## SOLUTIONS FOR NUCLEAR POWER



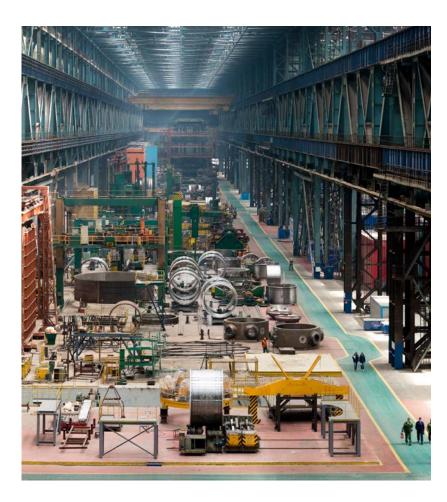




## **ABOUT COMPANY**

#### Atomenergomash —

is a power engineering division of the State Atomic Energy Corporation Rosatom. Global power engineering holding company operates in the key industries. >20
countries
is the geography
of our projects



100%
of all Russian-designed
NPPs around the world
are equipped with our
products

every third light bulb in Russia is lit with our help

7 mln miles
passed by nuclearpowered ships
equipped with our reactor units

- We assist our customers in delivering high performance, create new technologies and modern technical solutions that ensure efficient and safe operation of equipment throughout its entire lifecycle.
- We combine leading scientific research, engineering, manufacturing centers in Russia, CIS and European Union countries.
- Our products are present in nuclear and thermal power, oil & gas industries, shipbuilding, special steel market, in small hydro generation and other economic and industrial sectors.
- We see our mission in a constant work together with our partners and customers to improve the welfare of people today and tomorrow.

## **KEY MILESTONES**

On March 29, Atomenergomash company was created in the structure of the Federal Atomic Energy Agency. Its purpose is to ensure the development plans for the nuclear industry in the domestic and foreign markets and expand the industrial engineering potential of the Russian power machine-building complex.





The company continues to develop its design and production base both in Russia and abroad. In total, the structure consists of 16 companies.

2006

2007

2008

2009



Creation of the target structure of Atomenergomash, the organization of production and design competencies and the corporate circuit. The company consists of 11 enterprises.

The nuclear-powered icebreaker "50 Let Pobedy" was commissioned.

Power units №1,2 of Tianwan NPP (China) with a VVER-1000 reactor unit were brought into operation.

The organization of an industrial engineering complex for the production of nuclear steam supply system (NSSS) has begun.



The company expands international cooperation and forms a vertically integrated production chain of key equipment for nuclear power plants.

The shipment of equipment for unit №1 of the Leningradskaya NPP-2 CC was completed.



Atommash, the largest manufacturer of nuclear power plants equipment, became part of the AEM.

The first molten core catcher for NPPs was manufactured and shipped.

The development of a reactor unit for a typical project of a VVER-technology optimized computerized power unit (VVER-TOI) was completed.

2010

2012

2011

The organization of the production chain for the manufacturing of long lead time equipment continues.

The first experimental fast reactor with CEFR sodium coolant was commissioned.





Start of manufacturing of the main nuclear island equipment for units Nº 1,2 of the Belarusian NPP.



First VVER-1200 reactor vessel was delivered to Belarusian NPP.

Tests of the newly-designed reactor coolant pump (single-shaft configuration with water-cooled engine and bearing assemblies) were completed.

Power start-up and low power testing of power unit №4 with the BN-800 reactor of the Beloyarskaya NPP took place.

Work is underway on the production of equipment for the first 3+ generation power unit of the Novovoronezhskaya NPP.

2013

2014

A complete production chain from design to delivery has been formed for manufacturing nuclear power equipment.



Contracts for the packaged supply of nuclear island equipment for new nuclear power plants in the Middle East and Northern Europe are negotiated for the first time. 2015

2016

Innovative RITM-200 reactor units for the new-gen 'Arktika' icebreaker were delivered.

The second VVER-1200 reactor vessel was shipped to the Belarusian NPP.

Start of the production of equipment for the MBIR multipurpose fast-neutron research reactor.

The company became the parent organization for the development of an optimized floating power unit.

The production of two RITM-200 reactor units for the first new-gen 'Sibir' commercial icebreaker was completed.

The reactor physical start-up of three power units ( №3 of the Tianwan NPP (China), №4 of the Rostovskaya NPP, №1 of the Leningradskaya NPP-2 with reactor units designed by our enterprise and fitted with our equipment) took place. Designs of VVER reactor units for 8 more foreign sites are currently in development.

