RUSSIAN MARITIME REGISTER OF SHIPPING

Version: 01.10.2022

RULES

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

PART II

SAFETY STANDARDS

ND No. 2-020101-169-E

St. Petersburg
2022

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

Rules for the Classification and Construction of Nuclear Ships and Nuclear Support Vessels developed by Russian Maritime Register of Shipping (RS, the Register) have been approved in accordance with the established approval procedure and come into force on 1 October 2022.

The present edition is based on the 2022 edition of the Rules for the Classification and Construction of Nuclear Ships and Floating Facilities and on the 2017 edition of the Rules for the Classification and Construction of Nuclear Support Vessels, taking into account Circular Letters No. 110-312-1-1695c dated 04.02.2022 and No. 110-312-1-1702c dated 14.02.2022, amendments and additions developed immediately before publication.

The Rules set down specific requirements for the nuclear ships, nuclear support vessels and supplement the Rules for the Classification and Construction of Sea-Going Ships and the Rules for the Equipment of Sea-Going Ships of Russian Maritime Register of Shipping.

The Rules are published in the following parts:

Part I "Classification";
Part II "Safety Standards";
Part III "Hull";
Part IV "Stability. Subdivision";
Part V "Fire Protection";
Part VI "Nuclear Steam Supply Systems";
Part VII "Special Systems";
Part VIII "Electrical and Automation Equipment";
Part IX "Radiation Safety";
Part X "Physical Security".

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.

1 GENERAL

1.1 The requirements implemented by this Part of the Rules for the Classification and Construction of Nuclear Ships and Nuclear Support Vessels[1] are aimed at general safety of the nuclear ship which include the NSSS safety.

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

[1] Hereinafter referred to as "these Rules".

2 BASIC REQUIREMENTS

2.1 The following basic requirements shall be met to provide safety of the ship and to protect the environment against radioactive materials.

2.1.1 To reduce dissemination of ionizing radiation and radioactive materials into environment, radioactivity sources shall be surrounded by several sequential shielding barriers.

2.1.2 In addition to the main normal operation systems, special-purpose safety systems, which start automatically upon an accident, shall be provided.

2.2 To provide protection against ionizing radiation, the following is required:

.1 to provide proper biological shielding;

.2 to earmark radiation areas on board the ship;

.3 to reduce time of exposure;

.4 to prevent people from being in the vicinity of radiation sources unless it is necessary;

.5 in case of accidents, the personnel shall act in accordance with the Operating Manual for the ship;

.6 to provide personal protective equipment (PPE).

2.3 The SSS CPS, safety systems and other technical facilities specified in these Rules shall comply with a single failure concept (refer to Section 7).

2.4 To confirm that safety of the nuclear ship complies with requirements of these Rules, all required operating and emergency conditions shall be scrutinized in the detailed design with regard to purpose of the ship and their assumed frequency and effects shall be evaluated.

Based on this evaluation, safety design concepts are adopted assuming that the more severe effects may be permitted at less frequency.

2.5 The requirements to quality of structures, systems and equipment shall comply with their classification based on importance for the ship safety.

2.6 Under normal operation of the nuclear ship and SSS, all shielding barriers against radioactive materials shall be operational. SSS shall not be operated at power when design safety limits of shielding barriers or their safety arrangements are beyond those specified in the detailed design of the nuclear ship according to the safety operation conditions.

2.7 The provision shall be made that at astern power of propulsion unit the ship doesn't exceed the distance braking at full speed forward as specified in the technical assignment for the ship design. The same shall be checked during sea trails.

2.8 The nuclear ship equipped with one reactor shall have a stand-by power source to provide the ship movement, SSS cooling in case of its failure as well as to provide normal habitable conditions, steerability, unsinkability, fire safety, ship signals and communication, escape routes and operation of boat winches. This stand-by power source shall:

.1 be ready and provide sufficient power for safe operation of the ship in harbor and maintain steerability at sea equal to wind force of Beaufort scale 6 under any normal loading conditions;

.2 be ready when the ship is in restricted waters or areas of intense navigation;

.3 not depend on SSS;

.4 be placed outside the reactor compartment.

3 STATE CLASSES OF NUCLEAR SHIP AND STEAM SUPPLY SYSTEM

3.1 States of the ship and its SSS shall be subdivided into four groups (SC1, SC2, SC3 and SC4) depending on their possible frequency of possible accidents and effects as per Table 3.1.

