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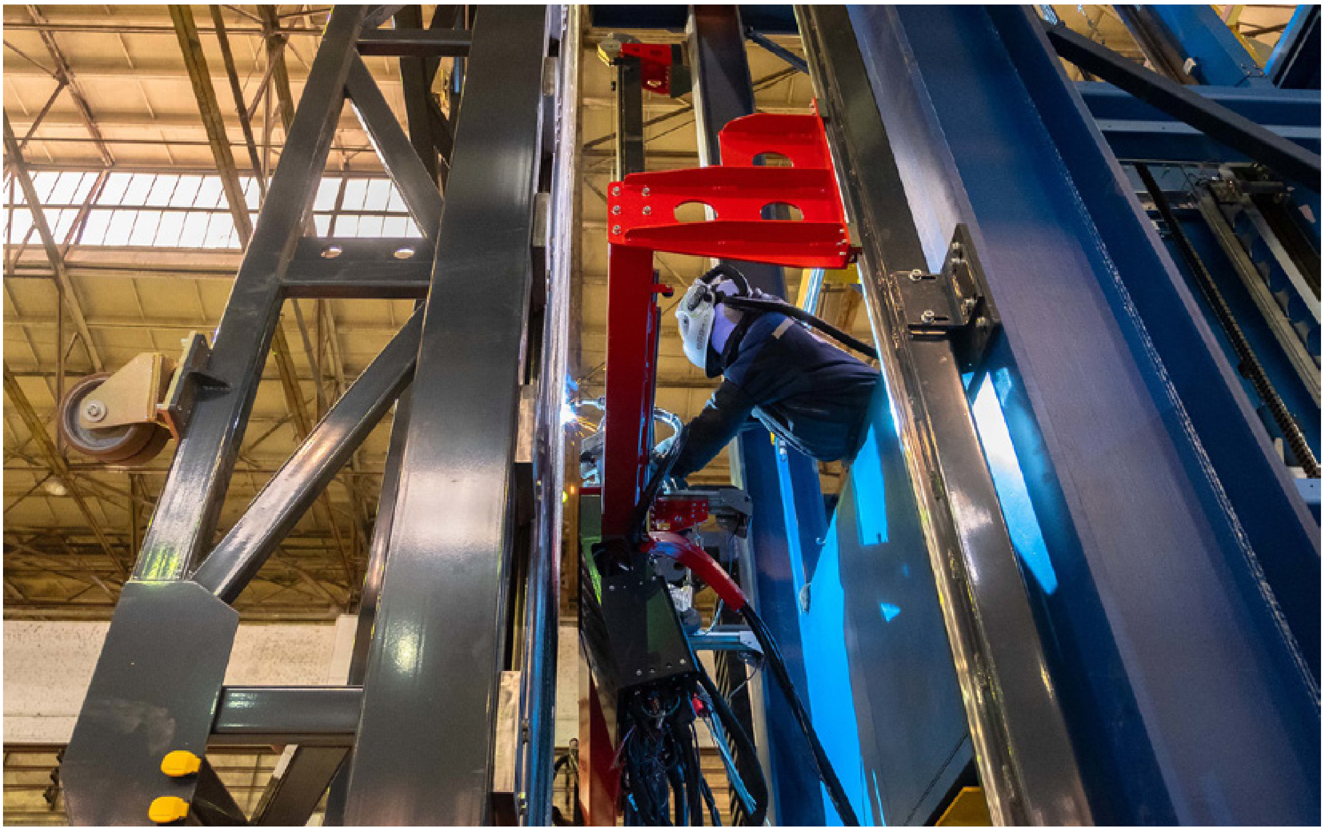

Energy from Waste

Atomenergomash (Rosatom's mechanical engineering division) participates in the Riverside Resource Recovery Facility project, which is a waste to energy plant constructed in the United Kingdom. The project is part of a broader cooperation with Swiss-Japanese Hitachi Zosen Inova under Russia's national Environment project.

