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Regulatory Control Features and Principles for a Land-Based RITM-200N SNPP Project

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Paper Purpose and Structure

Purpose



Inform the workshop attendees on the progress of the RITM-200N-based first-of-a-kind small-sized nuclear power plant project in the Republic of Sakha (Yakutia) and on the status of activities being done to take into account in the SNPP* project the requirements of Russian and international standards and regulations

Paper structure

1. RITM-200N-based FOAK** SNPP Project Characteristics and Status
2. Key Engineering Solutions in the RITM-200N Reactor Plant
3. RITM-200N Reactor Plant Main Equipment
4. Safety Concept
5. Approaches to Regulatory Assurance for the RITM-200N Project
6. Activities to Take into Account in the SNPP Project the Requirements and Recommendations of International Standards and Regulations
7. Conclusion

* SNPP – small nuclear power plant

** FOAK - first-of-a-kind

Caused by SNPP* Project Implementation, the Effects on the Socio-Economic Development of Remote and Isolated Areas

Reduced fossil fuel costs

The replacement of current diesel- and coal-fueled facilities will **reduce** annual costs of expensive externally sourced hydrocarbon fuel

Energy security of the region

Fuel has to be supplied to the SNPP **once every 5–6 years**

Reduced electricity rates

The remote region will be provided with an economically efficient and reliable modern energy source

Creation of new job vacancies

The SNPP construction creates new **jobs, especially** in the peak construction period

RITM Reactor Plants



- 2020**, the Multipurpose Nuclear-Powered Icebreaker (MNPI) **Arktika** commissioned
- 2021**, the MNPI **Sibir** commissioned
- 2022**, the MNPI **Ural** commissioned
- 2024**, the MNPI **Yakutiya** to be commissioned
- 2026**, the MNPI **Chukotka** to be commissioned

- 2027**, the Lead **Nuclear-Powered Icebreaker Leader** to be commissioned that will enable year-round navigation on the Northern Sea Route according to the RF President's Executive Order No. 635 dated Oct. 26, 2020
- 2028**, the **5th serial MNPI** to be commissioned
- 2030**, the **6th serial MNPI** to be commissioned

Name	RITM-200	RITM-200S	RITM-200N	RITM-200M	RITM-400	RITM-400M
Reactor plant (RP) power, MW	2×175	2×198	1×190	2×198	2×315	2×340
Design lifetime, h	320,000	340,000	495,000	480,000	320,000	340,000
Weight, t	2,200 (2 RPs)	2,300 (2 RPs)	1,500 (1 RP)	2,600 (2 RPs)	3,893 (2 RPs)	4,560 (2 RPs)
Overall dimensions, m	6×13.2×15.5	6.0×13.2×15.36	Ø8.7×21	6.8×14.6×16	9×18.2×17.5	20.76×8.4×18.0

RITM-200N-Based FOAK* SNPP** Project Characteristics and Status

Electric power, MW, gross:	55
Station area, acres (km²)	30 (0.12)
Refueling interval, year	6
Service life, year	60
Load follow operation in the power range, % of rated power	20–100
Steady-state availability factor over the reactor plant service life	over 0.9



PROJECT STATUS

- 2019**, technical and economic studies completed for the SNPP construction in Yakutia
- 2020**, the DOI*** approved for the construction of RITM-200N-based SNPP in Yakutia
- 2021**, materials developed for justification of investments for the construction of the RITM-200N-based SNPP
- 2022**, a detailed design developed for the RITM-200N reactor plant
- 2022**, a detailed design developed for the reactor core
- 2023**, a siting license obtained for a nuclear plant for the facility titled Yakutia SNPP Unit No. 1 (Ust-Kuiga village)
- 2023**, a detailed design developed for a nuclear fuel handling equipment complex