Table 3.1

State class	State of the ship and SSS	Possible frequency	Effects
1	2	3	4
SC1	Normal operation	Permanent or often	Ship and its SSS are in normal operating state. Radiation environment on board the ship is within standard limits.
SC2	Minor faults	Occasionally	Faults, which do not result in significant damage of ship operation. Short-term stop of die reactor may be required. Minor deviations of radiation from standard limits which do not result in increase in exposure of personnel on board die ship beyond standard limits.
SC3	Major damage	Rarely	Damages to ship structures/SSS equipment which affect safety of further ship operation. Long-term shutdown of SSS and containment isolation may be required. Possible deviations of radiation on board the ship from standard limits Exposure of personnel on board the ship/floating facility is not beyond the specified limits.
SC4	Sever accidents	Very rarely	Severe damages, which require activation of emergency cooling system/ containment operation but which do not result in unacceptable radioactive emissions into environment. Radiation on board the ship significantly deviates from permissible limits. Exposure of some persons on board the ship does not exceed the double value of permissible dose as specified by applicable Radiation Safety Standards for the Personnel.
Notes. "Permanent or often" means that the event occurs permanently or may occur often within service life of this ship. "Occasionally" means that the event may occur more than once within service life of this ship. "Rarely" means that the event is unlikely to occur within service life of this ship but may occur on some sister ships within their service life. "Very rarely" means that the event is unlikely to occur but anyway it may occur within the total service life of particular sister nuclear-powered ships.			

Assessment of frequency and effects of possible accidents, class assignment of possible event shall be justified and specified in the Nuclear Ship Safety Information submitted as a part of the ship technical design documentation.

3.2 The effects of events that are too unlikely to occur and followed by the total loss of operability of all ship's power sources (capsizing, flooding, grounding and stranding with heel more than 30°, etc.) including the effects of the beyond design-basis accident are not regulated by these Rules.

4 SSS STATE CLASSES

4.1 When designing SSS, arrangements to provide its safety and reliability shall be provided at regulated state of SSS and the ship as well as according to weather and other environmental effects.

4.2 Four classes (refer to Section 3) are established to assess the SSS state (including emergency one) depending on frequency and consequences of events/faults and failures for equipment to be considered in the SSS design.

4.3 SC1 is the normal state when SSS may be operated in any prescribed mode. In such a state, failures in some equipment components may occur. These failures do not affect the SSS safety operation and do not impose any restrictions to its operation.

SC1 includes the following SSS operation modes:

.1 startup;

.2 operation at prescribed power;

.3 mooring and sea trials;

.4 routine preventive inspections and maintenance;

.5 variable modes;

.6 exposure to bad weather conditions;

.7 sorbent handling;

.8 stoppage;

.9 neutronic and thermohydraulic measurements;

.10 recharging of reactor core.

4.4 SC2 is the SSS state in any prescribed mode. In this state, there may be failures or malfunctions of equipment due to some faults or operator's errors imposing timing constraints on the SSS operation (power reduction or short-term deactivation).

SC2 includes the SSS operation modes in case of occasional failures in equipment or scheduled actions during such abnormal operating conditions including:

.1 failure or malfunction of machinery or device which results in variation in primary coolant parameters/maneuverability of a self-propelled ship, for example: shutdown of power generator, turbine, condenser, fresh water heat exchanger, termination of sea water supply, closure of valves on the main pipeline, failure in the main electric system, shutdown of feed-water pump;

.2 unintended startup of feed-water pump/primary circulating pump;

.3 change in core reactivity as a result of cold water supply;

.4 sticking of one or more control valves of the reactor CPS or failure in emergency protection drive;

.5 reactor emergency protection actuation;

.6 shutdown/failure in primary circulating pump when other pumps are operational;

.7 failure in control (turbine, feed-water, water flow regulators, etc.);

.8 minor leakage in primary coolant circulating system;

.9 actuation of secondary safety valve.

