking corrosion, radiation resistance, strength, ductility, weldability, providing specified service life under safe operation condition taking into account the operating factors: mechanical, static, thermal, cyclic, vibration and impact loads. The SGU internals made of austenitic class steels (including welded joints) affected by technological heat treatment during the SGU manufacture shall have resistance to intergranular corrosion (shall pass sample tests) upon technological heat treatment;
.4 corrosion-resistant deposit materials of the SGU case components (made of perlite class steel) shall have a set of physical and chemical, mechanical and processing properties for: corrosion resistance in the primary, secondary and tertiary media, including resistance to intergranular corrosion, resistance to hot cracking, radiation resistance, strength, ductility, providing specified service life under safe operation taking into account the operating factors: temperature, radiation exposure, mechanical, static, thermal, cyclic, vibration and impact loads. Materials for corrosion-resistant deposition of products subject to heat treatment (tempering) after deposition shall have resistance to intergranular corrosion (shall undergo testing, including, inter alia, of mechanical properties on the heat-treated samples);
.5 in case of a new design, cobalt content in basic metal and welding consumables of the SGU internals as well as in materials of corrosion-resistant deposits contacting with the primary coolant shall not exceed 0,05 %.

7.7 Provision of cleanliness:

.1 cleanliness of the cavities and surfaces in contact with the primary, secondary and tertiary coolants shall be provided and monitored in accordance with the technical requirements of the standard approved by the Register and specified in the design documentation for manufacture and installation of the SGU equipment;

.2 cleanliness shall be provided at all stages of the SGU manufacture, assembly and installation, taking into account the appearance during manufacture, assembly and installation of the cavities and surfaces inaccessible and difficult to access for further cleaning and cleanliness monitoring;

.3 SG cassettes fitted inside the SGU case become inaccessible for further cleaning and cleanliness monitoring. Provision of their cleanliness and monitoring shall be carried out at the manufacturing stage, further operations on the SGU assembly and installation shall be performed by taking organizational and technical measures to prevent ingress of contamination and foreign objects into cavities of the SG cassettes. The ultimate cleanliness shall be provided upon the final installation by flushing cavities of the primary and secondary circuits with hot water according to the builder's procedure developed in accordance with the cleanliness standard approved by the Register.

7.8 The SGU equipment shall be designed to maintain operability on Safety Class 1 under conditions complying with Section 8, Part II "Safety Standards". Requirements for external conditions of the SGU operation may be specified by the customer in technical statement on NS taking into consideration the NS operating conditions.

8 PRIMARY COOLANT SYSTEM

8.1 Equipment, pipelines, valves and fittings forming the primary coolant system shall comply in full with the requirements applied to safety classes 1 and 2 equipment.

8.2 Means for detection of the primary coolant leakage shall be provided.

8.3 The primary circuit shall be designed with sufficient safety factor to ensure ductility of walls under stresses due to operation, maintenance, testing and emergency conditions adopted in the design. The safety factor shall account for impact of operating temperature on walls and radiation effects on material properties as well as other effects available in these conditions.

8.4 When selecting materials and manufacturing procedures, the following shall be taken into account:

.1 compatibility with working fluids;

.2 corrosive and erosive action of coolant, washing and decontamination fluids;

.3 forming of components with large half-life period;

.4 impact of neutron exposure on material properties.

8.5 The primary circuit shall be fitted with automatic arrangements, which prevent its overpressure. The choice of these arrangements is justified in the design. At least two of these shall be provided for installation of safety valves/devices. Fluid from actuation of these valves/devices shall be drained into overpressure protected container as agreed upon with the Register.

8.5.1 Safety valves shall have sufficient capacity to prevent pressure increase by more than 10 % as compared to the design pressure for all main design-basis accidents if one valve fails to actuate.

8.5.2 Usage of burst diaphragms instead of valves is not permitted.

8.5.3 No shutdown devices of safety valves opening and closing are allowed:

.1 unless effective locking device capable of automatic opening of auxiliary discharge valve of appropriate capacity is provided;

.2 unless the nuclear reactor protection system is fitted with shutdown devices upon the pressure increase signal.

8.5.4 Other equivalent safety valves may be used when the following criteria are met:

.1 such valves are at least of equal efficiency as compared to safety valves;

.2 risk is not increasing in quantity;

.3 primary circuit remains intact for SC1 to SC4 and maximum stresses in the reactor body and in the whole primary circuit are restricted i.e. possible stress shall not exceed permissible stresses due to safety factor;

.4 state classes which include release of coolant into environment (fourth circuit) are taken into account;

.5 it is proved that Criteria A, B, C specified in Part II "Safety Standards" are met;

.6 similar replacement is approved by the Register.

