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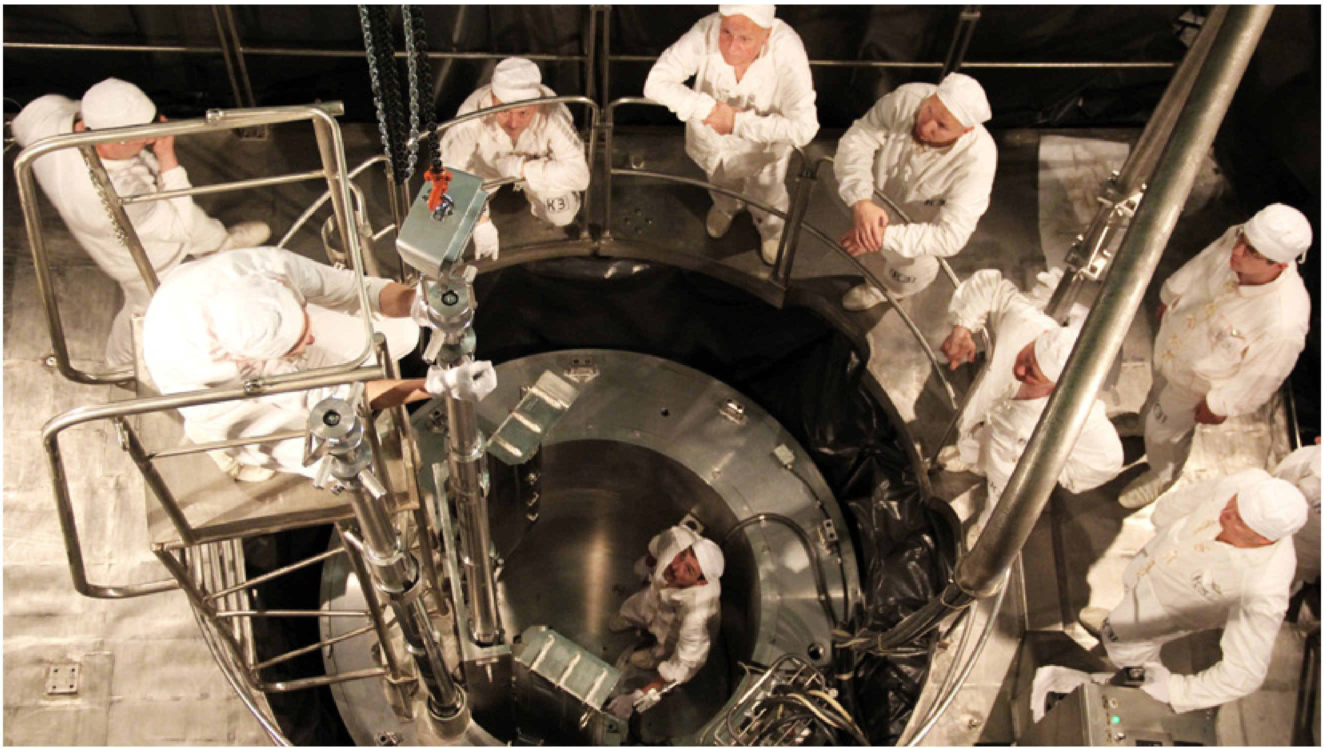

NEW BUILD

Power for Chukotka

Fueling operations for Akademik Lomonosov, Russia's floating nuclear power unit, were completed on October 2, 2018.

Baltic Shipyard engineers finished loading fuel into the second of two – the left-side – floating power unit (FPU) reactors. The vessel is currently at anchor in Murmansk. **"The next step includes system checks to be followed by integrated cold tests,"** says Vitaly Trutnev, Director for Floating Nuclear Power Plants. Units 1 and 2 will then go critical, and all the systems will be tested in operation during the power ascension process.