4.5 SC3 is the SSS emergency state which may require the SSS deactivation. SC3 includes the following rare accidents:

.1 failure in tightness of the primary coolant system which results in pressure drop in the system and requires such measures as containment isolation, primary circuit make-up and reactor deactivation;

.2 termination of forced circulation of the primary coolant;

.3 failure in the secondary feed-water supply;

.4 grounding and stranding of the ship with no failure in heat removal from the reactor in case of intact ship;

.5 ship collisions followed by flooding of two adjacent watertight compartments;

.6 fire/explosion on board the ship which does not result in the damaged reactor compartment;

.7 fire in engine room/central control station;

.8 accidents due to rare bad weather conditions and natural disasters in the scheduled navigation area/docking area of the ship. These accidents are too unlikely to occur;

.9 temporary blackout of the main electric system.

4.6 SC4 is a very rare severe SSS emergency state requiring the SSS urgent deactivation. SC4 includes very rare accidents where some power sources are capable of operation on board the ship:

.1 accident followed by integrity failure/depressurization of fuel element cladding, failure in heat removal and primary coolant loss;

.2 grounding and stranding of the ship followed by periodic loss of capability of heat removal to the coolant;

.3 extremely rare severe weather conditions and natural disasters;

.4 grounding or stranding of the ship with local damage to the double bottom over its height or with the long-length damage to the bottom;

.5 ship collisions followed by fire and/or explosion on board the ship;

.6 rupture of the main steam line/steam line within the shielding barrier;

.7 flooding of the ship in shallow waters (up to the upper deck);

.8 helicopter crash in the area of the reactor compartment and/or nuclear fuel storage facilities.

5 SAFETY CLASSES

5.1 The NPP systems and equipment are subdivided into four safety classes according to their importance for the ship. These systems and equipment shall comply with design requirements, requirements to materials, manufacture, testing and operation.

5.2 Division of systems and equipment into safety classes shall be justified in the detailed design according to impact of failure in systems and equipment on the ship's safety, as well as approved by the Register and included into the Nuclear Ship Safety Information.

5.3 The SSS equipment, machinery, systems and devices shall be divided into four safety classes depending on their importance for the ship's safety.

Classification below is given for indicative purposes.

5.4 Safety Class 1 covers the following SSS components:

.1 reactors, core supporting structures, fuel assemblies, pressure vessels and other primary components, including the systems and piping, which failure may result in emergency states SC3 and SC4 (refer to 4.5 — 4.6).

Equipment and piping associated with reactor cooling system and forming part of the primary circuit of reactor cooling are not required to meet requirements of Safety Class 1. In this case there shall be provision for disconnecting and cooling them conventionally by making up leakages using primary make-up system only in case of design basis failure in equipment or piping under normal operation of the reactor or there shall be provision for disconnecting equipment/piping from the reactor cooling system by means of two valves. Each open valve shall be ready for automatic closure. The time of closure for the valve shall be as to provide its operability and possibility of disconnection and conventional cooling of the reactor in case of design-basis failure in equipment/piping at the reactor normal operation;

.2 SG and secondary piping, including shut-off valves fitted on the main steam line and feed-water piping;

.3 reactor emergency protection system, including the reactor CPS drives and monitoring system sensors, which generate emergency protection signal and also produce and implement the SSS control algorithm according to emergency protection signals;

.4 primary circulating pump and its cooling pipelines, including shut-off valves.

5.5 Safety Class 2 covers the following components:

.1 primary circuit components, which are not covered by Safety Class 1;

.2 equipment and systems required for the following:

residual heat removal from the reactor core in case of SC2, SC3 and SC4;

monitoring the release of radioactive materials within the containment;

suppression of excessive hydrogen content within the containment after the accident followed by major leakage/loss of the primary coolant;

reactor core cooling and/or decompression in the event of an accident (residual heat removal system and core emergency cooling system, including emergency power supply, hydro pneumatic cylinders, coolant tanks, etc.);

reactor core cooling and/or decompression in the event of an accident followed by coolant loss;

making up leakages of the primary coolant (make-up system);

performing any other functions, which may be of similar importance for safety;

.3 SSS control and monitoring system;

.4 power supply systems and equipment for the SSS control systems and reactor CPS;

.5 containment air purification system from the primary circuit to the containment;

.6 overpressure protection means and system for removing primary coolant from the safety valves not covered by Safety Class 1.