Contracts are underway for the packaged supply of equipment for Russian-designed nuclear power plants that are currently under construction in 12 countries.



2017 2019

### 2018

Atomenergomash became the largest Russian machine-building enterprise by revenue.

AEM's total business portfolio amounted to 623 bln rubles.

The production of two RITM-200 reactor units for the second new-gen 'Ural' commercial icebreaker was completed.

Equipment for various purposes was shipped to the following nuclear power plants: Kudankulam NPP (№3,4), Armenian NPP (№2), Kurskaya NPP-2.

Start of manufacturing of packaged equipment for Akkuyu NPP (Turkey) and Rooppur NPP (Bangladesh).





## VVER-1200 REACTOR FOR 3+ GENERATION NPP

VVER-1200 (PWR) - the most innovative and safe pressurized-water reactor. It has combined the best solutions and technologies of previous units. Compared to its predecessor, VVER-1000 is defined by greater power, twice as long life time, higher utilization coefficient (UC), resistance to external danger sources.



11 185 mm Vessel height (with upper unit of 19 410 mm)

**323 tons**Total vessel weight

#### **TECHNICAL CHARACTERISTICS**



Up to 70 MW · day / kg Maximum fuel burnup



#### 28 800 MW

of power is generated per day by one power unit within an 18-month fuel cycle



92%



35,9% Efficiency



**1200 MW** Electric Power



**1,5 years**Interload period duration
Four- and five-year fuel cycles are also possible



- Water is used as a moderator and coolant
- The use of a steam generator eliminates the flow of radioactive coolant to the turbine



3200 MW Thermal Power



**60 years** Life cycle



Water is used as a moderator and coolant



**163 pcs.** The number of fuel assemblies

#### **MANUFACTURING**



254 atmospheres

The pressure at which the reactor is tested for strength. Equal to a water column height of 2.5 km.



