FEDERAL ENVIRONMENTAL, INDUSTRIAL AND NUCLEAR SUPERVISION SERVICE OF RUSSIA
(ROSTECHNADZOR)

Safety regulation aspects of floating power units with the RITM-200C reactor unit

The workshop on Small, Medium and Modular Reactors (SMMR)
Multinational Design Evaluation Programme (MDEP)

About the technical project of the Modernized floating power unit (MFPU) with the RITM-200 C control unit

The project was carried out in accordance with the requirements of the regulatory framework for nuclear ships and ship-based nuclear power plants of the Russian Maritime Register of Shipping, as well as the requirements of international treaties, legislative, regulatory legal acts, federal rules and regulations in the field of the use of atomic energy, applicable to the Modernized floating power unit (MFPU) and included in the List of-01-01-2021 .
The technical design defines the main design features and characteristics of the projected vessel. The basic architectural and structural solutions for MFPU correspond to the purpose and functions, as well as the appearance characteristic of structures of this type.

- Technical designs of the main equipment have been developed:
  - technical design of the RITM-200S reactor plant (developed by Afrikantov OKBM JSC);
  - technical design of an automated process control system (developed by JSC Concern NPO Aurora);
  - technical design of the PTU-58 steam turbine unit (developed by PJSC KTZ);
  - technical design of the electric power system (developed by JSC "New ERA").
- The composition and characteristics of the ship's component equipment are determined. The project uses materials and equipment that meet the requirements of regulatory documentation and are designed to provide resource indicators regulated by the terms of reference.
- A set of measures has been taken to ensure the nuclear and radiation safety of the MFPU, the classification of elements of systems important for safety has been carried out in accordance with the requirements of regulatory documents in the field of the use of atomic energy and the requirements of the RS.

Regulatory legal acts on ensuring nuclear radiation safety (NRS)

When implementing safety requirements in the development of a technical project, JSC was guided by the Constitution of the Russian Federation, federal laws, regulatory legal acts of federal executive authorities, the requirements of rules and regulations in the field of atomic energy use, the rules of the Russian Maritime Register of Shipping, standardization documents adopted in accordance with the legislation of the Russian Federation on standardization

The Constitution of the Russian Federation

International conventions and agreements (recommendations of the IAEA, ICRP, WHO, etc.)

Federal laws which are important for ensuring safety in the use of atomic energy (on radiation safety, on environmental protection, etc.)

Decrees and orders of the President of the Russian Federation, Resolutions and orders of the Government of the Russian Federation

Federal rules and regulations in the field of nuclear energy use, sanitary rules and regulations, fire safety rules, etc.

Regulatory legal acts of the bodies of the federal executive authorities, public administration, state regulation of safety and supervision in the use of atomic energy

On the review and approval of the technical design of the MFPU with RU RITM-200 C