5.6 Safety Class 3 covers the following components:

.1 any safety systems of SSS or their components not covered by Safety Classes 1 and 2;

.2 auxiliary systems for maintaining safety systems: lubricating oil systems, hydraulic systems, sea water and fresh water cooling systems (equipment), compressed air systems, emergency power supply fuel system for core emergency cooling system;

.3 sea water cooling system performing safety functions to meet the basic design criterion B;

.4 systems which are not directly associated with safety but which failure may result in release of radioactive materials into environment and normally requiring appropriate waiting time to reduce radioactivity.

5.7 Safety Class 4 covers the following components:

.1 feed-water and secondary vapor system downstream of the second shut-off valves not covered by Safety Classes 2 and 3;

.2 turbines, condensers and turbogenerators not covered by Safety Classes 1, 2 and 3 where they participate in the SSS cooling;

.3 other equipment which failure may directly lead to SC2.

5.8 When designing and manufacturing the equipment of Safety Classes 1, 2 and 3, the following requirements shall be taken into account:

5.8.1 When choosing materials, the following shall be considered:

their physical, chemical and mechanical properties (ductility, strength, brittle-to-ductile transition temperature, intergranular corrosion susceptibility, weldability, radiation resistance, etc.);

force actions under operating conditions (alternating loads, shocks, vibrations, pressure, temperature, radiation exposure, working fluids corrosive action, etc.).

The materials to be applied shall be approved by the Register.

5.8.2 Strength shall be calculated in accordance with the Rules for the Classification or documents approved by the Register.

Structures and their supports shall be capable of withstanding static and dynamic loads due to variations in operating parameters and ship motion in a seaway.

Pipelines with working fluid temperature of 120 °C and above shall be capable of withstanding static pressure and temperature loads with factors accounting for dynamic loads due to ship rolls under different loading conditions.

5.8.3 Manufacturing process and quality control:

all components of Safety Class 1 shall be manufactured in compliance with the approved procedure;

during manufacture all welds shall be subject to non-destructive testing. All components shall be also subject to non-destructive testing in the required scope in order to detect surface and internal defects and cracks. Test results shall be recorded into logbooks and operating documents and shall be further used for assessing the equipment state during non-destructive testing when surveying ships in service;

cavities and surfaces shall be clean and be checked for hygiene in compliance with the approved standards.

5.9 During design of the SSS equipment, the cyclic loads shall be considered.

Assessment of impact of every accident and every test shall be conducted to identify the remaining safety service life for the primary equipment with respect to cyclic loads.

6 BASIC DESIGN CRITERIA AND SAFETY FUNCTIONS

6.1 To provide safety for all state classes, the nuclear ship shall comply with the following criteria:

.1 criterion A: means shall be provided for proper shielding of ionizing radiation sources and minimization of radioactive materials dissemination to provide that people's exposure to radiation and environmental contamination are low to the extent practicable;

.2 criterion B: means shall be provided for effective removal of residual heat from the reactor core;

.3 criterion C: means shall be provided for safety control and reactor switching to subcritical state and its maintaining in this state within required time.

6.2 For compliance with the basic criteria specified in 6.1, the following safety functions shall be met:

.1 criterion A:

.1.1 fuel claddings in the reactor core being the first shielding barrier between nuclear fuel and environment shall be properly maintained;

.1.2 the integrity of the primary heavy duty circuit being the second shielding barrier shall be maintained;

.1.3 accidental release shall be excluded and leakage of radioactive materials from containment being the third barrier shall be reduced;

.1.4 leakage of radioactive materials from shielding being the fourth barrier shall be additionally reduced;

.2 criterion B:

.2.1 residual heat shall be removed from the reactor core to the coolant;

.2.2 coolant shall be supplied to the reactor core (core emergency cooling);

.2.3 power supply to the safety facilities specified in 6.2.2.1 and 6.2.2.2;

.3 criterion C:

.3.1 reactivity shall be properly monitored;

.3.2 reactor shall be switched to subcritical state without exceeding specified design limits for the core;

.3.3 power shall be fed to the safety facilities specified in 6.2.3.1 and 6.2.3.2.

6.3 To provide performance of the safety functions specified in 6.2 for states SC2, SC3, SC4, special-purpose safety systems shall be provided in addition to operation support systems. Based on analyzed possible accidents and effects it is determined whether special-purpose safety systems are required.