In May, ZiO-Podolsk (part of Rosatom's mechanical engineering division Atomenergomash) manufactured and shipped a third-stage superheater and two fourth-stage superheaters to the United Kingdom. With each steam superheater being nearly 9 meters long, 4 meters wide and 3.5 meters high, the total shipment weighed 100 metric tons.

That was the second shipment sent to the energy recovery plant in Riverside under the contract signed in early 2020. The first batch of machinery and equipment was shipped in March. ZiO-Podolsk will manufacture a total of eight items — six third-stage and two fourth-stage superheaters to replace similar components. The Riverside Resource Recovery Facility was built in 2010 and is undergoing a major upgrade.

The contract provides for the first shipment of Russian-made equipment for a waste-to-energy plant engineered by Hitachi Zosen Inova.

"We worked closely with the customer and technology partner at the preliminary stage of the project. The resulting production facility built at ZiO-Podolsk meets all Russian and international standards. Regardless of the customer country, all

products are similar in terms of quality, reliability and environmental safety," Atomenergomash CEO Andrey Nikipelov said.

Hitachi Zosen Inova is a Swiss-Japanese provider of turnkey waste-to-energy plants. Company's solution encompasses a variety of eco-friendly solutions, such as grate firing, reduction of nitrogen oxides destroying ozone (DeNox technology), flue gas cleaning, energy extraction, anaerobic digestion, intellectual recirculation of bottom ash and flue gas residue, and power-to-gas conversion.

Technology partnership between Atomenergomash and Hitachi Zosen Inova is part of Russia's national Environment project. **"Hitachi Zosen Inova as a technology provider and its Russian partner ZiO-Podolsk will supply technology for a waste-to-energy plant to be built in the Moscow Region. The plant will process 700,000 tonnes of waste to generate 70 MW of electric power. This is the second plant to be built by the consortium in the Russian capital region for Alternative Generating Company (AGC-1),"** Hitachi Zosen Inova said. The new plant will be constructed near the town of Naro-Fominsk, 80 kilometers away from Moscow. According to the contract, the consortium will supply technology and a complete set of equipment.

Equipment for the first plant was manufactured in 2019 and installation is now underway.

According to the Russian Ministry of Natural Resources and Environment in 2019 Russian municipalities generated 53.9 million tonnes of solid wastes. According to openaccessgovernment.org, UK households produce around 22 million tonnes of waste every year.

Rosatom volunteers: Vladislav Shchukin and his team

Good deeds Against Coronavirus

Volunteer initiatives and compassion are the two driving forces that help overcome everyday challenges caused by coronavirus. Volunteering, new means of protection and financial aid are just a few examples of the assistance offered by Rosatom employees in Russia and abroad.

Volunteers

Vladislav Shchukin, a senior manager at sales department at Scientific Research Institute for Instruments has demonstrated one of the most vivid examples of dedication and self-sacrifice working as a volunteer in largest COVID-hospital in Moscow. This is where people with severe coronavirus symptoms were brought at the peak of the epidemic. It was Vladislav's own decision to work in the most dangerous place in Moscow at a time. He became a doctor's assistant in the Epidemic Investigation

Department with a task of collecting and recording information about patients, their contacts and movements. Patients are usually interviewed over the phone, but sometimes Vladislav puts on an overall and goes to see some of the patients personally. He works seven days a week, while his wife and a child are in Zelenograd, a town near Moscow. **"When there is a flood, neighbors come to help; when there is a fire, everyone takes a bucket and fights the fire. It's the same now — we have to help,"** Vladislav explained.

Volunteers help Rosatom employees, too. For example, Gennady Komarov, Director General at the Instrumentation Plant in Tryokhgorny (Chelyabinsk Region), had to self-isolate after the treatment. His colleague, one of the plant's volunteers, brought him everything he needed.