The FPU has two KLT-40S reactors capable of generating up to 70 MW of electricity and 50 Gcal/h of heat in nominal operating conditions – enough to power communities with up to 100 000 residents. All tests on the FPU are planned to be completed by next March.

The floating nuclear power unit is an unparalleled low-power movable nuclear facility built by Rosatom. Designed to operate in the Chukotka region, the first FPU represents a new class of nuclear facilities built using Russian nuclear marine technology. FPUs will be deployed in Russia's Far North and Far East to supply power to industrial facilities, ports and offshore oil and gas platforms in remote areas.

At present, Rosatom is working to further improve the existing design and create the second generation of floating power plants that will be smaller than the current version. They will be equipped with two RITM-200M reactors with a capacity of 50 MW each.

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In Quick Time

Streamlined construction processes enabled Rosatom to commission Rostov Unit 4 with a VVER-1000 reactor three months ahead of schedule.

On September 25, Russia's nuclear regulator Rostekhnadzor issued a compliance certificate to confirm that Unit 4 of the Rostov NPP meets all technical specifications, including energy efficiency requirements. The unit was put in commercial operation on September 28, or three months ahead of the scheduled date – December 31, 2018.

"Rostov NPP is the first NPP in the newest history where the so called straight-line construction that provides both adherence to deadlines and maximum effective use of materials and financial resources was revived. It is due to this type of construction RoNPP was constructed not only 3 months earlier, but with the high quality," General Director of Rosenergoatom Andrey Petrov said. Shorter construction and faster commissioning saved over RUB 1.5 billion (USD 22.9 million) in project costs.

"For all the employees of the Division Rostov NPP is a very important facility, as when constructing the second, third and fourth power units we, in fact, revived the construction sector of nuclear power industry: we expanded the capacity, implemented new technologies, trained personnel," chief of the Engineering Division of Rosatom Valery Limarenko stressed.

The Rostov NPP is one of the largest power generation facilities in the Rostov region and Southern Russia. Unit 4 will serve as a stable and secure source of power for all the neighboring regions. At present, the plant generates 46% of electric power in the southern part of the country. Now, with Unit 4 commissioned, the Rostov NPP will account for 54% of total power output in Russia's southern regions.

"Russian nuclear power plants have generated more than 147.5 billion kilowatt-hours of electricity in 2018. A sizable contribution to this amount was made by Unit 4 at Rostov and Unit 1 at Leningrad-II NPP," Rosatom's Director General Alexey Likhachev said.

Uzbekistan Goes Nuclear

The first large-scale NPP construction project in Uzbekistan was launched at an official ceremony on October 19, 2018.

The event marked the beginning of site surveys to determine the best location for construction. Geotechnical drilling is

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currently underway at one of the sites, pre-selected for the project based on seismological, geological, environmental and economic feasibility studies.

Uzbekistan's President Shavkat Mirziyoyev and Russia's President Vladimir Putin have launched the drilling by pressing a symbolic button.

The Uzbekistan nuclear power plant will be the first large-capacity NPP in the Central Asia. The project envisages building two Generation III+ power units based on VVER-1200 reactors. Thanks to its enhanced reliability and modern design, the facility will be fully compliant with the IAEA safety standards.

"Uzbekistan and Russia have been cooperating in nuclear for more than half a century, and we are proud that Uzbekistan has chosen the Russian technology to build its first nuclear plant," Rosatom's Director General Alexey Likhachev said, speaking at the event.

As of now, natural gas accounts for nearly 84% of Uzbekistan's energy mix. The local government seeks to replace some of its gas power plants with nuclear generation. Doing so will help in raising Uzbekistan's natural gas exports and make its energy mix 'greener'.

For reference:

In 1953, the Republic of Uzbekistan started mining uranium at a large deposit near Uchquduq in the Bukhara Region. As soon as 1958, the government made a decision to set up a mining company (later known as NMMC) and a town of Navoi. The town and the plant were built primarily by engineers and workers from Russia (the Russian Socialist Federative Soviet Republic at that time). NMMC is currently a Top-10 gold and uranium producer in the world.