7 SINGLE FAILURE CONCEPT

7.1 In the design process, safety systems shall properly respond to any initial event related to SC2, SC3 and SC4 despite of supposed single failure in any system component.

7.2 When analyzing the safety system for compliance with a single failure concept, the single failure in each component is supposed, thereby:

.1 safety system shall be evaluated assuming that the initial event (together with any other failures resulting directly from the initial event) is combined with an accident failure in one component of safety system.

Two or more simultaneously independent failures are not required to be considered;

.2 operator's error shall be considered as the kind of a single failure or initial event.

Failures in well-designed, manufactured and tested passive components (such as pipelines, vessels, heat exchangers, electric cables) are not required to be considered, provided that there are no sufficient grounds.

7.3 To comply with a single failure concept, the equipment and systems shall be reliable and appropriate redundancy methods shall be used (component wise or subsystem-based redundancy) supplemented by the following, where necessary:

.1 components/subsystems shall be divided by bulkheads or located apart from each other;

.2 subsystems shall operate independently;

.3 components/subsystems shall be designed differently by operating principle, design, etc.

7.4 A single failure concept shall be applied rather to the safety system considered as the system of facilities intended for safety purpose than to components of this system even though these components/subsystems are capable of operation as a system.

7.5 A single failure concept is not required to be complied with in case of the states, which are more unlikely than SC4 followed by the total loss of operability of ship's power supply units (capsizing, flooding, etc.).

8 ENVIRONMENTAL CONDITIONS

8.1 The states of the nuclear ship and its NPP to be designed shall be considered under extreme environmental conditions in assumed operation area (e.g., hurricanes, tsunami, ice, seismic conditions).

8.2 Inertial forces affecting the ship at a sea state shall be accepted with regard to the equipment safety class. When calculating inertial forces, ship six degrees of freedom roll shall be considered over the sea spectrum within the navigation/docking area. In general case, sea spectrum based on statistical data for the North Atlantic region may be used.

8.3 Components and structures of safety classes 1 — 4 shall be capable of withstanding inertial forces of accepted sea spectrum acting for a time specified in Table 8.3.

Table 8.3

Safety class of components and structures	Time, days
1	15000
2 and 3	1500
4, as well as hull and machinery not subject to the requirements of international standards and rules	150

8.4 Machinery providing operation of SSS shall remain operational under heel and trim conditions in compliance with the requirements given in Table 8.4. Requirements for resistance to external actions of other NPP machinery are given in 2.3, Part VII "Machinery Installations" of the Rules for the Classification.

Table 8.4

No.	Conditions	Machinery and systems providing SSS operation
1	Long-term heel, deg	30
2	Roll, deg	45
3	Long-term trim, deg	10
4	Pitch, deg	15
Note. When proper justification is provided, the Register may lower the requirements specified in item 3. In this case the lowered requirements shall he mentioned in the Nuclear Ship Safety Information.		

8.5 When choosing location for the SSS machinery and equipment, their protection at internal and external emergencies shall be considered. It is required to provide shielding for the SSS machinery and equipment.

9 SSS ACCIDENT ANALYSIS

9.1 Analysis of possible accidents of the nuclear ship SSS shall be performed for SC2 — SC4. The analysis results shall be specified in designs of SSS and the ship and presented in the Nuclear Ship Safety Information.

9.2 Analysis of possible accidents shall be approved by the Register and shall include the following:

.1 conditions at the beginning of an accident, initial data for analysis;

.2 accident control measures, guidelines on systems and equipment being activated by the SSS protection systems, including the reactor CPS and other measures to be taken by the personnel;

.3 data on analysis procedures, physical and mathematical models, experimental data and computer codes;

.4 assumptions and theory of calculated radiation effects (e.g., increase in the primary coolant specific activity in case of a failure in the fuel assemblies cladding, efficiency of coolant purification, its leakage, radioactivity propagation factor, doses);

.5 data for assessing propagation range of radioactive materials into surrounding air (radioactive materials emission height above the upper deck, weather conditions);

.6 description of accident development, including predicted representation of radiation and other effects;

.7 measures to prevent failures in safety systems due to one reason;

.8 measures to protect personnel on board the ship during an accident.

9.3 For making assumptions on the accident occurrence and sequence of events, it is required to take into consideration the provisions of Section 6 and to be based on the following.