Rosatom employees abroad also make their contribution to solving COVID-related problems. For example, employees of the Central European office of Rusatom International Network (RAIN) in the Czech Republic learned that the country was critically short of seasonal construction workers. RAIN representatives asked the authorities of Třebíč, a town in Czechia,

how they could help and were given a task to renovate a fence around the central bus station. **"The volunteer team consisting of our colleagues was briefed on safety and started working. They removed old paint first and then covered the fence with new paint,"** Oleg Spoyalov of RAIN Central Europe said.

Miloš Hrůza, Deputy Mayor of Třebíč, and the volunteers had a short talk. **"We came to the opinion that we need to expand our cooperation. Then local media visited the site,"** Oleg Spoyalov explained.

A total of 689 nuclear industry employees joined the ranks of volunteers during the epidemic. For the last few weeks alone, they helped nearly 1,500 people, who could not buy food or drugs because of the quarantine.

Know-how

The last issue of Rosatom Newsletter covered a few instances of cooperation between Rosatom Group companies and hospitals. There are a plenty of other examples as well. Personal contacts between doctors and engineers contribute to the development of new devices that make patient care much safer.

Viktor Mishukov, Director of the Federal Biomedical Agency's Clinic No. 91, asked his friend Maksim Dergachov of Elektrokhimpribor (Lesnoy, Sverdlovsk Region) to develop an isolation bed for safe patient handling. It took him a week to create a new modification of the isolation bed with six hand openings so that three doctors can have access to a patient simultaneously. Each opening has a protective silicone trimming to prevent hand gloves from tearing. Many parts, including fixtures, pins, shields and air filter adapters, were 3D-printed. The adapters were used to connect air filters to a full-face diving mask to turn it into a filtration system. A set of filters increase air flow and allow doctors to work longer while meeting all required safety regulations.

Financial aid

New rules and requirements for hospitals during the pandemic mean a huge increase in expenditures on personal protective equipment, which needs to be purchased urgently. Akkuyu Nükleer, the owner of the Akkuyu NPP project, provided funds to the state hospital in Silifke and the family health center in Büyükeceli. Silifke and Büyükeceli are two towns in the vicinity of the nuclear power plant construction site. Each hospital received 70,000 liras (more than $10,000) to be spent on improvement of the infrastructure.

The pandemic made some businesses shut down, leaving people without income. In order to support Büyükeceli families, Akkuyu Nükleer gave locals food gift baskets for Eid al-Fitr. In previous years, Akkuyu Nükleer organized a feast (iftar) for all the people of Büyükeceli, who gathered at the common table. The pandemic dictated its rules this

A hospital close to Akkuyu NPP site receives financial aid from Rosatom

year — no gatherings were allowed, and Akkuyu Nükleer employees delivered the presents to family homes while maintaining safety rules, wearing masks and gloves and leaving the presents at the door.

In April, more than 200 top managers of Rosatom joined the national #WeTogether campaign and donated their one-month salaries to the campaign fund. The initiative was also supported by employees of Rosatom Group companies. The donations will be spent on food and essentials for seniors and physically challenged people, antiseptics and personal protective equipment for volunteers, aid to medical workers, and support of local volunteer teams.

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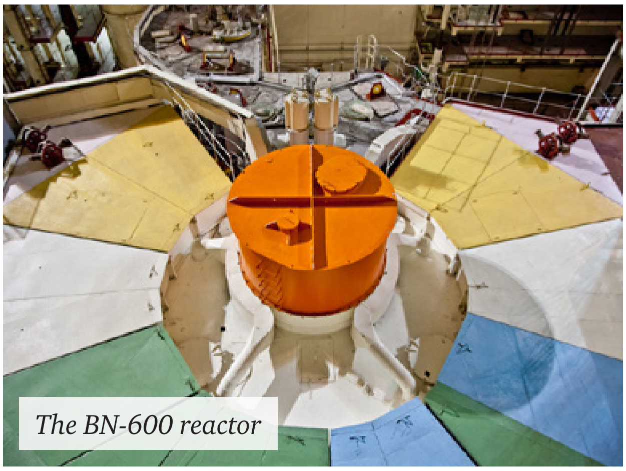
Fast Neutron Science

A. I. Leipunsky Institute of Physics and Power Engineering celebrates its 74th anniversary. Its history is intertwined closely with the world's first nuclear power plant. These days, the institute is engaged in research into the closed nuclear fuel cycle, therapeutic applications of radioisotopes, and experiments with new materials and lasers.