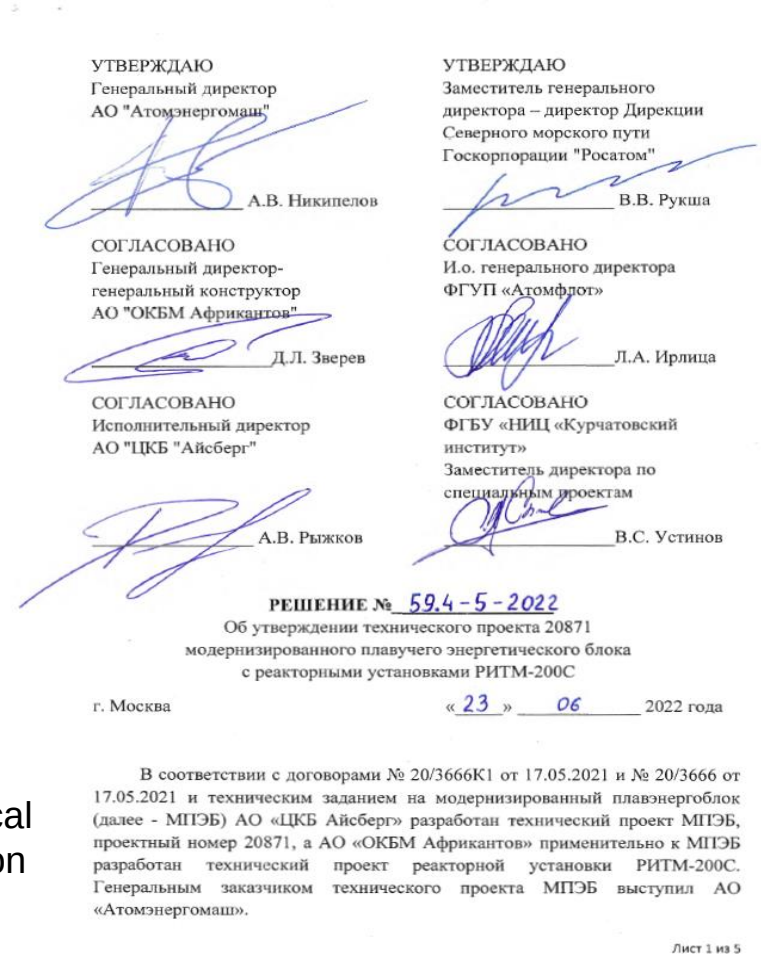
The documentation of the technical project was developed in accordance with the requirements of the Rules of the **FAA "Russian Maritime Register of Shipping"** and has a corresponding positive conclusion, as well as reviewed by expert organizations:

- **Central Research Institute Prometheus** in terms of the use of structural materials in the 20871 MFPU project;
- **JSC PPO "TSNIIMF"** in terms of compliance of project 20871 with the requirements of regulatory documents on labor protection and sanitary and epidemiological requirements;
- **FSUE SRI PMM** in terms of compliance with the requirements of sanitary norms and rules in the materials of technical project 20871 MFPU.

The development of the MFPU technical project was carried out with the scientific and technical support of the main scientific organizations of
FSUE Krylovsky SSC and
SIC Kurchatov Institute

The technical draft of the MFPU was reviewed at the Scientific and Technical Council “Iceberg” Central Design Bureau, Scientific and Technical Council OKBM Afrikantov and Scientific and Technical Council No. 1 "Nuclear Power Plants and Nuclear Power Plants" of the Rosatom State Corporation on May 26, 2022, where it was recommended for approval.

As a result, the technical design of the 20871 modernized floating power unit was approved Decision No.59.4-5-2022 from 06/23/2022



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РЕШЕНИЕ № 59.4-5-2022
Об утверждении технического проекта 20871 модернизированного плавучего энергетического блока с реакторными установками РИТМ-200С

г. Москва «23» 06 2022 года

В соответствии с договорами № 20/3666К1 от 17.05.2021 и № 20/3666 от 17.05.2021 и техническим заданием на модернизированный плавэнергоблок (далее - МПЭБ) АО «ЦКБ Айсберг» разработан технический проект МПЭБ, проектный номер 20871, а АО «ОКБМ Африкантов» применительно к МПЭБ разработан технический проект реакторной установки РИТМ-200С. Генеральным заказчиком технического проекта МПЭБ выступил АО «Атомэнергомаш».