**840 days**Manufacturing time

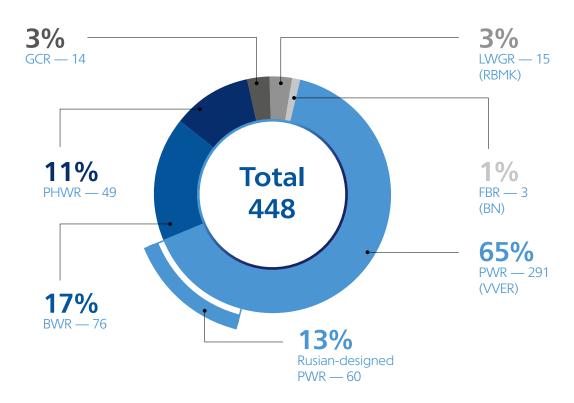


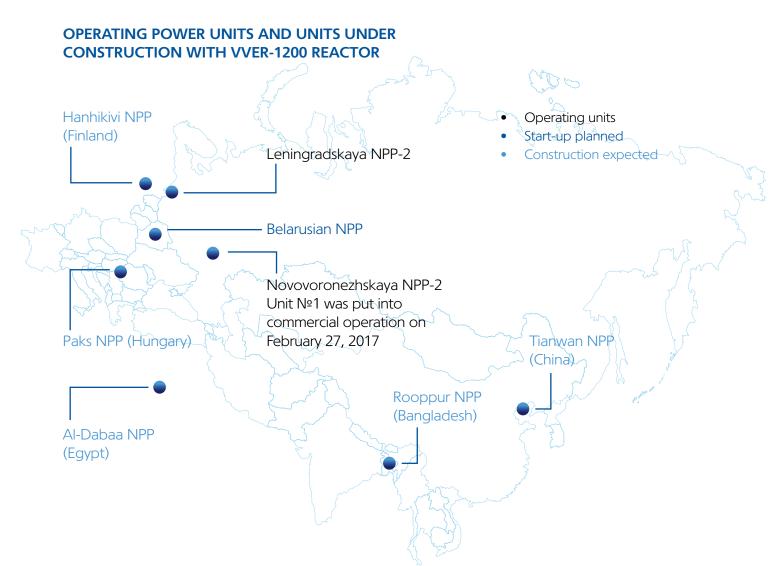
**315 points** of quality control



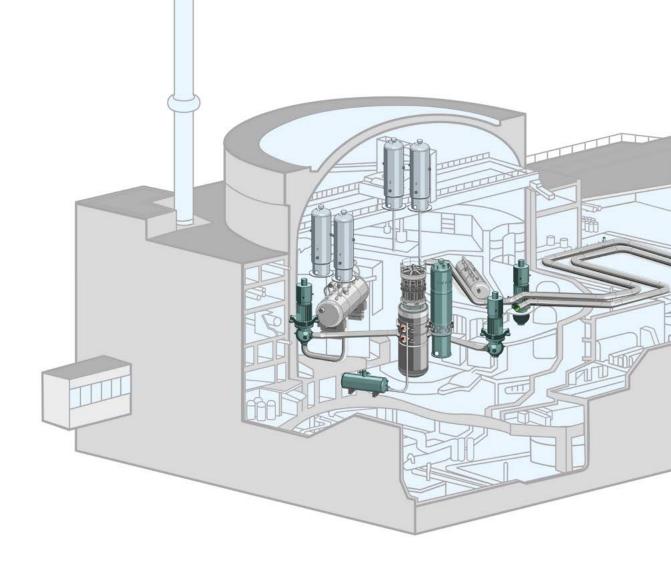
**768** manufacturing operations

#### RATIO OF REACTORS OPERATING WORLDWIDE, PCS.





# PACKAGED SUPPLY OF EQUIPMENT FOR NUCLEAR STEAM SUPPLY SYSTEM (NSSS) AND TURBINE HALL



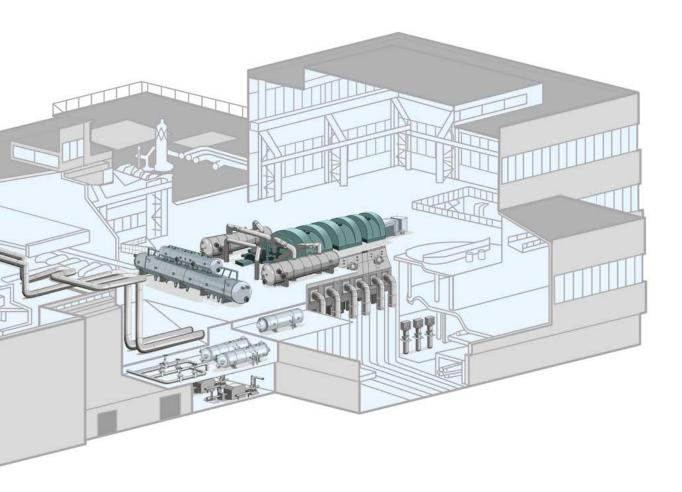
## Packaged supply of equipment for NSSS

- Reactor assembly
- Supporting and retaining rings
- Control & protection system (CPS) drives
- Steam generator

- Reactor coolant pump
- Core passive deluge system tank
- Emergency core cooling system
- Main circulating pipeline
- Pressurizer
- Relief tank



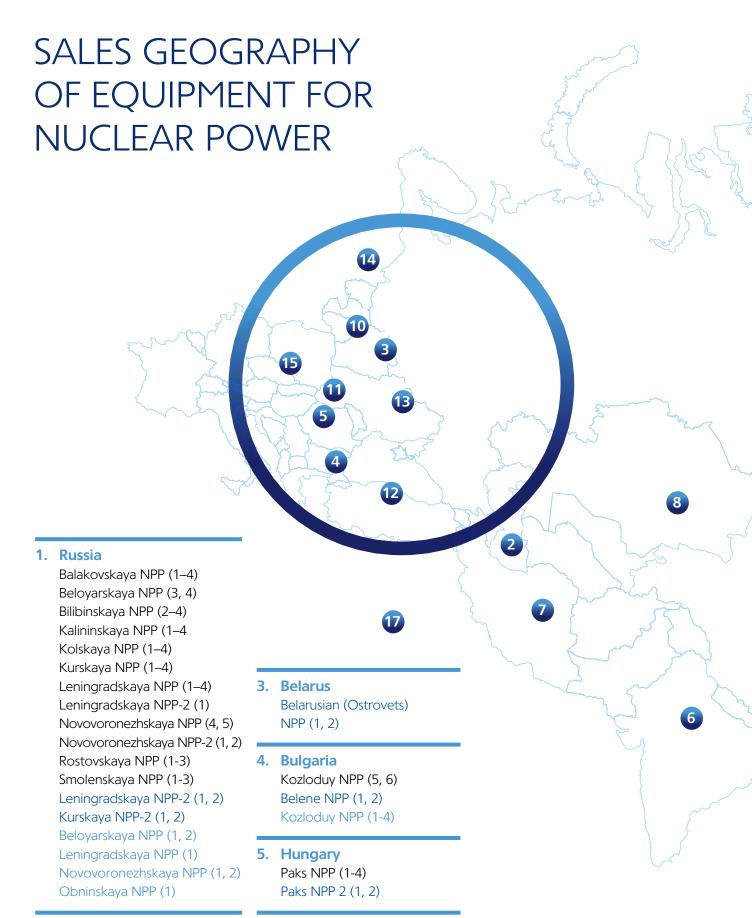
Atomenergomash JSC follows the market trends in terms of the packaged supply of equipment to nuclear power plants. In present-day conditions, the customer benefits from this supply chain. AEM enterprises provide a packaged supply of equipment for NSSS and turbine hall.