The institute was established on April 27, 1946 as a research laboratory codenamed Laboratory B. Its task was to develop a nuclear reactor for power generation. In 1946–1947, researchers considered the possibility of creating a "uranium machine running on enriched uranium and light water". Among the first employees of Laboratory B, there were Alexander Leipunsky, after whom the Institute of Physics and Power Engineering was later named, and Dmitri Blokhintsev, the first director of Laboratory B.

In the late 1940s and early 1950s, Alexander Leipunsky was making calculations for reactors with different cores, coolants, controls, etc. His work laid a foundation for research into fast neutron and intermediate neutron reactors, one of the key research areas for the laboratory.

At the same time, Dmitri Blokhintsev agreed to Igor Kurchatov's proposal to turn the laboratory into an R&D center for the first nuclear generating station. In July 1951, Laboratory B was commissioned to engineer a water-cooled nuclear power plant and build


The BN-600 reactor

it in Obninsk. Construction began later the same year. On June 26, 1954 the word's first nuclear plant was connected to the grid.

After the Obninsk nuclear power plant was put into operation, Laboratory B got down to developing a nuclear power plant design for the Arctic. The first practical embodiment of this design was Bilibino NPP. The work on the plant began in 1963. The Bilibino NPP consists of four 12 MWe power units commissioned in 1974–1976. EGP-6 reactors were developed at Laboratory B specifically for the Arctic nuclear station. What differs them from other reactor designs is natural coolant circulation. Saturated steam is produced right in the core channels and not in the superheater. In fact, Bilibino power units are an example of small modular reactors, 50 years ahead of broad interest towards small-scale generation. The plant is still in operation but will be shut down soon and replaced with the world's only floating nuclear plant, another SMR developed at Rosatom.

Fast neutron reactors have long become a trademark and a symbol of the laboratory. Back in 1950, Alexander Leipunsky prepared a memorandum entitled 'Fast Neutron Systems', which set a direction for research and outlined an area of future studies. A pilot fast neutron reactor was started up in 1955. Its second modification, BR-5, was the first to use sodium as a coolant and created an opportunity to study materials and physical properties of fast neutron reactors.

In 1960, the laboratory was renamed the Institute of Physics and Power Engineering. In the first half of the 1960s, the institute was developing a sodium-cooled power reactor BN-350 and a research reactor BOR-60 and making calculations for BN-600.

The BN-350 reactor was built in the city of Shevchenko (now Aktau, Republic of Kazakhstan) and commissioned in July 1973. It had a triple purpose: along with generating electricity and heat, the reactor also powered a desalination unit. The city sits on the coast of the Caspian Sea, which is a huge terminal salt lake, so abundance of fresh water improved the quality of life there.

BOR-60 was an initial step towards BN-600, which became the first electricity-only fast neutron reactor. Since April 8, 1980 BN-600 has been generating electricity as Beloyarsk Unit 3.

The Institute of Physics and Power Engineering was also engaged in the development of water and liquid metal cooled nuclear reactors for submarine propulsion units.

Leipunsky Institute Today

The institute's latest project in fast reactors is MBIR, a multi-purpose fast neutron reactor, which has been in development since 2007 under the scientific guidance of the Institute of Physics and Power Engineering.

MBIR is intended to test new types of fuel and structural materials in combination with different coolants and to study safety, reliability and efficiency improvement solutions for nuclear power plants with fast neutron and thermal neutron reactors. Having a 150 MW design capacity, this is the most powerful research reactor under construction. To compare, two research reactors constructed in France and Argentina will have a capacity of 100 MW each, according to the IAEA. Such a large capacity reactor will ensure high density fast neutron flux. With high density flux, the study of changes in structural materials for fast reactors will take three to five years. Using BOR-60 to conduct similar studies would take decades to obtain results.