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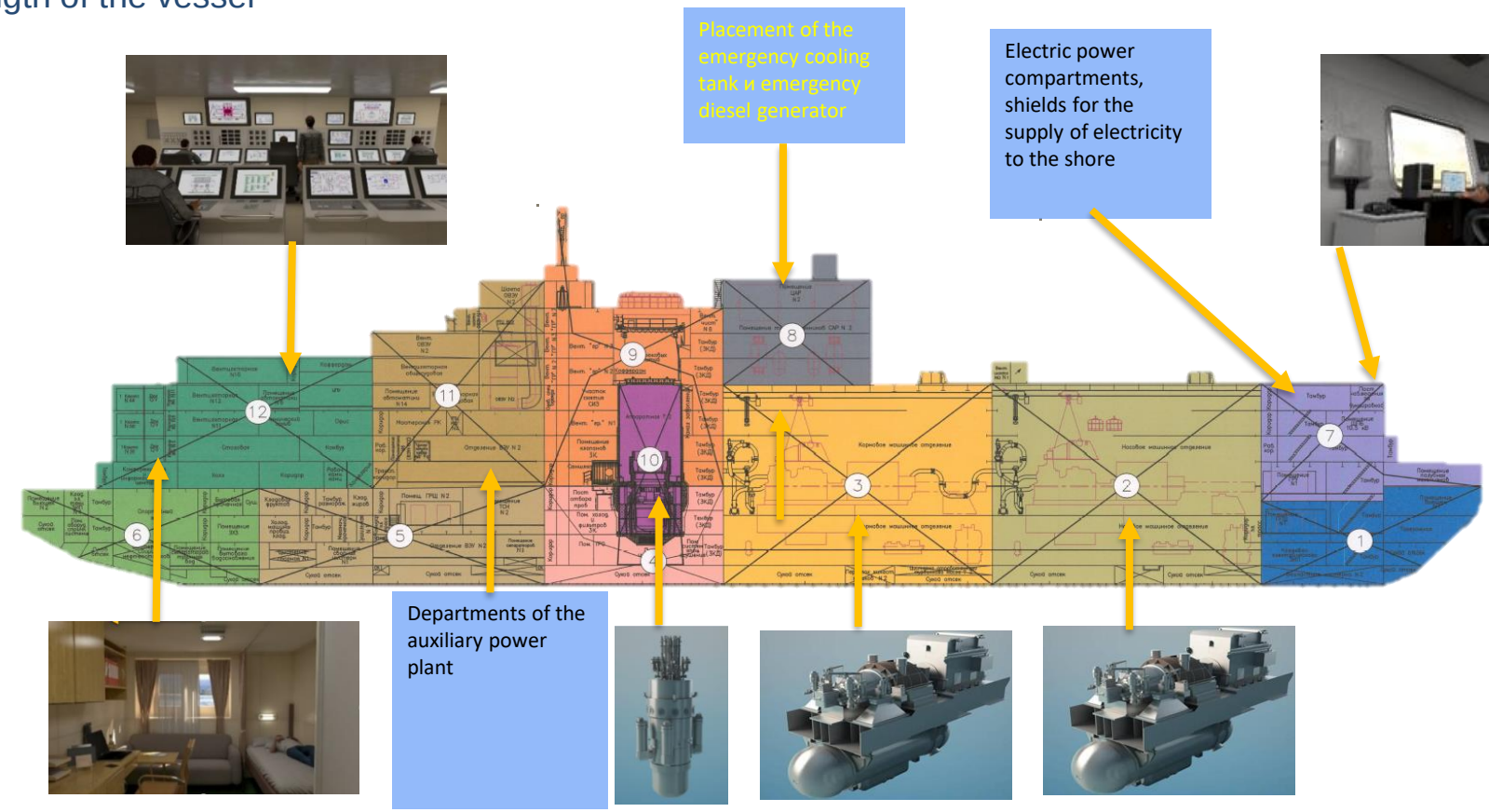
The main characteristics of MFPU with RU RITM-200C

The MFPU is designed to operate in remote areas as a source of electricity as part of the infrastructure for the placement of MFPU, including onshore hydraulic engineering and technological structures. The MFPU is a non-self-propelled rack-type vessel with a multi-tiered superstructure developed along the length of the vessel

The power output to consumers is 106 MW (generated up to 116 MW)

Length – 143.3 m
Width – 30.0 m
Draft – 5.50 m
Displacement - 21261 tons



The MFPU nuclear power plant.
Reactor installations

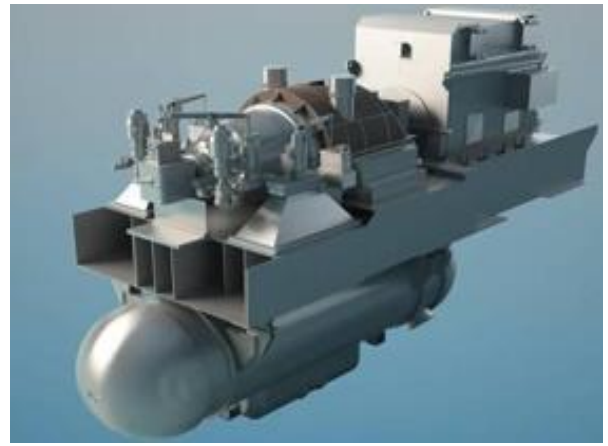
The MFPU nuclear power plant consists of two independent steam power plants on the starboard and port sides with their own systems and equipment, as well as systems common to both installations. Two RITM-200C reactor plants With a nominal thermal capacity of 198 MW are intended for use as the main sources of MFPU steam.