8.5.5 Evidence confirming that requirements of 8.5.4.1 – 8.5.4.5 are met shall be given in the Nuclear Ship Safety Information.

9 SECONDARY COOLANT SYSTEM

9.1 The secondary coolant system shall comply with Part VIII "Systems and Piping" of the Rules for the Classification in addition to provisions of these Rules.

9.2 SG with pipelines and fittings up to the second shut-off stop valve included shall comply with the same design standards and be of the same reliability as the primary equipment.

9.3 SG with fittings under internal pressure shall be tested as per Table 1.3.1 of the Guidelines on Technical Supervision of Nuclear Ships, Nuclear Floating Facilities and Nuclear Support Vessels in Service.

9.4 Each reactor shall be provided with at least two SG or one SG with two separate sections capable of being switched off.

The SG cassettes inbuilt into the SGU reactor body shall be combined by the secondary circuit (steam and feed water) as independent SG piping systems (at least two per one SGU) and deactivated in case of steam and feed water.

9.5 The secondary steam lines and feed-water pipelines shall be fitted with two shut-off stop devices with draining of water in-between into the protected contained within the controlled area. Stop devices shall be fitted as close as possible to SG. At least one stop device fitted on steam and feed-water pipelines shall be capable of being remotely and locally controlled, the other devices may be locally controlled only. Steam and feed-water pipelines shall be fitted with one automatic stop device which actuates upon the signal of failure in leak tightness of the SG piping.

9.6 Provision for washing SG shall be provided.

9.7 In case of multi-section SG provision for isolation and disconnection of the non-tight sections shall be envisaged.

9.8 Means for overpressure protection of the secondary coolant system shall be provided.

9.9 Each SG (or assembly of steam generating units connected as to prevent isolation from each other), unless rated for the primary pressure, shall be fitted with at least two safety valves located upstream of the first shut-off valve. Safety valves shall comply with Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification, as far as applicable.

9.9.1 Safety valves shall have sufficient capacity to prevent pressure increase by more than 10 % as compared to design pressure for all main design-basis accidents if at least one valve fails to actuate.

9.9.2 When leakage of coolant from the primary to secondary circuit may result in actuation of safety valves of the secondary circuit, water through these valves shall be drained in a container located within the containment/shielding barrier.

10 REMOVAL OF RESIDUAL HEAT FROM REACTOR

10.1 The equipment for residual heat removal from the core during normal or emergency shutdown of the reactor as well as during core handling and repair shall be provided in the nuclear ship design.

The equipment for residual heat removal from holdup tank and irradiated fuel assemblies storage facilities shall be provided in design of the nuclear support vessel[1].

The residual heat removal system shall comply with a single failure criterion.

10.2 The residual heat removal system shall remain operational in the course and after all accidents on board the ship except for the following:

.1 capsizing of the ship;

.2 flooding at a depth where it may be proven than heat may be removed by containment flooding.

10.3 The residual heat removal system shall remain operational for a period as specified during analysis of operating and emergency situations.

10.4 The residual heat removal system shall be effective and have sufficient capacity and safety margin for the following purposes:

.1 to ensure integrity of fuel elements cladding through core cooling in case of SC1 and SC2;

.2 to ensure core cooling in case of SC3 and SC4 and to prevent exceeded permissible exposure of persons and environmental pollution due to damaged claddings of fuel elements.

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[1] Hereinafter referred to as "the NS vessel".

11 CORE EMERGENCY COOLING

11.1 Core emergency cooling system is a safety system.

11.1.1 This system shall comply with a single failure criterion.

11.1.2 This system shall maintain, as far as practicable, integrity of fuel elements after the maximum design-basis accident followed by the reactor stoppage. Core coolant supply means shall ensure effective operation until residual heat removal means appear to be capable of removing the remaining continuous heat release of the core.

11.1.3 In case hydropneumatic cylinders are used for core emergency cooling, they shall be fitted with the safety valves, gas pressure and water level indicators. Sources for maintaining gas cushion in such vessels shall be provided.

11.1.4 All switches of the core emergency cooling system other than the main switch, shall be mechanically locked in a position required for system operation.

11.1.5 The core emergency cooling systems shall be controlled from the central control station.

11.1.6 Machinery, devices and fittings of the core emergency cooling systems shall be accessible for testing and checks of operability.