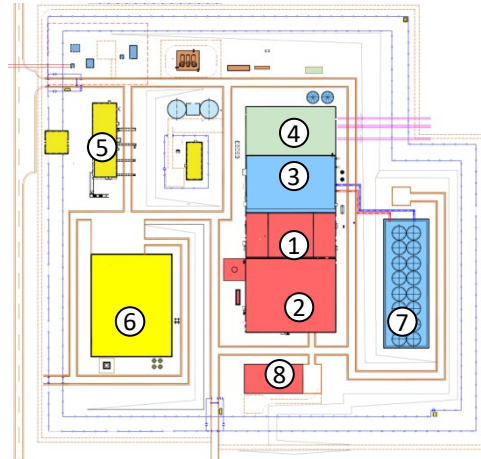
* FOAK - first-of-a-kind

** SNPP – small nuclear power plant

*** DOI – Declaration of Intentions

RITM-200N-based SNPP General Layout Diagram

55 MWe Yakutia SNPP



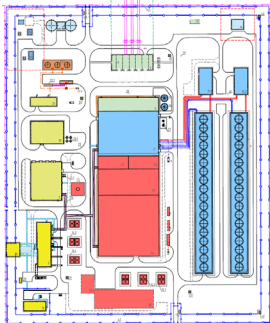
- 1, Reactor unit
- 2, Special unit
- 3, Turbine unit
- 4, Electric unit
- 5, Administrative and household building
- 6, Auxiliary building
- 7, Dry sectional cooling tower
- 8, Radwaste container storage point



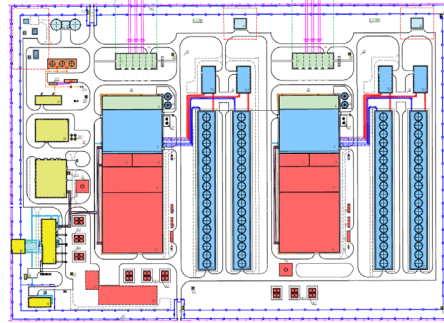
Ust-Kuiga
village



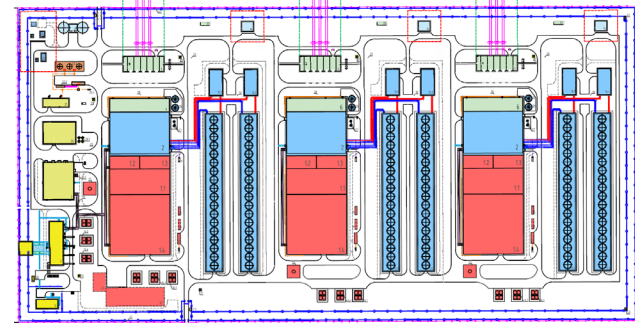
110 MWe SNPP 40 acres (0.16 km²)



220 MWe SNPP 220 MW, 67 acres (0.27 km²)



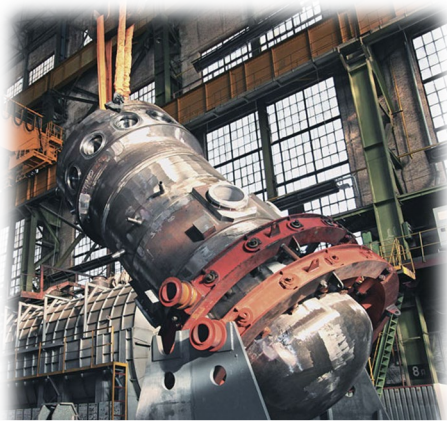
330 MWe SNPP 330 MW, 94 acres (0.38 km²)