At present, Uzbekistan operates VVR-SM nuclear research reactor designed by Dollezhal Research and Development Institute of Power Engineering (a Moscow-based subsidiary of Rosatom). The reactor is installed at the Uzbekistan Academy of Sciences Nuclear Physics Institute located in Ulugbek, a town near the country's capital Tashkent.

In 2009, the VVR-SM reactor was upgraded to use IRT-4M, a low-enriched nuclear fuel grade with 19.8% of U-235. The design was developed by Uzbek engineers with Kurchatov Institute as an academic advisor.

On December 29, 2017, Uzbekistan and Russia signed an agreement on peaceful uses of nuclear power.

On July 19, 2018, President of Uzbekistan Shavkat Mirziyoyev issued a decree to establish the Nuclear Energy Development Agency (Uzatom) with the Cabinet of Ministers of Uzbekistan.

On September 7, 2018, the prime ministers of Uzbekistan and Russia, Abdulla Aripov and Dmitry Medvedev, signed an agreement to build a nuclear power plant in Uzbekistan. The project is aimed at constructing two VVER-1200-based power units, the first of which is scheduled for commissioning by the end of 2028.

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On October 19, 2018, Rosatom, the Academy of Sciences of Uzbekistan and the Nuclear Energy Development Agency (Uzatom) signed a memorandum on cooperation in workforce training for the country's nuclear power sector and related industries. The memorandum also provides for a branch of the National Research Nuclear University (MEPhI) to be set up in Tashkent. These agreements will help Uzbekistan in developing nuclear infrastructure to operate the NPP safely.

General Director of Uzatom Zhurabek Mirzamakhmudov, and Alexey Likhachev also signed a memorandum of understanding to raise public awareness regarding nuclear power in Uzbekistan.

Likhachev told reporters that the contract for construction of Uzbekistan's first nuclear power plant could be signed as soon as the spring of 2019.

AGREEMENTS

India Plans Further Nuclear Development

The Government of India signed a roadmap for six VVER reactors from Rosatom.

The Action Plan for Prioritization and Implementation of Cooperation Areas in the Nuclear Field was signed on October 5 by Alexey Likhachev, Director General of

Rosatom, and Kamlesh Vyas, Chairman of the Indian Atomic Energy Commission, on the margins of the 19th India-Russia Summit in New Delhi.

The parties agreed to work on a project to construct six Russian-designed nuclear power reactors on a new site in India. No exact location has been revealed so far.

The Action Plan also specifies that the new reactors will be built under the VVER design, an evolution of Generation III+ with a demonstrated history of successful commercial operation.

At present, civil nuclear cooperation between Russia and India is concentrated around the construction of a Russian-designed nuclear power plant near Kudankulam. The construction site is located in the state of Tamil Nadu in Southern India. It will be home to six VVER-1000 nuclear power reactors. The project was commissioned by the Nuclear Power Corporation of India Limited (NPCIL). As of now, Units 1 and 2 of Kudankulam NPP are operational and generating power. "First concrete" for Units 3 and 4 was poured in 2017. Preparations are underway at Units 5 and 6, with "first concrete" expected to be poured in 2019 and 2020 respectively.

In total, Rosatom will build at least 12 Russian-designed nuclear reactors in India by 2034.

In addition to the construction of power reactors, the Action Plan for Prioritization and Implementation of Cooperation Areas in the Nuclear Field also provides for joint projects in third countries and partnerships in other civil nuclear areas. Indian companies are currently engaged in construction and installation works at the Rooppur nuclear site in Bangladesh.

MAINTAINANCE

VVER-1000 to Be Annealed

Rosatom plans to anneal a VVER-1000 reactor pressure vessel for the first time ever to extend its service life by 30 years. The operation is scheduled for the beginning of November.