Fabrication of radioactive isotopes for therapeutic applications is another important area of the institute's activities. Leipunsky Institute is working to develop an actinium-225 (Ac-225) based generator of alpha particles. In medicine, Ac-225 is seen as a high potential radio pharmaceutical for the treatment of metastatic prostate cancer. Berillium-213, a daughter isotope of Ac-225, is used to treat neuroendocrine metastases and bone marrow cancer.

The third area of research is safe production of hydrogen. The idea is to use the interaction of liquid metal coolants and water. The institute seeks to develop stationary and mobile hydrogen fabrication units utilizing liquid metal cooled reactors (as well as natural and associated gases) as a source of heat.

In fundamental studies, Leipunsky Institute of Physics and Power Engineering is engaged, among other things, in the development of ytterbium-doped liquid lasers. Their advantages over solid-state lasers are more effective heat removal and lower price.

Leipunsky Institute of Physics and Power Engineering contributes to fighting the coronavirus pandemic. Its researchers have developed a new therapy against viruses, which may be helpful in treating COVID-19. As Andrei Goverdovsky, Director of Leipunsky Institute, said in an interview to the Strana Rosatom newspaper, scientists call the new method a 'luminescent gas'. They suggest treating patients with coronavirus by disinfecting lungs from the inside with ultraviolet light. Scientists have selected a combination of molecules and gas components that remain active when inhaled and emit ultraviolet light right in the lungs, Andrei Goverdovsky says. According

to him, the new method may also be used to treat other diseases like tuberculosis and oncologies. **"What we were missing so much is back — the most interesting science and research yielding ideas and products that will make a name for the Russian nuclear corporation and the entire country,"** Andrei Goverdovsky said in an interview to Strana Rosatom.

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Who is Alexander Leipunsky (1903–1972)

Alexander Leipunsky was a Soviet experimental physicist. In 1939, he was put in charge of research into uranium fission and studied the role of neutrons in the chain reaction. Leipunsky was a member of the Nuclear and Uranium Commissions of the USSR Academy of Sciences. Starting from 1949, he studied the possibility of building fast-neutron reactors.

Who is Igor Kurchatov (1903–1960)

Igor Kurchatov was a prominent Soviet nuclear physicist and the "father" of the Soviet nuclear project. In the early 1930s, he was one of the first in the Soviet Union to study nuclear physics. He contributed to the development of the first Soviet cyclotron, which was used to continue nuclear research. In 1943, Igor Kurchatov became a member of the USSR Academy of Sciences.

Starting from 1942, he studied nuclear energy. In 1945, he was appointed as the scientific advisor to the First Chief Directorate, a government division managing the Soviet nuclear weapons project. It was him who led the development and testing of the first Soviet atomic and thermonuclear (hydrogen) bombs. He also supervised civilian nuclear programs in the Soviet Union. The world's first nuclear power plant in Obninsk was engineered and constructed under his leadership.

FNPP in Operation

In May, the world's only floating nuclear power plant Akademik Lomonosov was put into operation. Despite growing interest towards small modular reactors (SMRs), Akademik Lomonosov is the only example of a small nuclear power plant in operation. Rosatom steps up its work in the field and discusses construction of RITM-200 reactor-based nuclear power plants with potential customers in Russia and abroad.

What is Akademik Lomonosov

The floating nuclear power plant Akademik Lomonosov has two KLT-40S reactors with a capacity of 35 MWe each. The total capacity of the FNPP is up to 77 MW of electricity and 146 Gcal/h (300 MW) of heat. With a displacement of 21,500 metric tons, Akademik Lomonosov is 140 meters long and 30 meters wide. Its design life is 40 years; the repair interval is 12 years.