## Packaged supply of equipment for turbine hall

- Steam turbine ARABELLE™
- Turbine generator
- Moisture separator-reheater
- Turbine condenser
- Condensate Extraction Pumps
- Low-pressure preheaters

- Deaerator and feedwater storage tank
- Feedwater pumps
- High-pressure preheaters
- Auxiliary equipment (including tanks, oil and drain pumps, heat-exchange equipment, filters etc.)
- Valves (isolating, control etc.)
- Piping with associated hangers and supports

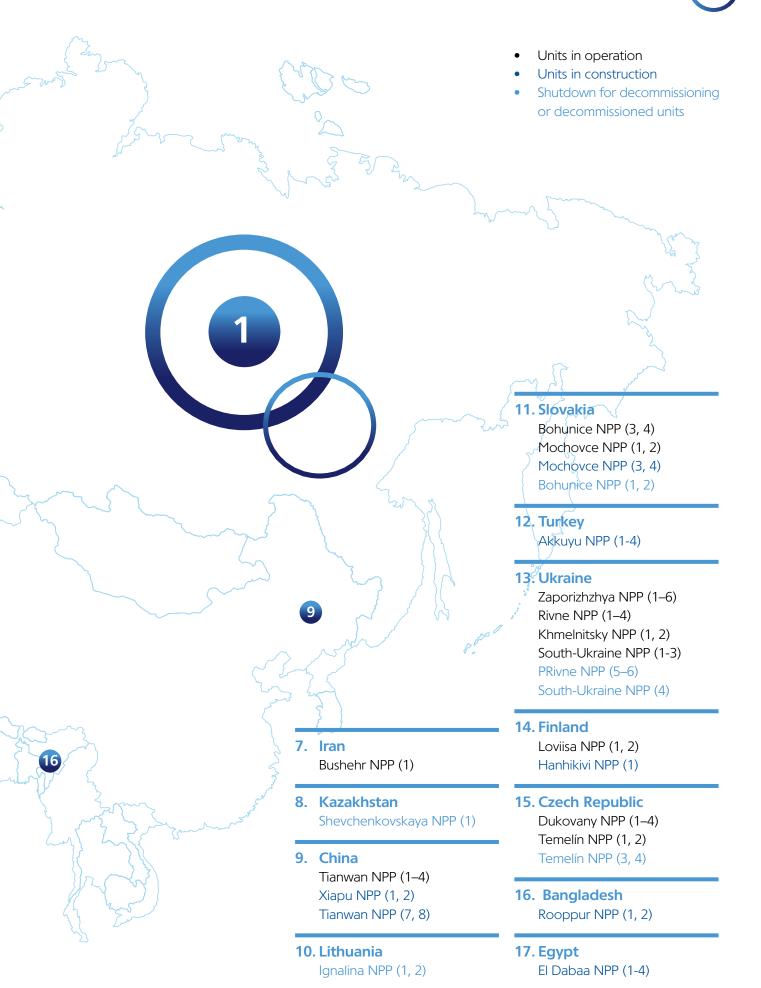


#### 2. Armenia

Armenian NPP (2) Armenian NPP (1)

#### 6. India

Kudankulam NPP (1, 2) Kudankulam NPP (3, 4)