11.2 Emergency cooling systems in the multiple-reactor SSS shall be completely separated unless it is shown in the design that using their assemblies in different reactors does not impair the capability of this system to perform its intended functions.

12 SSS SYSTEMS AND PIPING

12.1 The SSS systems and piping of safety classes 1 and 2 shall comply with the following requirements:

.1 strength of systems and pipelines shall be calculated based on their safety classes according to the procedures approved by the Register;

.2 design pressure and temperature shall be selected based on analysis of the SSS operation modes;

.3 pipes and fittings shall be made of easy-to-weld, corrosion- and erosion resistant materials which are non-susceptible to intergranular corrosion and which maintain their strength and ductility when exposed to radioactive radiation during operation on board the ship. The materials shall be capable of being decontaminated;

.4 system piping shall be made of seamless pipes;

.5 pipeline connections located in the containment and outside it up to the second shut-off valve shall be welded;

.6 structure, welding and test of piping welded joints as well as welded joints of branches shall be performed as per welding provisions and regulations for weld inspection approved by the Register;

.7 when non-radioactive fluid shall be supplied to the piping with radioactive fluid, the intake pipe shall be fitted with non-retum and stop valves;

.8 system fittings and valves shall be fitted with welded neck flanges and typically with bellows sealing;

.9 piping shall be thermally insulated with regard to possibility of decontamination.

.10 materials and structure of thermal insulation shall be approved by the Register; Thermal insulation shall be of non-combustible materials;

.11 upon final treatment at the workshop and installation on board the ship, pipes and fittings shall be subject to hydraulic test at the test pressure and to leak tightness test. Standards for hydraulic tests shall be agreed upon with the Register.

12.2 Systems and piping of safety classes 3 and 4 of the nuclear ship shall comply with Part VIII "Systems and Piping" of the Rules for the Classification.

12.3 All pipelines penetrating the containment shall comply with 4.3 and 4.4.

12.4 Fittings and valves of the SSS equipment, systems and pipelines shall be fitted with local position indicators and legible nameplates. Remotely controlled fittings and valves shall be additionally fitted with devices for its local control from the point of its location. Fittings and valves to be controlled from the central control station shall be additionally marked similarly to the console marking.

13 SSS HEAT EXCHANGERS AND PRESSURE VESSELS

13.1 The SSS heat exchangers and pressure vessels shall be designed with regard to their safety class.

13.2 Heat exchangers and pressure vessels of safety classes 1 and 2, except for the reactor, shall meet the following requirements:

.1 strength of heat exchangers and pressure vessels shall be calculated according to the procedures approved by the Register;

.2 sealing procedures for main connectors shall be approved by the Register;

.3 cases of heat exchangers and pressure vessels shall be adapted for hydrostatic tests;

.4 heat exchangers and pressure vessels, except for the primary circuit, shall be protected against unacceptable pressure increase by means of safety devices, where necessary;

.5 it is allowed not to install safety devices on heat exchangers and pressure vessels of safety classes 1 and 2 when they are connected to the vessel fitted with safety devices through non-isolated pipes;

.6 heat exchangers and pressure vessels shall be made of easy-to-weld, corrosion- and erosion resistant materials which are non-susceptible to intergranular corrosion and which maintain their strength and ductility when exposed to radioactive radiation during operation on board the ship. The materials shall be capable of being decontaminated and approved by the Register;

.7 structure, welding and test of welds of heat exchangers and pressure vessels shall be performed according to the welding provisions and regulations for weld inspection approved by the Register. All welds shall be subject to non-destructive testing;

.8 upon manufacture and installation on board the ship, heat exchangers and pressure vessels shall be subject to hydraulic tests at test pressure and leak tightness test according to the standards for hydrostatic test approved by the Register;

.9 prior to applying insulation/protective coating to heat exchangers and pressure vessels, they shall be subject to hydrostatic tests and other mechanical strength tests.

13.3 Heat exchangers and pressure vessels of safety classes 1 — 4 shall also comply with Part X "Boilers, Heat Exchangers and Pressure Vessels" of the Rules for the Classification insofar as they do not conflict with these Rules.

14 CONTROL AND PROTECTION SYSTEM

14.1 CPS shall be provided for the following purposes:

.1 continuous monitoring of the reactor operating state;

.2 automatic and remote control of SSS which prevents exceeding of the reactor design specifications critical for safety;

.3 automatic and remote control of the reactor at a given power;

.4 perception of emergency state signals and activation of systems and equipment critical for safety.