Proven and Unified Engineering Solutions for RITM-200-Type Reactor Plants



Steam generator cassette



Reactor vessel installed in a special slipway



Fuel handling process



Installing the RITM-200 steam generating unit



Assembling the upper core support structure

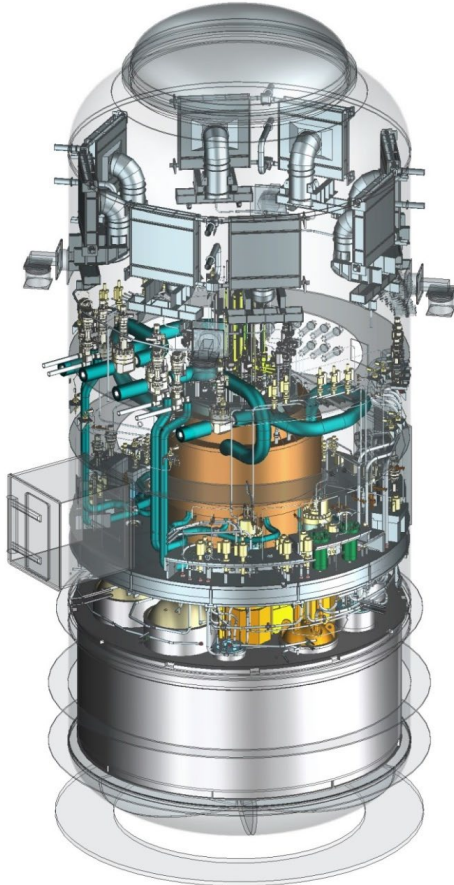


Transporting the RITM-200 steam generating unit



Icebreakers *Arktika*, *Sibir* and *Ural*

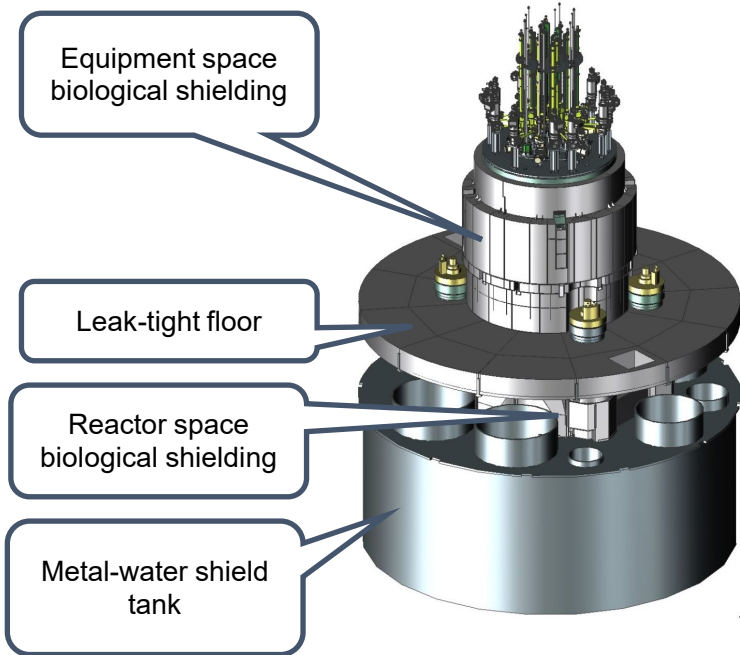
Key Engineering Solutions in the RITM-200N Reactor Plant



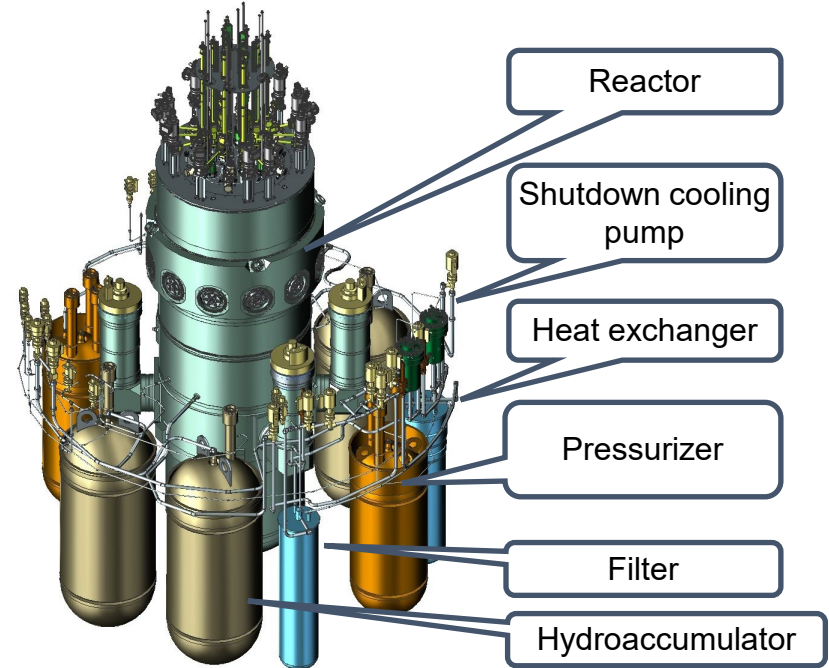
- ✓ **integral** water-cooled water-moderated **reactor**
- ✓ **once-through** steam generator
- ✓ **canned** reactor coolant pump
- ✓ reactor plant main equipment inside a **steel containment**
- ✓ external **gas pressurizer system**
- ✓ **purification and cooldown system (PCDS)**, a normal operation system and a safety system
- ✓ **electromechanical reactivity control system**; no boron control
- ✓ self-sustaining **ammonia water chemistry**
- ✓ operational **power variation range from 20 to 100%**
- ✓ refueling with the use of containers and the central hall crane