Characteristics of the reactor plant	Parameters
Rated thermal power, MW, not less	198
Parameters of the second circuit:	
Steam capacity (at tp.v. = 150 OC), t/h	305
Parameters of superheated steam at the outlet of the RC (at the boundary of the PO):	
–temperature, CELSIUS at least	294
–pressure, MPa (abs.)	3,76
Feedwater parameters at the entrance to the RU (at the boundary of the PO):	
–temperature, CELSIUS, not less than	150
–pressure, MPa (abs.), no more	5,83

The MFPU nuclear power plant .
Steam turbine installations (STI)

The STI is designed to provide electricity generation to provide power to external consumers (outside the MFPU) and shipboard consumers for their own needs, as well as to supply steam from the selection of a steam turbine to ensure the operation of a heating plant for their own needs

Наименование характеристики	Значение
The number of STI per MPEB, pcs.	2
The power at the terminals of the generator at a generator efficiency of 97.5 % and the design temperature of the cooling water, MW	58
Rated power of turbine capacity for own needs, MW	4
Steam parameters before quick-stop valve of the main turbo generator: pressure, MPa (abs.) temperature, CELSIUS	 3,5 Plus 284
Steam consumption per STI, t/h	305
The temperature of the seawater at the entrance to the main capacitor, CELSIUS, - calculated	Plus 15
Generator Parameters: current type rated voltage, kV	 Permanent 10.5



The MFPU Electric Power System (EPS)

The MFPU EPS consists of:

- the main electric power system;
- emergency electric power system;
- systems for receiving and distributing electricity.

The technical design of the EPS MFPU was developed by JSC "New ERA" (Housing and Communal Services.674513.021TU)

The MFPU EPS provides three−phase alternating current with a frequency of 50 Hz and a voltage of

- 10500 V for main turbo generators, power distribution systems and power reception and distribution systems;
- 400 V for power consumers of the main and emergency electric power system;
- 230 V for main and emergency lighting, signal and distinguishing lights, consumers of radio communications, telephony, alarm systems and household equipment;
- 27 V for portable equipment

Regulation of the safety of ships and other vessels with nuclear reactors

The improvement of the regulatory framework has been ensured in advance

- General safety assurance provisions for ships and other floating craft with nuclear reactors (NP-022-17)
- Requirements for the safety justification report for ships and other vessels with nuclear reactors
- Rules of nuclear safety of ships and other vessels with nuclear reactors
- Requirements to planning of measures for actions and protection of personnel at nuclear and radiological accidents on vessels and other watercraft with nuclear reactors (NP-079-18)
- Requirements to physical protection of vessels with nuclear power plants and vessels transporting nuclear materials (NP-085-10)

Operational experience in civilian vessels with nuclear reactors

- The total operating experience is more than 400 reactor years
- Operational data on reliability indicators of systems and elements are available for RI RITM
- The initial data for the implementation of the PSA is the experience of operating prototypes and similar RI as part of civil vessels

8 RI RITM are operated at the "Arctic", "Siberia", "Ural" and "Yakutia"

2 RI RITM are made for "Chukotka"

6 RI RITM are made for MFUP and for 5 and 6 serial icebreakers

The concept of safety

Internal self-protection

•A set of technical solutions that prevents the reactor plant from going beyond the limits of normal operation, and in emergency mode facilitates the occurrence of an accident.

Active security systems

•A complex of active systems that ensures the safety of the reactor plant in all types of design and beyond-design basic accidents in the presence of power supply.

•The operating time of the emergency power supply system is 30 days.

Passive security systems

•A complex of passive systems that ensures the safety of the reactor plant in the absence of power supply.