# LARGE SCALE PROJECTS IMPLEMENTED IN THE LAST 5 YEARS

#### **Kudankulam NPP**



#### **Equipment produced for Kudankulam NPP**

#### **ZiO-Podolsk**

- 8 sets of high-pressure moisture separator-reheaters PVD-K-5.6
- 2 separation tanks
- 2 condenser tanks

#### **Atommash**

- 4 steam generators
- 4 steam generators (PGV)

#### **CDBMB**

- 5 pull-out parts
- 2 pump units for heating steam condensate extraction
- 7 pump units for lifting ejectors

#### Petrozavodskmash

- 2 relief tanks
- 4 sets of RCP shells
- 4 main circulating pipeline spools
- Pressure compensators

#### **Belarusian NPP**



#### **Equipment produced for Belarusin NPP**

#### **ZiO-Podolsk**

- 8 sets of high-pressure moisture separator-reheaters SPP-1200
- 2 relief tanks

#### **PZM**

 2 sets of emergency core cooling system

#### **Atommash**

- 2 VVER-1200 reactor units
- 2 molten core catchers
- 8 steam generators (PGV-1000)

#### **CDBMB**

• 8 RCP (GCNA-1391)

#### **Ganz EEM**

8 cooling pumps

#### **Gidropress**

 reactor unit equipment project (NSSS)

#### **OKBM**

pumping equipment



#### Novovoronezhskaya NPP-2



#### **Equipment produced for NNPP-2**

#### **OKB GIDROPRESS**

- reactor unit equipment project (NSSS)
- complete reactor unit equipment project (nuclear island)

#### **Atommash**

- Molten core catcher
- Equipment airlock

#### **CDBMB**

- RCP (GCNA-1391)
- primary circuit pumps of emergency and planned cooling (emergency pumps -ACN-1721, ACN-1722)

#### Petrozavodskmash

- ECCS emergency core cooling system
- Steam generator superheaters
- Core passive deluge system tank (CPDST)

#### **ZiO-Podolsk**

- Steam generators
- High-pressure preheaters (PVD)
- Moisture separator-reheaters (SPP-1200)
- BRTI (block removable thermal insulation)
- HP, ECCS, PC pipelines

#### **Afrikantov OKBM**

 a working pole in telescopic design. A working pole is a part of the fuel-handling machine

#### **CNIITMASH**

 design supervision works (technology and material supervision) of the reactor vessel, RCP, steam generator, and equipment airlock production

## RITM-200 REACTOR UNIT FOR LOW CAPACITY NUCLEAR POWER PLANT



#### Main design parameters for 1 SGU

SGU type	integrated
Thermal power, MW	175
ICUF (technical requirement at RU)	0,65
On-stream period, h	26 000
Assigned energy source r.c., TWh	4,5 (7,0*)
Fuel enrichment	< 20%
Specified lifetime:  – non-replaceable equipment, years  – replaceable equipment, years	40 20
Specified service life: – non-replaceable equipment, years – replaceable equipment, years	320 160

<sup>\*</sup> Design perspective.

Starting with the first domestic nuclear-powered ships, we create reactor equipment for all ships with a nuclear propulsion system.

The latest generation is the RU RITM-200 range and its modifications. They will be used not only in the nuclear icebreaker fleet, but will also become the basis for low capacity nuclear power plants, both onshore and offshore.

Operating time of a single fuel load

A single load of nuclear fuel is equivalent to

tsd tons

of Arctic diesel fuel, which would require to be transported by 3 VLCC classsupertankers

A non-nuclear icebreaker of the same capacity would have consumed

mIn tons of coal

in 7 years of operation. This is 2 years of operation of the TPP in a city populated with 30 000 people.



## LOW CAPACITY NUCLEAR POWER PLANT



#### Low capacity nuclear power plant

is a new concept in nuclear power when it comes to the local supply with energy resources, replacement of decommissioned capacities, and electric power supply to remote and inaccessible regions.



## LOW CAPACITY NUCLEAR POWER PLANT ADVANTAGES



#### **Small size**

The small size of low capacity low capacity NPPs provides wide opportunities for their placement.



## Wide scope of application

Low capacity low capacity NPPs can be used for desalination and heat generation.



#### CO<sub>2</sub> Emission

Low capacity low capacity NPPs is a way to add to the green projects portfolio with a low carbon footprint.



## Shortened construction time

The construction time of a low capacity low capacity NPP is shorter than that of larger capacity nuclear power plants.



#### **Desalination**

Hybrid desalination technology based on multi-stage distillation and reverse osmosis.