Nuclear power in Chukotka

On May 22, the world's only floating nuclear power plant (FNPP) Akademik Lomonosov was put into operation. **"Starting today, the project to build and commission a floating nuclear power plant in Pevek, Chukotka, can be considered complete. It has become the eleventh operating nuclear power plant in Russia and northernmost in the world,"** Andrei Petrov, CEO of Rosatom's electric power division Rosenergoatom, said when signing the commissioning order.

The plant fed first electricity to the local power grid on December 19, 2019. POWER Magazine, a US media outlet for the energy industry, named the commissioning among six key events in the global nuclear generation industry in 2019. As of June 8, the FNPP produced 51.89 million kWh of electricity.

Akademik Lomonosov operates in Chukotka, one of the northernmost regions of Russia. Chukotka is located in the northeastern part of Russia and washed by the Pacific and the

Arctic oceans divided by the Bering Strait. This remote region is not connected to the Russian national power grid and therefore a reliable local source of electric power and heat is vital for the regional economy and everyday life. **“As a new source of energy for the local economy, it will ensure safe supply of electric power for companies and households in the Chaunsky-Bilibino Industrial Area,”** Viktor Bochkaryov, the head of the Regional Department for Industrial Policy said.

The FNPP will be the main source of hot water for Pevek. In March 2020, the local authorities signed a contract, according to which the FNPP will begin supplying heat to Pevek’s District 5 on July 1. The remaining districts will be supplied with heat from the FNPP starting in 2021. This work is being done by Rosatom’s subsidiary Elkon Mining and Metallurgical Plant.

Today, the FNPP supplies power to about 20% of consumers in the Chaunsky-Bilibino area. The Bilibino nuclear power plant remains a major energy supplier for now, with the Chaunskaya Combined Heat and Power Plant providing power to a tiny percentage of local consumers. Power fed to the grid of the Chaunsky-Bilibino Industrial Area is distributed to the cities of Pevek and Bilibino, towns of Rutkuchi, Keperveem and Chersky, Mayskoye and Karalveem mines, and Chukotka gold-mining cooperative. According to the Chukotka authorities, Kekura and Peschanka mines will be connected to power supply later this year. When a transmission line is constructed between Bilibino and Pevek, where FNPP is moored, the Bilibino NPP will be decommissioned gradually. The new transmission line is expected to be built in 2023.

Why SMR?

Credits: A. I. Leipunsky Institute of Physics and Power Engineering, a subsidiary of Rosatom

- SMRs can replace outdated power plants running on fossil fuel
- Ideal as a source of heat and power in remote territories
- Less money and time needed to construct; more attractive to investors
- Compatible with non-nuclear sources of power
- Fully factory-assembled; modules can be added to one another
- Easier maintenance; fewer maintenance staff required
- Reactor modules can be removed or decommissioned on-site after their service life expires

There are currently four basic designs:

1. Light-water reactors
2. Fast-neutron reactors
3. Graphite-moderated reactors
4. Molten salt reactors

Light-water reactors have the lowest technology risk. Fast-neutron reactors can be made smaller and simpler and have a longer refueling interval. Molten salt reactors also have certain advantages.

The Bilibino NPP constructed in 1974–1976 was the first small nuclear power plant in the Soviet Union. It has been supplying remote areas with electric power, which is exactly the purpose for which SMRs are designed. Along with generating power, the Bilibino NPP helped to accumulate extensive experience in nuclear operation in extreme environmental conditions.

Another Chukotka-based project that is of interest for Rosatom is a small generating station at the Baimsky mining plant, which will process ore from the Peschanka porphyry copper deposit. It will need 250 MW of electric power. Rosatom has proposed to build a 342 MW nuclear power plant with three RITM-200 reactors. In Chukotka conditions, such a plant is estimated to cost around RUB 200 billion (USD 3 billion). Rosatom is discussing construction of the nuclear power plant for the Baimsky mining plant with Peschanka Project stakeholders.