RITM-200N Reactor Plant Main Equipment

Reactor Plant Biological Shielding

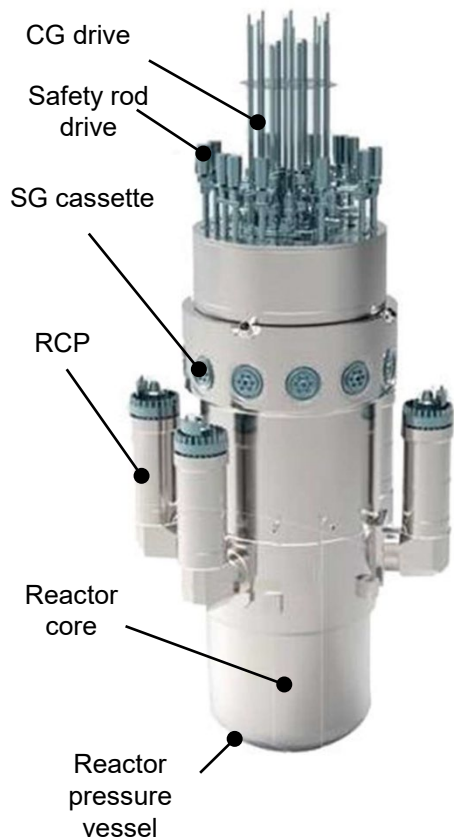


Reactor Plant Main Equipment



The purpose of the development is to create, for the pilot land-based SNPP, the RITM-200N reactor plant that would be based upon marine reactor plant mature engineering solutions verified by experience in design, manufacture and operation, and that would meet modern safety requirements for nuclear power plants

RITM-200N Integral Reactor with the AS-14-15 Core Comprised of an Array of Fuel Assemblies, for the SNPP



Integral reactor

Manufactured in series.
8 RITM-200 reactor plants have been installed in 4 MNPIs *Arktika, Sibir, Ural and Yakutiya*
Arktika, Sibir and Ural have been commissioned

Reactor pressure vessel

Assigned service life: **60** years
Assigned lifetime: **495,000** h

SG cassette

Assigned service life: **20** years
Assigned lifetime: **165,000** h

RCP

Assigned service life: **20** years
Assigned lifetime: **165,000** h

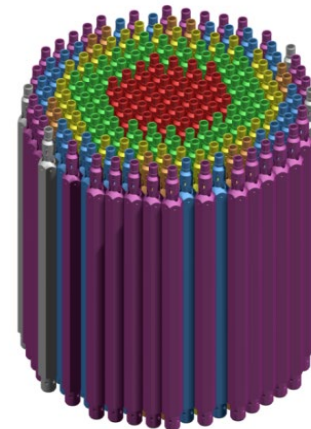
CG and safety rod drives

Assigned service life: **20** years
Assigned lifetime: **165,000** h

AS-14-15 reactor core

The analogs are cores comprised of an array of fuel assemblies:

- **14-15-1** for the RITM-200 reactor plant (MNPIs)
- **14-14** for the KLT-40S reactor plant (FPU *Akademik Lomonosov*)



Fuel type: cermet fuel enriched to below 20%

Safety Concept

Preventing abnormal operation

Assessing and selecting the site, developing the design on the basis of a conservative approach; quality assurance; using proven engineering solutions; well-developed plant inherent safety features (negative reactivity feedbacks, integral reactor layout, high heat storage capacity of the primary system, etc.).