9.3.1 Systems and arrangements specified in 3.8, Part VI "Nuclear Steam Supply Systems" shall remain operational in the event of a single failure.

9.3.2 The stand-by subsystem of the safety system shall not be considered as operational in the event of a single failure in case it may be repaired during reactor operation as per its Operating Manual of the nuclear power plant.

9.3.3 Protective arrangements shall automatically actuate upon start of reactor accident. If operator's actions are required, it shall be considered that they are not possible within the first 30 min. Operator's actions shall not obstruct normal operation of protection systems. SSS shall be shown to be in safe condition when no operator's actions are taken for at least 30 min after an accident.

9.3.4 If the results of event being considered cannot be envisaged in a definite manner, the appropriate safety factors shall be adopted in assessment of possible accidents.

9.4 When assessing effects of possible accidents, their long-term effects shall be also considered. They shall be specified in the design documents.

9.5 When analyzing possible SSS accidents, it is required to consider the events coming as result of accidents on board the ship. Despite of collision, grounding and stranding protection as required by Part III "Hull", the following concepts shall be accepted in analyzing specific SSS accidents related to accidents on board the ship.

9.5.1 In case of collisions or grounding and stranding, the ship gets damaged to the maximum extent as accepted in 3.1, Part IV "Stability. Subdivision".

All equipment located within the damage penetration, including the equipment located in flooded spaces shall be considered as non-operational. Equipment designed specifically for underwater operations may be considered operational if its power supply units are shown as remaining operational.

9.5.2 It is assumed that the ship is sunk with the reactor disabled and is flooded up to the level above the upper continuous deck (flooding in shallow water). Shielding barrier and containment remain unflooded unless special-purpose equipment is provided for flooding these spaces at such a depth. Hydrostatic pressure stabilizing devices fitted on the containment, if any, may remain non-operational and the ship may remain at inclinations as defined in 8.5.

9.5.3 When the ship is flooded on deep water, at least criterion A specified in 6.1.1 shall be complied with.

Radioactivity shall be efficiently retained for a long period to ensure the minimum possible release of radioactive materials by keeping at least one significant structural barrier of sufficient leak tightness and corrosion resistance around highly radioactive sources.

9.5.4 The development of flooding process in terms of timing shall be considered regarding that the reactor got plugged before immersion of the ship.

9.5.5 Horizontal components of shock loads due to collisions, grounding and stranding shall be determined based on analysis. Conclusions shall be given in the design document.

9.5.6 According to 3.2, capsizing of the ship shall be considered. The conditions of heat removal from the reactor core of capsized ship shall be analyzed and the results shall be given in Nuclear Ship Safety Information.

9.5.7 Ship grounding and stranding with heel as specified in 8.5, shall be evaluated with regard to the following:

.1 loss of ability to intake sea water through the side or bottom openings;

.2 grounding and stranding in tidal waters with regular interruption of sea water supply;

.3 grounding and stranding of the ship with heel above 30° shall be considered in terms of possible effects not regulated by these Rules.

9.5.8 Fires and explosions on board the ship shall be analyzed with regard to the following:

.1 it may be accepted that fire originates from a single source in any compartment with combustibles;

.2 the analysis shall reveal that appropriate structural fire protection, fire alarm and extinguishing systems which ensure sufficient protection of the reactor safety system are provided;

.3 if cargo holds/tanks may be subject to fire/explosion hazards, these cases shall be analyzed and based on the analysis results it shall be proven that the reactor safety is not impaired;

.4 collisions followed by fire and/or explosion shall be analyzed as well as impact of long-term fires on RS shall be addressed;

.5 if the ship is fitted with a helicopter, the effects of helicopter crash on board the ship shall be analyzed. It is to be proved that this accident followed by fire shall not impair the ship safety.