Special technical means for managing emergency situations

•A set of systems designed to facilitate the occurrence of out-of-design accidents in conditions of mass failure of reactor plant systems.

•The use of self-actuating devices ensures the development of safety algorithms in case of complete failure of control systems.

Physical barriers

•A set of physical barriers that ensures the localization of radioactive substances inside the protective shell in accidents with depressurization of the primary circuit system.

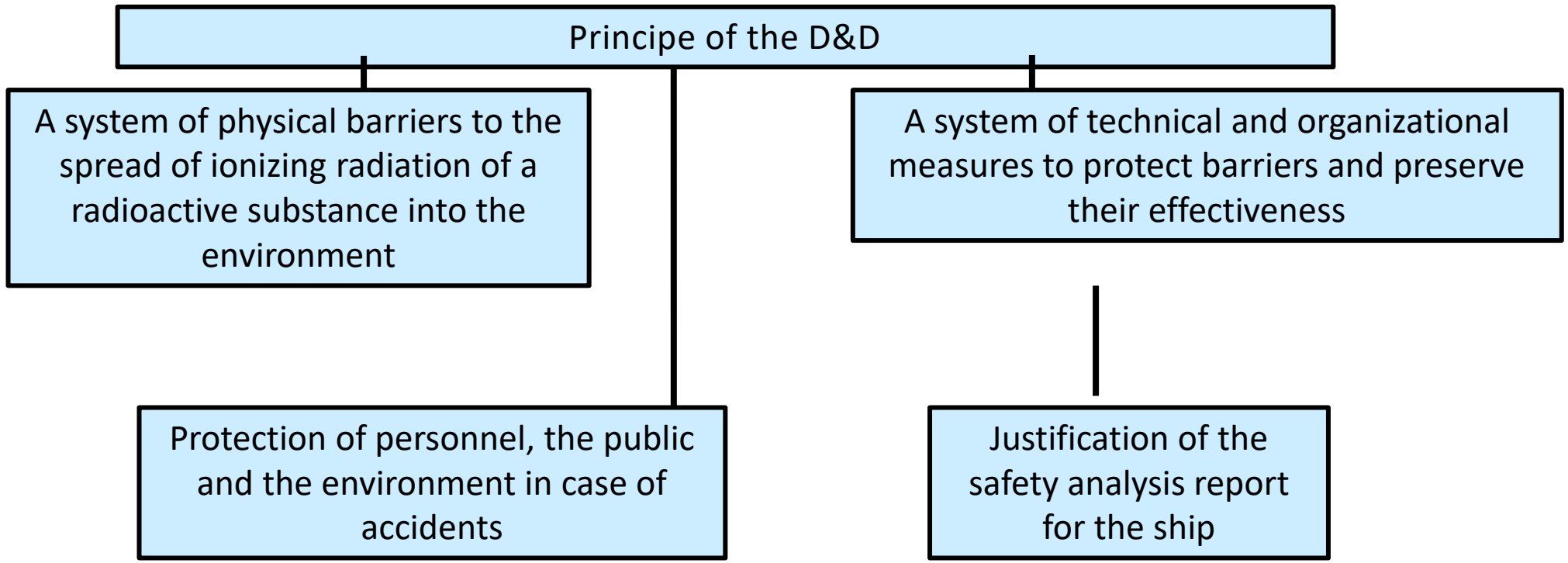
Implementation of the established safety requirements of the MFPU technical project

The implementation of the established safety requirements of the MFPU technical project is carried out, inter alia, by taking into account the following requirements in the field of nuclear energy use:

- consistent implementation of the principle of D&D protection at the design stage;
- application of a system of physical barriers to the spread of ionizing radiation (IR) and radioactive substances (RS) into the environment;
- implementation of a system of technical and organizational measures to protect barriers and preserve their effectiveness;
- development of the ship's design documentation based on a conservative approach;
- ensuring the required quality of the design of systems and elements of the vessel that are important for safety;
- justification of the limits and conditions of safe operation of nuclear power plants;
- the use of prototypes of technical solutions approved by previous experience, tests, research, and operational experience, taken to ensure the safety of the nuclear power plant of the vessel;
- determination of the list of nuclear power plant systems important for safety, establishment of safety classes of nuclear power plant elements;
- using the principles of security system design to achieve the necessary reliability.