Preventing design-basis accidents

Timely detecting deviations from normal operation and eliminating the deviations; control in operation with deviations (structure and algorithms of control systems, redundancy of normal operation equipment).

Preventing beyond-design-basis accidents

Using safety systems that perform control, protection, confinement and safety functions and that prevent initial events from escalating into design-basis accidents; and design-basis accidents, from escalating into beyond-design-basis accidents.

Ensuring passive core cooling in a complete blackout:

- ✓ with a leak-tight loop, for an unlimited time
- ✓ in LOCAs, for at least 72 hours

Beyond-design-basis accident management

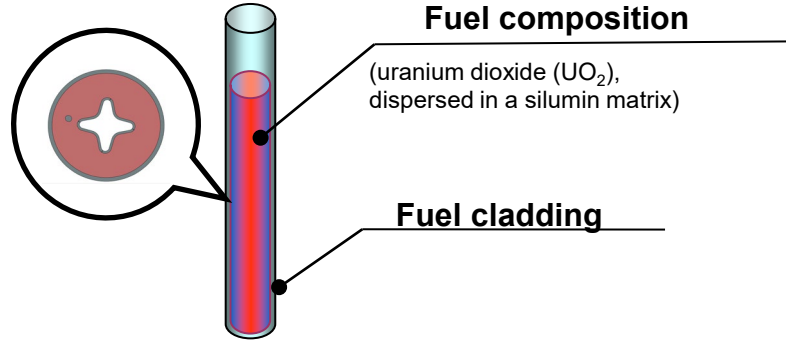
Preventing the escalation of beyond-design-basis accidents and mitigating their consequences with the use of special engineered features for beyond-design-basis accident management (an emergency core cooling system with hydraulic accumulators, a passive residual heat removal system, pressure-actuated circuit breakers), as well as any systems and elements capable of performing the required functions under the existing conditions.

Protecting the reactor plant leak-tight enclosure against destruction and maintaining the enclosure operability (retaining the corium within the reactor pressure vessel, excluding criticality in the course of melting, excluding hydrogen formation, relieving the containment emergency pressure).

SAFETY CRITERIA AND TARGETS

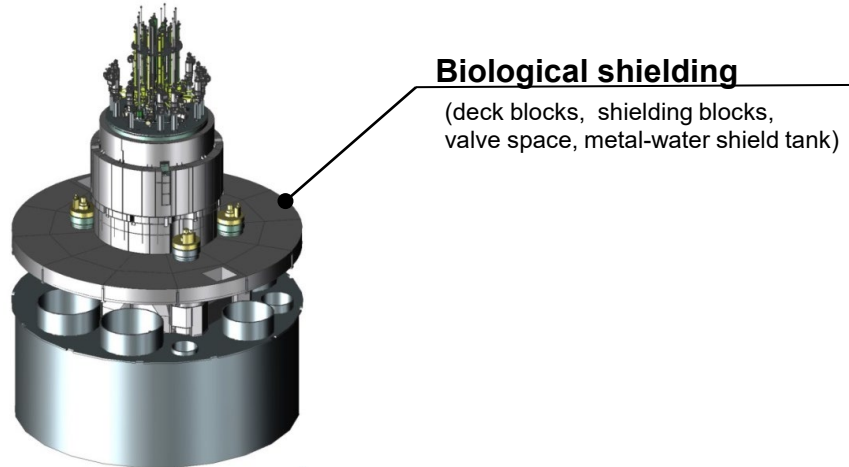
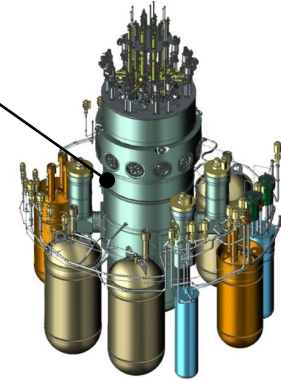
- buffer area within the SNPP site limits;
- radiation exposure for the population during normal operation: less than **0.01%** of the natural background radiation;
- total probability of severe accidents for the reactor plant: below **10^{-6}** at an interval of 1 year;
- total probability of severe accidents for the reactor plant: below **10^{-5}** at an interval of 1 year;
- total probability of a major accidental release for the SNPP: below **10^{-7}** at an interval of 1 year.