Until 2018, annealing had been performed on VVER-440 reactors only. The vessel is the nuclear island's integral component that determines the duration of its service life. Neutron radiation is one of the factors that may shorten it by embrittling the vessel's welded seams. Irradiation embrittlement depends heavily on nickel content in the vessel steel.

The annealing process is recognized as an effective way of ensuring safe and reliable reactor operation. It helps recover physical and mechanical properties of irradiated steel. This unparalleled technology was developed at the Kurchatov Institute in the late 1980s.

As for VVER-440 the annealing furnace is first disassembled, then transported into the reactor building and assembled inside the reactor vessel. Its steel walls are slowly heated to 475°C, soaked for 150 hours and then gradually cooled. The procedure takes 15 days on average. After that, NPP engineers carry out a feasibility study for the life extension of the reactor vessel.

"Unlike VVER-440, VVER-1000 reactors have never been annealed before. Since its walls are thicker, the annealing temperature must be approximately 150°C higher. Why Balakovo NPP Unit 1? Because its reactor vessel is made of steel with higher nickel content," said Vladimir Asmolov, Advisor to Director General of Rosatom.

The "regeneration" effect will extend the vessel's service life by at least 30 years. The feasibility study for the annealing procedure was carried out on a mock-up at Atommash in Volgodonsk (Russia). The design of the annealing furnace for Balakovo NPP was commissioned by Rosenergoatom.

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"It is just another business product developed by Rosatom. We are now able to offer annealing services to domestic nuclear plants, as well as to Czech and Bulgarian nuclear operators. We can also offer this technology to nuclear power plants with western PWR-type reactors," Vladimir Asmolov said.

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At present, there are 13 units with VVER-1000 reactors operating in Russia, with 22 more in operation in Bulgaria, Ukraine?the Czech Republic, China and Iran. In the future, though, reactor vessels will need no annealing as new generation stainless steel alloys have very low nickel content.

TRENDS

Radiation Technologies in Agriculture and Food Industry

Food loss is not just a waste of food itself, but also a major squandering of resources, including water, land, energy, labor and capital, and, last but not least, it is needlessly produced greenhouse gas emissions contributing to global warming and climate change, the Food and Agriculture Organization of United Nations (FAO) states.

Approximately 1.3 billion tonnes of the food produced for human consumption worldwide gets lost or wasted annually, making roughly up to one third of the total food production.

In industrialized countries more than 40% of losses happen at retail and consumer levels. In developing countries 40% of losses occur at post-harvest and processing levels and can be traced back to financial, managerial and technical constraints in harvesting techniques as well as storage and cooling facilities. Strengthening the supply chain through the direct support of farmers and **investments in infrastructure, transportation, as well as in an expansion of the food and packaging industry could help to reduce the amount of food loss and waste.**

One of the most effective food preservation technologies is irradiation. Rusatom Healthcare (RHC) – Rosatom's integrator of nuclear medical and irradiation products and services -has revised available irradiation solutions offered by Russian nuclear companies to come up with a business development strategy for various industry segments. RHC has also analyzed global markets and conditions in Russia and interviewed food manufacturers, medical suppliers and agricultural producers to further its goal.

The analysis showed a resurgent interest in irradiation technology. First and foremost, it is driven by a growing number of negative effects caused by the existing chemical-based treatments in agriculture.

Medical equipment manufacturers also take particular interest in irradiation methods as they make it possible to sterilize packaged medical products in full compliance with applicable sanitary and microbiological requirements, with no need for heat treatment or contamination control.

Agricultural producers believe that the current processing methods involving chemical agents and heat treatment (used either together or separately) affect the quality of the final products, specifically their sensory properties, vitamin content and microbiological composition.

Food irradiation is considered to be a more reliable practice than those currently used as it poses no risk of chemical contamination or consumption of contaminated products. Such incidents, if they occur, may adversely impact financial standing and reputation of a food producer.