#### **Heat production**

The RITM range is suitable for use in district heating systems.



#### **Modularity**

The power capacity of the station can be changed due to new power units. All modules are delivered ready-made, which is cost and time efficient.



#### Load following

Low capacity low capacity NPPs can operate in a follow-up mode, making it a flexible solution for supplying markets with relevant demand of power.



#### **Stable generation**

The power output power of low capacity low capacity NPPs is easy to predict, which allows you to plan the basic load for a long time considering its 60-year life cycle.

## ONSHORE LOW CAPACITY NPPs

Rosatom is ready to offer a flexible tailor-made SMR solution designed to meet the most specific customer needs.

Two SMR deployment options (onshore and offshore) were developed considering all climate, regional and geographic specifics.

#### Suitable for supplying power, heat and desalinated water to

- local municipalities
- industrial sites
- isolated areas
- (1) Reactor building
- 2 Turbine hall
- (3) Radwaste building
- **4** Switchyard
- 5 Administration building
- **6** Cooling water pumps

- **7** Cooling towers
- 8) Water treatment building
- 9 Fire pumphouse
- (10) Security gates
- (11) Backup generators

10,7 ha

Total area

2,5 ha

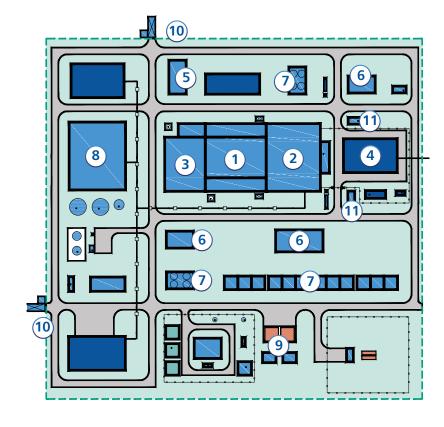
Building area

1,8 ha

Passages and transit areas

6,4 ha

Green areas

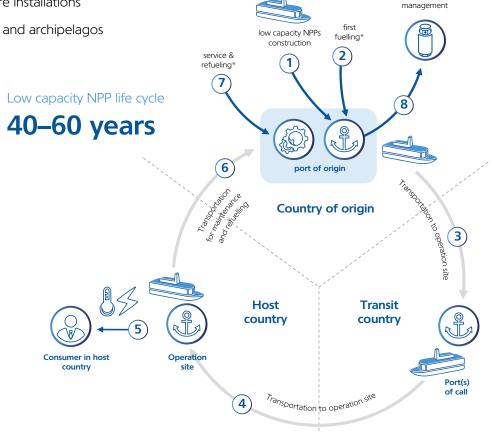




## OFFSHORE LOW CAPACITY NPPs

#### Suitable for supplying power, heat and desalinated water to

- coastal areas
- offshore installations
- islands and archipelagos



- low capacity NPP construction and firstfueling in the country of origin \*
- Transportation to operation site through the territorial sea of transit countries
- (5) Power and heat production at operation site in host country (up to 10 years before refueling)
- (6) Return to the country of origin for maintenance and refueling
- Maintenance and refueling in the country of origin\*

RW

- Radwaste Management in the country of origin
- 9) Return to operation site







<sup>\*</sup> An option. Other customized options are available upon each Project conditions.

## COMPANY'S PRODUCTION CHAIN

## Scientific and research developments



#### **Processes**

- Basic and applied research
- Development of new materials and operating processes
- Prototypes and tests
- Welding technology and nondestructive testing

## Design and engineering



#### **Processes**

- Development of reactor equipment for all Russian-designed NPPs
- Reactor units for the nuclear icebreaking and submarine fleet
- Advanced research in the production of reactor units for medium-power NPPs and low capacity NPPs

The unique manufacturing capabilities of AEM make it possible to provide customers with key equipment for nuclear plants in accordance with the highest requirements. The quality and production timeline is ensured by a regular production chain and close cooperation of enterprises within the Atomenergomash group.

#### Semi-finished metallurgical products and special steel



## **Equipment** manufacturing



#### **Supply**



#### **Processes**

- Production of semi-finished steel products for the nuclear, power and other industries
- Creation of new constructional materials
- Design and production of customized equipment

#### **Processes**

- Production of equipment for the nuclear and turbine islands
- Production of auxiliary equipment for NPPs
- Unique technological and manufacturing competencies

#### **Processes**

- Combined delivery of oversized cargo, including land and water routes
- Own port terminal with access to maritime transport routes
- Close control at every stage of cargo transportation

## **RESEARCH & DEVELOPMENT**

The Atomenergomash JSC enterprises include leading institutes and design bureaus with unique competencies in the development of innovative power solutions. Investments in innovations, additive technologies and various digital solutions are one of the company's priorities.