Physical Barriers Preventing the Propagation of Radioactive Substances



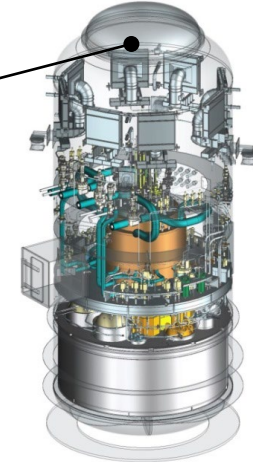
Primary coolant boundary

(integral reactor, pressurizer system and PCDS)





Reactor plant sealed enclosure


(cylindrical steel containment designed to hold the internal overpressure in beyond-design-basis accidents)





Approaches to Regulatory Assurance of Safety for the RITM-200N Project

-  **The RITM-200N-based SNPP project is being developed in compliance with the applicable federal standards and regulations in the field of nuclear energy use for nuclear power plants.**

-  **As part of developing the reactor plant detailed design, the Analysis of SNPP Nonconformities with the Requirements of the Applicable Regulatory Documentation in the Field of Nuclear Energy Use as Regards the RITM-200N Reactor Plant was formalized. The final design for the RITM-200N reactor plant was completed in June of 2022.**

-  **The SNPP project materials provide information on justifications and measures adopted in the project to compensate for deviations from regulatory documentation requirements for NPPs of the Russian Federation.**

-  **The regulatory assurance objectives for the SNPP project are achieved in compliance with the approved “Road Map...” and aimed at harmonizing the marine reactor plant engineering solutions and the applicable regulatory documents for the land-based NPPs.**

-  **The work is in progress to take into account, in the land-based SNPP project incorporating the RITM-200N reactor plant, the requirements and recommendations of international standards and regulations.**

Activities to Take into Account in the SNPP Project the Requirements and Recommendations of International Standards and Regulations (1/3)



SECTION 1. Analysis results for IAEA, EUR, ASME regulatory documentation (2020–2022)

Radiological criteria for dose rates for the personnel and population

SP AS-03, NRB-99/2009
SSR-2/1 (rev.1), SSG-2 (rev.1),
GSR Part 3, EUR (rev. E)

It has been identified that the requirements in the regulatory and legal documents on safety of Russian nuclear plants are analogous to the IAEA requirements or propose the same approaches to the implementation of the design requirements.

However, individual radiation safety criteria in the requirements of international regulatory documents are more stringent.

Safety analysis requirements

SF-1, GSR Part 4 (Rev.1), SSR-2/1
(Rev. 1), SSR-2/2 (Rev. 1)

The IAEA requirements for a deterministic safety analysis are largely concur with similar requirements in the Russian regulatory documents. However, the requirements in the IAEA regulatory documents are characterized by a greater level of detail on the matters of deterministic safety analysis and implementing the analysis procedures.

In the vast majority of cases, the probabilistic safety analysis requirements coincide in the Russian regulatory documents and in the IAEA regulatory documents.

The work is planned to harmonize the Russian deterministic analysis methodologies and the recommendations in the IAEA regulatory documents.

Strength analysis requirements for equipment and systems

ASME Boiler and Pressure Vessel
Code, Section III—Rules for
Construction of Nuclear Facility
Components—Division 1 (2015)

The basic requirements in the Russian Standards used for strength analysis are in a majority of cases more stringent than those in the ASME Code.

In individual cases, the ASME Code has more conservative requirements than those in the Russian regulatory documents. For certification under the ASME Code, project design documentation may have to be slightly reworked, in a number of cases, without changing design and schematic solutions in the project.

Activities to Take into Account in the SNPP Project the Requirements and Recommendations of International Standards and Regulations (2/3)



SECTION 2. Work results of the IAEA Working Group “Review of Applicability of Safety Standards to Novel Advanced Reactors” (2020–2021)

✓ The IAEA SSG-52, SSG-56, SSG-63 guides were analyzed. The results of the analyses were provided to the IAEA.