Manufacturers also stress the need for a one-size-fits-all solution. Without it, they often have to use a combination of different processing methods (such as inhibition and disinfection) in a production cycle, with production costs increasing significantly.

The industries mentioned above also recognize the necessity of making processing technologies more eco-friendly.

Having considered the outlook for this line of business and competences offered by Rosatom companies in related industries, Rusatom Healthcare made a decision to bring to the market its new product, a multipurpose irradiation center.

The center will be a template solution (or a set of engineering solutions) that is customizable to the needs of a specific customer. It will ultimately become a basis for a commercially attractive irradiation business.

This template solution is based on the marketing research aimed at estimating types and volumes of goods that would be processed by prospective customers. The most in-demand facilities are gamma ray units capable of emitting 2,000 kCi of radiation on the average (with the total radiation range of 400 to 5,000 kCi), and 10 MeV electron accelerators with a capacity of up to 20 kW (the total range is 5 to 10 MeV and 10 to 300 kW).

The solution is unique in its flexibility both in terms of performance (variable capacity of irradiation units) and design (irradiation center systems and facilities are engineered so as to comply with specific product handling requirements).

At present, RHC has contracts with a number of international companies interested in establishing private irradiation centers to process both medical and agricultural products.

TRENDS

Electron accelerators are of particular interest since these machines generate radiation on demand and therefore are viewed by prospective customers as more reliable irradiation facilities in terms of operational safety. Radiation-generating devices make it unnecessary to import or export sealed radioactive sources that are required to comply with strict radiation safety regulations and meet many other standards. Besides, sealed radioactive sources (or natural ionizing radiation sources) used in gamma ray units need to be operated 24/7 in a continuous mode to ensure their efficient utilization. At the same time, the use of electron accelerators is subject to restrictions in certain countries importing irradiated products. For example, the processing of produce with bremsstrahlung (i.e. braking radiation) in the USA and EU is only permitted for electron accelerators with a maximum energy of 5 MeV. The USA also allows the import of products irradiated in electron accelerators with energy of up to 7.5 MeV provided that specific materials are used when switching from electron radiation to bremsstrahlung.

Efficient irradiation of different product groups requires information on optimal absorbed doses and process parameters (irradiation time, dose uniformity ratio, etc.). This is why a key task at the moment is to carry out extensive research on the impact of irradiation on various products and adjust irradiation parameters accordingly. For instance, a Rusatom Healthcare partner in the Philippines has initiated research on the impact of gamma rays on bananas in 2018. In 2016–2017, the Russian Radiology and Agroecology Research Institute and the Budker Institute of Nuclear Physics worked out a detailed plan to study the use of radiation technologies in agriculture and food industry.

Rusatom Healthcare is also studying the possibility of using ionizing radiation sources for other purposes, such as sewage and drain water disinfection, exhaust gas purification, etc. These research projects will require creating specific engineering designs and solutions to integrate irradiation units into manufacturing processes and delivery vehicles.

At present, the success of local and international projects depends heavily on joint efforts of Russia's leading irradiation equipment suppliers, R&D centers studying ionizing radiation and its impact on different materials, and legislative bodies. NL