14.2 CPS shall be redundant in terms of safety functions and be able to perform its intended functions assuming a single failure.

14.3 CPS shall ensure proper control of reactor power as per operating demands of the ship for all operating maneuvers under normal and emergency situations and appropriate sea states. CPS shall, as far as practicable, prevent operating restrictions for the nuclear ship not applied to ships of similar dimensions with conventional propulsion plant of the same power.

14.4 CPS shall receive signals from sensors of parameters measured via different channels, including neutron flow.

Parameters critical for the reactor control shall not be measured via one channel.

14.5 CPS shall be capable of being in-service tested without impairing safety.

14.6 The reactor adjusters shall be designed to ensure automatic and remote control of the reactor.

14.7 Means for testing operability of each channel of the reactor CPS and means for detecting faulty components shall be provided.

14.8 To detect faults/accidents in the reactor, at least two naturally different parameters characterizing the operating process shall be tested. In case it is unreasonable or impracticable, additional redundancy shall be envisaged for variable parameters in the test channel.

14.9 Devices of reactor protection system required for monitoring in SC3 and SC4 shall remain operational in such conditions.

14.10 The light signal shall be supplied in case of a failure or damage to the channel of the reactor CPS.

14.11 Basic design provisions for reactivity control to be taken into account for design process.

14.11.1 Events, which may result in unintended increase in reactivity, shall be very occasional as specified in Section 3, Part II "Safety Standards" and shall not result in situations more hazardous for the crew, population and environment than mentioned in Part IX "Radiation Safety".

14.11.2 The anticipated accidents of reactivity change shall not result in spontaneous chain reaction or depressurization of primary coolant system and impede shutdown of reactor.

14.11.3 When reactor is operating at power corresponding to ship running modes, reactivity factor shall be negative with regard to design roll and acceleration of the ship.

14.11.4 CPS shall be capable of shutting down the reactor automatically when the ship is inclined up to an angle of vanishing stability and maintain the reactor in such state at all angles. In addition, CPS shall actuate automatically if the ship is sinking, or its static heel is 45°, or its trim is 10°.

In case of less static heel and trim angles, the CPS automatic actuation for reactor shutdown is not required.

14.12 CPS shall meet the following requirements.

14.12.1 The system shall comprise at least two independent reliable reactivity control subsystems of different design.

14.12.2 One subsystem shall be mechanical and have the following features:

.1 be capable of automatically switching the core to the subcritical state and maintaining it in a cold subcritical state without neutron poison within the core life considering that the most effective control of the reactor CPS is extracted from the core and may not be inserted again;

.2 be capable of effectively controlling variations in reactivity and preventing exceeding design restrictions on fuel specifications of the core for any operating and emergency design state;

.3 contain devices for preventing unintended motions of any control of reactor protection and control system;

.4 properly operate in case of a failure in one stand-by channel which generate signals for actuation of emergency protection including measurements;

.5 reduce reactor power at a rate preventing exceeding any design restrictions upon receipt of the emergency signal;

.6 display position readings of each neutron poison element on reactor control console;

.7 be designed to reduce the possibility of unplanned continuous removal of control of the reactor CPS from the core down to the acceptable level;

.8 issue sequence of commands to the CPS actuators to minimize the possibility of operator's error;

.9 be fitted with devices for preventing removing controls of CPS from the core by abnormal groups or in abnormal order.

14.12.3 The other reactivity control subsystem shall be capable of switching and maintaining the reactor core in a subcritical state.

14.12.4 Reactivity control subsystems shall remain completely operational for all design inclinations of the ship and ensure functional checks, regular calibrations of device within the measuring power range and tests for proper operation of devices.

14.12.5 Controls of the reactor CPS being inserted into the core shall be capable of maintaining the core in a subcritical state with sufficient margin within its entire life and after total exhaust of energy including periods of maintenance, fuel handling, emergency states of reactor and ship including capsizing and flooding.

14.12.6 The reactor shall remain operational at powers sufficient for steerability of the ship under SC1 within the specified energy of the core in case of sticking of the most effective control in the core at energy level of power and its failure to be removed from the core except for cases when the core is poisoned with xenon.

14.12.7 The reactivity control means shall be designed to ensure control from central control station and possibility of switching and maintaining the core in the subcritical state from the emergency cooling station.