The state nuclear corporation is also discussing the possibility of building a small nuclear power plant at two other sites, in the Chelyabinsk Region and in Yakutia. The two plants will supply power to large industrial facilities.

Rosatom is ready to build RITM-200-based generating stations in other countries, too. Representatives of Rusatom Overseas spoke about capabilities of small nuclear power plants at the Small Modular Reactor conference held in the Czech Republic in 2019. In May, they also held a seminar to present advantages of RITM-200 reactors for onshore small nuclear power plants, such as long service life (60 years and more),

CAREM site

FNPP Akademik Lomonosov

predictable power prices, compatibility with renewable sources of power, possibility of heat generation and water desalination. Advantages of small nuclear power plants are detailed below.

Onshore applications will be the next step in the development of RITM-200 technology. Six reactors of the same design are installed on the Arktika, Sibir and Ural icebreakers.

International context

According to the IAEA, there are nearly 50 different SMR concepts and designs. **"Most of them are in various developmental stages and some are claimed as being near-term deployable. There are currently four SMRs in advanced stages of construction in Argentina, China and Russia, and several existing and newcomer nuclear energy countries are conducting SMR research and development."**

Here is a brief overview of the most well-known SMR concepts.

In the USA, NuScale has come closest to bringing its idea to life. However, NuScale's reactor, which is going through a certification process, raised questions

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with the Advisory Committee on Reactor Safeguards (ACRS, part of the U. S. Nuclear Regulatory Commission). According to media, activation of the emergency core cooling system and design of steam generators raise certain concerns. The agenda for the ACRS meeting in June includes issues related to the magnitude of differential boron worth and a final memo on the NuScale design certification.

The NuScale design uses helical coil steam generators (HCSG) with small size being their main advantage. This does not pertain, however, to the steam generator that the US company plans to use. The length of its pipes is 26.5 meters and, even though they are coiled, the generator is very high. Making both the reactor and the generator vertically elongated is an attempt to reduce steam generation by increasing pressure.

Despite the increased height, some steam is still formed in the primary loop. And it is not clear yet whether steam bubbles collapse or merge. If they merge, the growing steam volume increases the flow rate of coolant and fluctuations in its temperature and density (cold/hot alternations) at the entrance into the core, leading to reactivity disturbance.

What is worse, the impact of certain factors on the process of steam generation has not been studied thoroughly yet. Such factors include delayed heat transfer from fuel elements to the coolant, heat conductivity and temperature (accumulated energy) of fuel elements, and effects of these factors (weakening or strengthening) when acting in combination. As a result, fluctuations in steam generation — temperature — density — reactivity at power changes are not regular either. The pressurizer cannot compensate for these fluctuations in due time. The reactor core is not self-controlled either, so it is not quite clear yet what and how will be used to respond to reactivity disturbances, which need to be responded in a fraction of a second, in fact, instantaneously.

This April, the US Department of Energy announced plans to create a new generation of nuclear reactors. The DOE tendered out a contract to support the development of a new-generation reactor and allocated USD 5.4 million to prepare a site for the demonstration reactor in Portsmouth, Ohio.

In Argentina, construction of the 25 MW CAREM small modular reactor beside the operating Atucha I Nuclear Power Plant was suspended last year. The suspension was due to violations by a subcontractor, according to Argentina's energy secretary Sergio Lanziani. In its turn, the subcontractor said that the suspension was caused by the government's failure to pay for the work on time, changes in the design, and a failure to timely submit technical documents. In April, it was announced that the construction would be resumed.

China decided to develop its own design of a floating nuclear power plant. A framework agreement was signed in China this January to make preparations for the construction of a demonstration reactor. The signatories to the agreement are CIMC Marine Engineering Research Institute and Taihai Clean Energy (Shandong) Company (part of CNNC).

Our overview shows that the operating Akademik Lomonosov is yet the only example of a small nuclear power plant commissioned in recent years. Development of other designs is underway in many countries, but they are still far from deployment.


The RITM-200 reactor

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