DOCUMENT	FUNDAMENTAL DIFFERENCES
<p>SSG-56 “Design of the Reactor Coolant System and Associated Systems for Nuclear Power Plants”</p>	<p>There is no boron control system, and there are no requirements to continuously monitor the boron solution concentration in the reactor and in the reactor coolant system. A vertical once-through steam generator is used that is placed in the reactor pressure vessel. In the regions that require the reactor to be completely disassembled, the reactor pressure vessel inspection and testing periodicity (for non-destructive testing and destructive testing of witness samples) is tied to the mid-life repair dates. The steam generator design does not allow steam generator tubes to be inspected in the course of operation. Nevertheless, continuous parametric monitoring of the SG cassette integrity is ensured. A quick detection of microleaks with rapid localization has been ensured.</p>
<p>SSG-52 “Design of the Reactor Core for Nuclear Power Plants”</p>	<p>It is not provided for that there be any partial refuelings, variations of loading patterns and off-design core modifications. Boron dissolved in the coolant is not used to control reactivity in the RITM-200N-based SNPP project. Fuel pellets are not used in the RITM-200N-based SNPP project. The fuel matrix has a strong metallurgical bond with the cladding; there is no free volume under the cladding.</p>
<p>SSG-63 “Design of Fuel Handling and Storage Systems for Nuclear Power Plants”</p>	<p>Uncertainties associated with reshuffling partially burned fuel assemblies are excluded. Off-design core modifications are excluded. There are no partial refuelings in the reactor plant. Fuel assemblies are discharged after the design stored energy has been exhausted. The RITM-200N reactor plant design features rule out a possibility of using a refueling machine for fuel handling. As a reference solution for the nuclear fuel handling system, a process is used in the SNPP project that employs a transfer container to transport the fuel from the reactor to the spent fuel storage.</p>



SECTION 3. Results of activities performed under the ROSATOM's Implementation Plan (2022–2023)



The Thematic Working Group of specialists from Afrikantov OKBM JSC and GSPI JSC has developed proposals for the research work report on the “**Analysis of the IAEA safety standards to determine the need to develop new IAEA documents and/or make changes to the existing ones, taking into account the SNPP features**”—the proposals to be eventually sent to the IAEA.







For 2023, the work is planned to develop proposals for harmonizing the Russian federal standards and regulations in the field of nuclear energy use with the IAEA standards as regards the SNPP and innovative reactors.

Proposals to Develop New IAEA Documents and/or Make Modifications to the Existing Documents with Account of SNPP Features

- Taking into account the RITM-200N reactor core features, develop an IAEA safety guide titled "Design of the Dispersion Fuel Reactor Core for Small-Sized Nuclear Power Plants" (an **SSG-52 analogue**).
- Taking into account the nuclear fuel handling features (the fuel is moved in air in a special shielded container), develop an IAEA specific safety guide titled “Design of Fuel Handling and Storage Systems for Small-Sized Nuclear Power Plants” (an **SSG-63 analogue**)
- Add to **Section 3.115** of the **SSG-56** Safety Guide the following provision: “If it is impossible to inspect tubes in a compact SG, it is necessary to ensure continuous parametric monitoring of SG tube leak-tightness in the course of operation and the possibility of localizing the leaking SG without shutting down the reactor.”

Conclusion

-  The activities completed for the land-based RITM-200N SNPP have verified that it was a correct strategic decision to use the multipurpose nuclear-powered icebreaker RITM-200 reactor plant type in the small-sized nuclear power plant for the specified power range.
-  It is noted that there is prospective demand for modular-type SNPPs equipped with the RITM-200N reactor plants due to the economic features of the SNPPs.
-  The RITM-200N SNPP project is being developed in compliance with the applicable Russian regulatory documentation in the field of nuclear energy use for nuclear power plants.
-  The analysis of the requirements in the Russian regulatory documentation and in the IAEA Safety Standards, as well as the analysis of the WENRA and EUR requirements has shown that the requirements in Russian regulatory documents are mainly harmonized with modern approaches and requirements used outside Russia. There is no need to develop new IAEA upper-level documents (SF, GSR, SSR). The assessment of the IAEA Guides (SSGs) in terms of their applicability for the SNPP project has shown that the existing IAEA Guides (SSGs) should be updated or new ones to be developed.

Thank you for your attention

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