9.6 The SSS accidents shall be classified by the SSS states and marked as the main design-basis accidents.

9.7 Accidents of the SSS equipment, machinery, systems and devices related to SC2, SC3 and SC4 shall be analyzed. Particularly, the following cases shall be analyzed and results shall be specified in the Nuclear Ship Safety Information:

.1 deactivation of any single reactor control or parts of reactor control and protection system from the core which are being driven by common drive or controlled from common control device with the maximum possible speed at any initial state (cold/hot), in any conditions of subcritical or critical core regardless of its power;

.2 leakage of the primary coolant into the secondary circuit via loose joints of the SG piping with regard to possible isolation of steam and feed-water lines after increase in activity in the secondary circuit. Predicted dose rates in the machinery space shall be specified in the Nuclear Ship Safety Information and Operating Manual for SSS;

.3 sticking of the reactor control and protection system control valves in any position by height in the core and under the worst conditions for the nuclear fuel bum-up or failure in core control rod drive;

.4 unintended startup of the primary circulating pump with injection of cold water into the reactor;

.5 cold water supply to the reactor from the make-up systems, feed-water systems or other sources with the maximum possible water flow;

.6 pressure increase in the primary coolant system due to stoppage of vapor removal;

.7 unintended decrease in neutron poison concentration in the primary coolant;

.8 possible failures in the reactor power control system;

.9 loss of ability for sea water heat removal;

.10 accidents followed by loss of the primary coolant;

.11 leakage of the primary coolant out of storage for the primary water drainage.

9.8 When analyzing the loss of ability for heat removal, the following shall be taken into consideration:

.1 stoppage of the main turbine;

.2 failure in the main condenser without using auxiliary condenser unless it is operating/or in stand-by mode;

.3 failure in the feed-water pump, closure of feed-water line or other failure in the secondary feed-water line;

.4 failure to use one of reactor cooling ducts when the ship is berthed.

9.9 Accidents followed by the primary coolant loss shall be analyzed with regard to the following:

.1 possible rupture of any primary pipe except for reactor body branches;

.2 coolant loss rate through the assumed damaged pipe shall correspond to the two-sided coolant escape rate unless it may be proven that there is a sufficient restriction of the broken pipe ends motion or other two-side coolant escape means are provided;

.3 accident followed by the primary coolant loss shall be considered as the maximum design-basis accident with regard to the following:

stresses in containment structure and its systems shall be within the specified limits and design pressure shall be taken with the appropriate margin of estimated pressure;

radiation effects shall be within those as specified in Part IX "Radiation Safety";

reactor core and its fuel elements shall be capable of withstanding thermal and mechanical loads and possible deformations shall not exclude heat removal by circulating coolant;

variation in position of the ship due to wind and sea states as accepted for SC1 and SC2 in the design process shall not impair actuation of coolant removal tanks from safety valves and pressure drop tanks;

.4 when analyzing the accident followed by the coolant loss, the following initial or boundary conditions shall be considered:

one subsystem of emergency cooling system supplies the coolant to the damaged piping rather than to the reactor body;

second subsystem is being repaired (if core emergency cooling system may be maintained in service according to design);

single failure may occur in the operating system;

reactor is switched off and maintained in safe condition for 30 min after occurrence of an event;

SSS automatic and remote control system provide the operator possibility to activate safety systems;

chemical reactions (e.g., hydrogen and zirconium reactions) proceed;

only those systems remain operational which are specially designed for operation in case of accidents with the coolant loss.

9.10 Whenever necessary, loss of the secondary vapour/feed-water after the main steam line/feed-water line is completely ruptured shall be considered as the main design-basis accident. In any case, impact of such an accident on the reactor shall be evaluated and described in the Nuclear Ship Safety Information.

9.11 Failure of the active component or control error of radioactive waste treatment system shall be addressed; this failure/error shall not impair safety junctions of the system for SC3 and SC4.

9.12 Analysis of any failure impact in the electric installation critical element on the SSS safety shall be performed based on a single failure criterion.

Total blackout of the main electric installation shall be considered as the main design-basis accident.

10 DIVIDING NUCLEAR SHIP INTO RADIATION SAFETY AREAS

10.1 The nuclear ship shall be divided into controlled, supervised and unrestricted areas according to existing or potential radiation hazard. Area borders may be established in the form of physical structures or administratively.

10.2 Requirements to the controlled area spaces of the nuclear ship are given in Section 2, Part IX "Radiation Safety".

Russian Maritime Register of Shipping

Rules for the Classification and Construction of Nuclear Ships and Nuclear Support Vessels
Part II
Safety Standards

FAI "Russian Maritime Register of Shipping"
8, Dvortsovaya Naberezhnaya, 191186, St. Petersburg
www.rs-class.org/en/