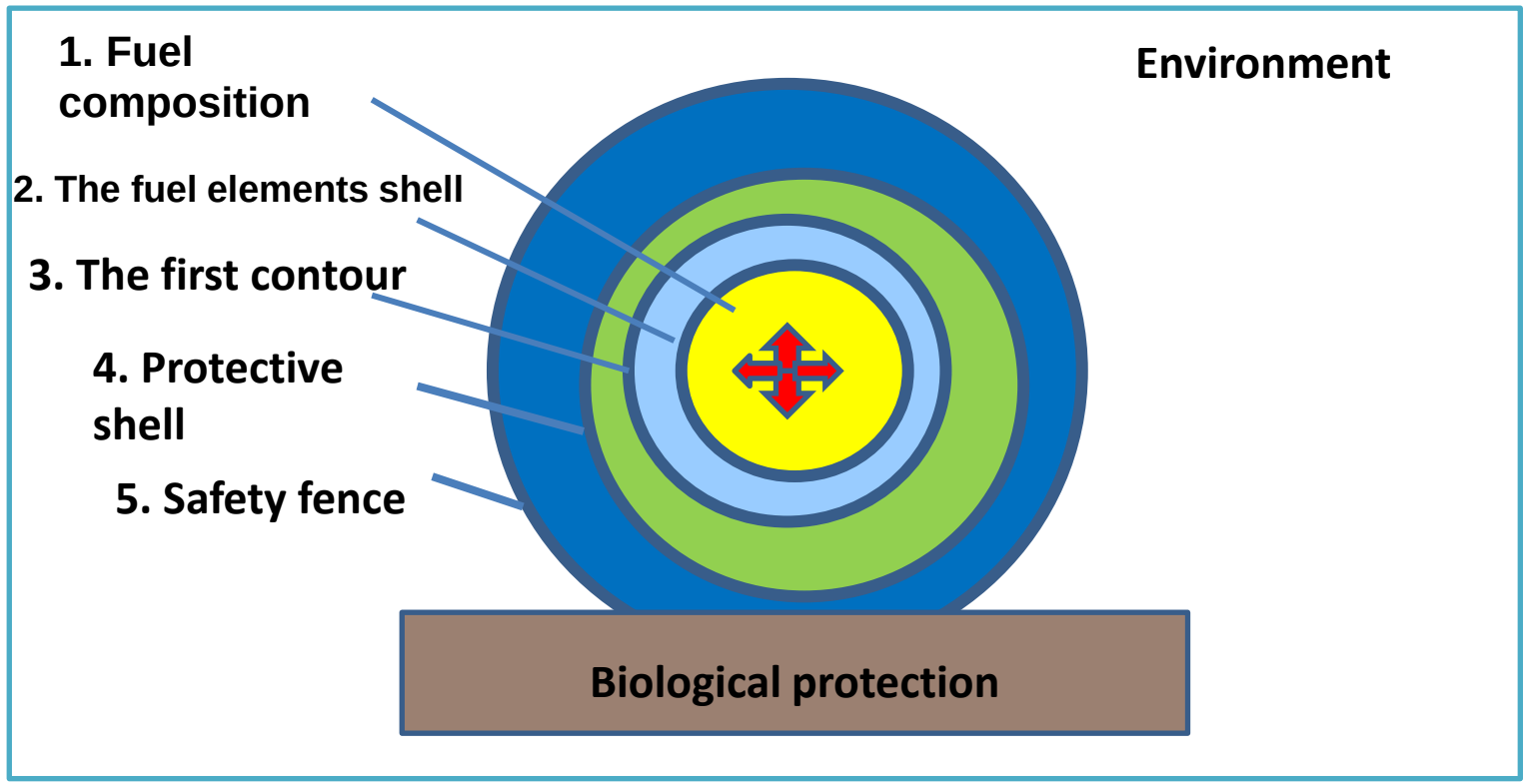
Implementation of the established safety requirements of the MFPU project

The nuclear and radiation safety of the MFPU is ensured by the consistent implementation of the principle of D&D protection and design principles specified in NP-022-17 " General safety assurance provisions for ships and other floating craft with nuclear reactors ".