Fundamental, basic and applied research, development and technological works on the creation of progressive, environmentally friendly and resource-saving technologies and equipment is carried out by:

- CNIITMASH
- OKB GIDROPRESS
- Afrikantov OKBM
- SverdNllkhimmash
- CDBMB



The largest in Russia branch scientific center for power machine-building is being created on the basis of JSC CNIITMASH in order to form a unified technical policy and develop competitive solutions in the machine-building division.

Integrated scientific potential of the Atomenergomash enterprises will allow to solve industry-specific problems in developing innovative high-tech full-scale products and their service support at all stages of their life cycle.

## **DESIGN ENGINEERING**

Atomenergomash develops and designs equipment for various NPP designs.

The Atomenergomash group of enterprises includes OKB Gidropress, which is the only Russian developer of VVER-type reactor units operating at NPPs in Russia and abroad.

Long-term experience in the development of reactor units allows the company's specialists to offer

unique designs that consider the factors of possible technological impact, as well as hydrometeorological and geological features of the NPP location.

The common feature for all reactor unit designs developed by OKB Gidropress is top quality standards and highest safety level requirements.





The development of fast-neutron reactor units an important area of activity of the Atomenergomash enterprises. The design and manufacture of this reactor type is handled by Afrikantov OKBM, the largest design bureau of the division.

The enterprise is also a leading developer of marine and ship nuclear reactor units, industrial nuclear reactors, reactors for medium-power NPPs and low capacity NPPs, and basic and auxiliary equipment for the nuclear power.





## SEMI-FINISHED STEEL PRODUCTS

Material research and metallurgical enterprises are an integral part of the holding's well-formed production chain. The steel and welding materials specifications for key equipment of NPPs developed at the state scientific center of the RF JSC NPO CNIITMASH allow to manufacturing products with unique features.





Atomenergomash JSC presents a wide range of metallurgical products for various industrial sectors:

#### **Nuclear island**

- steam generator shells
- reactor vessel shells
- details of the reactor coolant pump
- bottom of the reactor vessel
- details of the steam generator collector for VVER-1000, VVER-1200 reactor units

#### **Turbine hall**

- turbine vessels
- medium-pressure turbine rotors
- low-pressure turbine rotors, shanks, discs
- rotors of generators
- high-pressure turbine rotors

#### **Metallurgical production**

- production of castings up to 150 tons
- production of ingots up to 500 tons
- castings from steels and nonferrous alloys up to 60 000 tons per year

The research in the field of metallurgy and materials processing technologies is being carried out on the basis of JSC NPO CNIITMASH. The presence of in-house institutes studying metals, materials, welding and control, nanomaterials allows to offer comprehensive solutions for the creation of new materials and advanced technological processes while producing new-generation equipment.



## **EQUIPMENT MANUFACTURING**

High-performance facilities and modern technologies are the basis of the Holding. In recent years, a key program for modernization of the production park has been implemented at main machine-building enterprises. At present, Atomenergomash JSC integrates enterprises with unique technological and production competencies.





boring-and-turning, deep-boring, plane-milling, mortising, gear-hobbing,

#### **Technological capabilities**

#### Forging and thermal process

- Press forging treatment
- Heat treatment

#### **Machining**

machining of parts up to 300 tons

#### **Production capabilities**

- 100% of Russian-designed NPPs in Russia and abroad are equipped with our products
- production and packaged supply of equipment for the reactor and turbine islands
- simultaneous production of up to 4 sets of reactor equipment for VVER-type NPPs, including up to 9 steam generators per year
- capabilities for finning pipes with a volume of 7-8 tsd tons per year

## KEY PRODUCTION FACILITIES

## VOLGODONSK BRANCH OF AEM-TECHNOLOGY — "ATOMMASH", VOLGODONSK, RUSSIAN FEDERATION



"Atommash" enterprise is the largest manufacturer of equipment for nuclear power in Russia.



Upgraded production facilities allow the simultaneous manufacture of up to 4 reactor equipment sets for VVER-type NPPs. The branch also manufactures products for the largest Russian and foreign oil refining, mining and power companies. Own riverside wharf for loading oversized cargo allows the enterprise to deliver products to anywhere in Russia and abroad.