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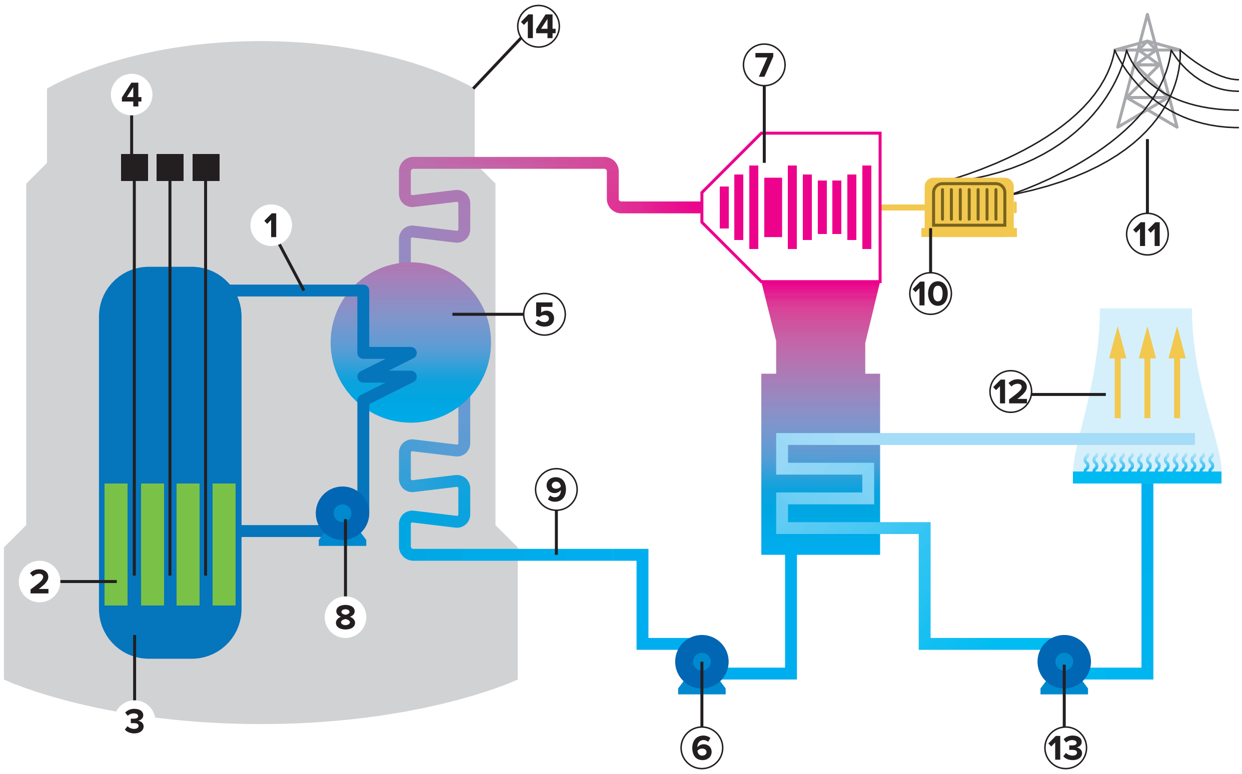
INFOGRAPHICS

HOW A VVER-TYPE NUCLEAR POWER PLANT WORKS



A nuclear power plant with a VVER reactor has two separate co-existing water circuits. The primary circuit *(1)* contains water heated by nuclear fuel rods *(2)* to up to 239,7 °C in the reactor pressure vessel *(3)*. Chain reaction stability is ensured by the reactor control and protection system *(4)*. All the primary circuit equipment is placed inside the containment building *(14)*.

Water remains in its liquid state in the primary circuit due to high pressure (17,6 MPa),. Once heated in the reactor, the water passes onward to the steam generator *(5)* – huge cylinders with tubes located inside them. VVER-type steam generators (SGs) are placed horizontally, four per reactor island, ensuring an even higher degree of safety. Primary circuit water is transferred to high pressure tubes, while secondary circuit *(9)* water is pumped by feed water pump *(6)* into to the steam generator. Secondary circuit pressure is twice as low as the primary circuit pressure – which is why secondary circuit water vaporizes, absorbing heat from primary vessel tubes inside the SGs. The generated steam is transferred into the turbine *(7)* that it rotates. The primary circuit water leaves SG tubes and is then pumped into the reactor through a primary reactor coolant pump *(8)*.

The steam turbine rotates the generator. The produced electricity is transferred to the switchyard *(11)*.

The steam cools as it goes through the turbine, turning into hot liquid. It needs to be further cooled down before being directed back to the steam generator. This is done either in a cooling tower *(12)* or in a cooling pond. After that, the circulating water pump *(13)* pumps the water back into the secondary circuit.