Implementation of the established safety requirements of the MFPU project

The MFPU system of physical barriers to the spread of ionizing radiation (IR) and radioactive substances (RS) into the environment includes:



Implementation of a system of technical and organizational measures to protect barriers and preserve their effectiveness

Technical and organizational measures

- **The first level** - the prevention of violations of normal operation
- **The second level** - the prevention of design accidents by normal operation systems
- **The third level** - the prevention of out-of-design accidents by security
- **The fourth level** - the management of out-of-design accidents
- **The fifth level** - emergency planning

First level

- The use of technical solutions tested during the operation of nuclear icebreakers for 65 years and the operation of the Akademik Lomonosov MFPU since 2019 in the project of normal operation systems.
- Design of systems (elements) In accordance with the requirements of regulatory documents in the field of nuclear and radiation safety, the implementation of a quality assurance system
- Application of certified programs and techniques

The second level is to identify deviations from normal operation and eliminate them, as well as to manage nuclear power plants during operation with deviations

Second level

- Prevention of deviations of the technological parameters of nuclear power plants above the limits of normal operation by monitoring and control systems, the use of self-regulation properties of the reactor plant.
  Compliance with the limits and conditions of safe operation in case of deviations and violations that determine the possibility of further operation of the RI at capacity
- Identification of deviations from normal operation caused by violations in control systems, partial or complete loss of operability of redundant equipment of normal operation systems, deviations in the indicators of the water-chemical regime of the RI, radiation indicators, erroneous actions of personnel and other reasons.
- Performing corrective actions by personnel in accordance with the regulations and operating instructions based on information about deviations provided on the control panels of the operational diagnostics system included in the automated control system.
- Justification of the permissible time for the output of safety system channels for inspection and maintenance, including the elimination of detected violations, the power level and the operating time of the RC at capacity (time to eliminate violations) in the project using reliability analysis and probabilistic safety analysis.

The third level is to prevent the development of initial events into design accidents, and design accidents into beyond design, as well as to mitigate the consequences of accidents

Tthird level

Preventing the development of design accidents through design solutions and the choice of physical and thermohydraulic parameters of the reactor plant, using the properties of the internal self-protection of the reactor.

Security systems have been developed in accordance with the requirements of regulatory documents using proven technical solutions.
Complex of security systems

Protective

- Electromechanical emergency stop system
- Active channels of the emergency cooling system
- Active emergency cooling systems of the reactor core channels

Localizing

- Protective shell and protective fence
- Localizing fittings of 1, 2, 3 circuits
- Emergency pressure reduction system in the protective shell

Managers

The Mars-871 system
The Shkval-871 system
The "USBE-871" system

Supporting

- Emergency power supply system
- Valve pneumatic control system (in terms of performing safety functions)
- Carbon dioxide fire extinguishing system of protective shell and protective fence

The fourth level is to prevent the development of out-of-design accidents and mitigate their consequences, prevent the destruction of the protective shell and protective fence, and return the nuclear power plant to a controlled state

Fourth level

Special technical means for managing beyond design basis accident, developed in accordance with the requirements of regulatory documents using proven technical solutions.

A set of special technical means for managing beyond design basis accidents

- Liquid absorber input system
- Passive **CAP** channels
- Passive channels of emergency cooling systems with **GA-EG**
- The system of filling the **PGB caisson** with water
- Self-working devices **(RED-1, RED-ZO, GUP)**
- Tools of recharging the **CAR** using hand pumps

The fifth level involves actions for the preparation and implementation of emergency response plans on the ship, and if necessary on shore and assistance to the ship from shore and from other watercraft