14.13 To prevent unplanned variations in reactivity due to moderator density variation, means for estimation and control of power arbitrary fluctuations and variations within the reactor core shall be provided unless calculation results prove that such fluctuations are minimum and along with acceptable margins do not result in conditions where limited estimated specifications may be exceeded.

14.14 For SC2, CPS shall switch on the reactor after its short-term shutdown at the specified time to ensure maneuverability of the ship without impairing safety.

14.15 Failure in any control shall not impede safe stoppage of the reactor.

14.16 CPS shall be located as to ensure total monitoring and control of reactor for SC1, SC2, SC3 from the central control station as well as reactor shutdown and control its state from the navigation bridge or from emergency cooling control station.

Central control station for reactor shall be located in less vulnerable place (against fires, explosions, flying fragments, radioactivity, etc.) but as close to the reactor and machinery installation as possible in order to reduce length of control circuits. Central control stations shall be provided with at least two escape exits.

14.17 The reactor emergency cooling control station located away from the central control station shall be provided for the following purposes:

.1 independent shutdown of the reactor. The reactor may also be shutdown from the other continuously manned station;

.2 possibility of further independent reactor cooling;

.3 monitoring of the reactor state and primary circuit and maintenance of the reactor in a cold state as well as indication on reactivity control position.

The emergency cooling control station shall be located at sufficient distance from central control station in order to avoid damage in case of fire or any other emergency in central control station.

The emergency cooling control station may be functionally connected to the bridge.

14.18 Measures to prevent effects caused by incorrect operator's actions shall be provided in the control system.

14.19 Where locking devices for emergency protection actuation are permitted by design, these locking devices shall be clearly marked on the reactor control station. Generally, locking devices for emergency protection actuation are not required in CPS.

14.20 In addition to automatic and remote control, the CPS drives shall be manually controlled directly from the point of their location. The direction of manual handle rotation and appropriate direction of motion of controls (CPS) shall be clearly marked.

15 INSTRUMENTS

15.1 Instruments shall be provided to ensure equipment performance in normal operational conditions and during design-basis accidents.

15.2 These shall include instruments ensuring reliable measurements of the parameters characterizing the operating conditions and the system’s operation control.

15.3 The most critical SSS parameters shall be automatically recorded by the appropriate instruments with time and date indication.

15.4 The CPS instruments shall ensure continuous measurement of neutron flow (including reactor startup period) from minimum controlled power to the maximum design power of the reactor.

15.5 The CPS instruments shall be redundant and separated from the instruments designed for measuring the parameters and testing operation of systems.

15.6 Instruments (including cables and penetrations) located in the containment and performing the following safety-related functions shall remain operational during design-basis accidents:

emergency stoppage of the reactor and its maintaining in the subcritical state;

emergency heat removal from the reactor;

maintenance of radioactive materials and ionizing radiation within design limits.

Equipment, fittings, valves and automation means are listed in Appendix.

15.7 Instruments, cables and equipment shall be located and backed up so as to ensure the operability of reactor protection system instruments in case of design-basis accidents.

15.8 Indicating gauges shall be marked with the limiting values and the setting range.

15.9 Measuring channels shall be fitted with built-in automatic self-test system.

15.10 Alarm shall be installed actuating in case of faults of measuring channels and instruments.

15.11 The structure of the control system shall be such as to provide prompt and precise assessment of the SSS condition.

APPENDIX

LIST OF THE EQUIPMENT, VALVES, FITTINGS AND INSTRUMENTS THAT SHALL REMAIN OPERATIONAL DURING MAXIMUM DESIGN-BASIS ACCIDENTS

1 Equipment:
.1 reactor, including the reactor CPS (going down and position control).
2 Pneumatically controlled valves of the following systems (position control):
.1 HPG system;
.2 decontamination and cooling systems;
.3 primary circuit sampling systems;
.4 secondary circuit system (first shut-off steam and feed-water valve);
.5 tertiary circuit system (first shut-off valve);
.6 core emergency cooling systems.
3 Instrumentation for the following parameters (operability):
.1 primary circuit system pressure;
.2 water level in the primary circuit pressure compensators;
.3 reactor coolant temperature;
.4 reactor power;
.5 medium temperature in the containment space;
.6 pressure in hydraulic accumulators;
.7 water level in hydraulic accumulators;
.8 medium pressure in the inter-valve space of core emergency cooling system channels.

Russian Maritime Register of Shipping

Rules for the Classification and Construction
of Nuclear Ships and Nuclear Support Vessels
Part VI
Nuclear Steam Supply Systems

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