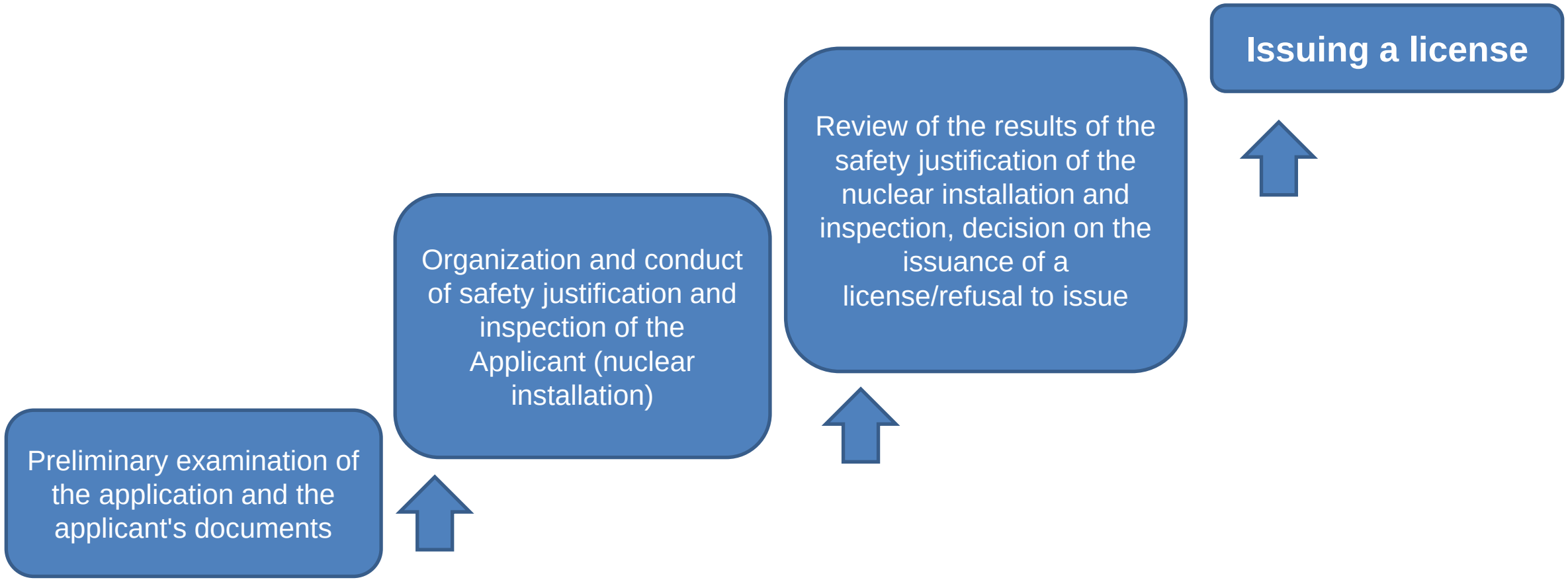
Fifth level

Preparation and implementation of emergency response plans, if necessary

Plan for the elimination of the consequences of a nuclear and radiation accident, protection of personnel and the public in the event of a nuclear and radiation accident during the construction and operation of the modernized floating power unit of project 20871

Instructions for the prevention of nuclear and radiation accidents, fire and elimination of their consequences during the construction and operation of the MFPU project 20871

The process of licensing



Licenses corresponding to the life cycle stages of a floating power unit

Design of nuclear installations (“Iceberg” Central Design Bureau)

Design and manufacture of equipment for nuclear installations. Activities and services in the field of nuclear energy use (issuance of licenses)

Construction of a nuclear installation (Baltic Shipyard)

Operation of a nuclear installation (operating organization)

- The development of the reactor installation (RI) project was carried out taking into account the maximum possible borrowing of equipment and technical solutions from the RI RITM-200 UAL. The reloading complex and the service station, made for the RITM-200, can be used for the RITM-200C.
- Safety regulation of floating power units used as part of floating nuclear power plants is carried out on the basis of legislative requirements for nuclear energy facilities – ships and other vessels with nuclear reactors.
- The regulatory and technical safety system in force in Russia makes it possible to regulate and create floating power units taking into account international safety requirements for nuclear vessels.
- The development of a transportable nuclear energy based on floating power units requires consolidated efforts to determine the international legal status of the floating nuclear ships in the system of safety regulation in the field of nuclear energy use and maritime law.

Thank you for attention!