## PETROZAVODSK BRANCH OF AEM-TECHNOLOGY — "PETROZAVODSKMASH", PETROZAVODSK, RUSSIAN FEDERATION

One of the largest production facilities in the northwest of Russia. It has its own foundry and processing industry. It manufactures hull, capacitive and other equipment for nuclear and traditional power, petrochemical and pulp-and-paper industries.





#### ZIO-PODOLSK, PODOLSK, RUSSIAN FEDERATION





One of the leading enterprises in the power engineering industry of Russia. ZiO-Podolsk specializes in the production of equipment for nuclear and thermal power, shipbuilding, oil and gas industry enterprises, as well as for waste incineration plants.

The plant's equipment is installed at nuclear power plants in Russia, Ukraine, Armenia, Finland, Germany, Cuba, Bulgaria, Iran, China, and India. Currently, the enterprise is manufacturing a reactor unit for newgen Russian nuclear icebreakers. When it comes to thermal power, ZiO-Podolsk is one of the main Russian manufacturers of boiler equipment for thermal power plants.

#### CDBMB, SAINT-PETERSBURG, RUSSIAN FEDERATION

CDBMB is the only designer and manufacturer of main circulation pumps for all types of Russian reactors in the country.

The latest development of the design bureau is a circulation pump without an oil system (GCNA-1753), in which all components are lubricated and cooled by water (including motor units). The absence of an oil system significantly increases the fire safety of NPPs. This technical solution is off the scale throughout the world.

The enterprise possesses the only facility in Russia for conducting full-scale testing of pumping equipment under conditions that simulate the operation of the reactor over all factors (pressure, temperature, coolant type). All enterprise's products, delivered to NPPs, are tested in various modes, allowing timely detection of possible deviations of the operation parameters and troubleshooting.





#### AFRIKANTOV OKBM, NIZHNY NOVGOROD, RUSSIAN FEDERATION

Leading Russian enterprise in the field of nuclear machine-building. JSC "Afrikantov OKBM" has a developed and well-functioning infrastructure with a complete production and technological cycle from design, manufacturing and testing to the packaged delivery of products to the customer and providing service support throughout the life cycle.

Afrikantov OKBM carries out a large amount of work to create unified pumping and ventilation equipment for NPPs, upgrade the thermal and mechanical equipment of existing NPP units and create import-substituting equipment for NPPs under construction.

Proven competencies allowed the enterprise to become a packaged supplier of equipment for BN-800 and KLT-40S reactor units.





#### **ENERGOMASHSPETSSTAL, KRAMATORSK, UKRAINE**

One of the world's largest manufacturers of special cast and forged products aimed at individual or limited production for the nuclear industry, metallurgy, shipbuilding, power and general machine-building.

The enterprise possesses the latest metallurgical, metal and mechanical processing equipment and performs a full production cycle from generating marketing and technical ideas to turning them into finished products. The production capacities of EMSS include an arc-furnace shop, a foundry, a mechanical processing production.

Turning machines of the enterprise allow the processing of parts with a diameter of up to 4 m, a length of 24 m, a weight of up to 300 tons. It is possible to process parts with a diameter of up to 8 m and a height of 6 m with a maximum mass of a part of 250 tons using boring-and-turning machines. Boring machines allow the production of parts with a length of up to 32 m and a height of up to 5 m. Products under the EMSS brand are supplied to more than 50 countries worldwide.





## **SAFETY**

Russian-designed NPPs are operated reliably and safely, which is confirmed by regular inspections of both independent domestic authorities (Rostekhnadzor) and international organizations. A high generation 3+ safety level is ensured through the use of interredundant passive and active systems.

The equipment manufactured by Atomenergomash JSC enterprises is used in emergency and planned cooling systems, emergency feedwater supply, emergency core cooling, and passive afterheat removal.

The molten core catcher (melt trap) is an important innovation in the passive safety system of NPPs.

The unique Russian safety technology produced by Atomenergomash JSC is a cone-shaped vessel, which is mounted on supports at the bottom of the reactor's concrete shaft. The vessel is filled with special materials, which are mixed with the core melt ensuring uniform melt allocation in the trap vessel in the situation of a hypothetical emergency. Depending on the modification, the weight of the molten core catcher can be up to 800 tons with a diameter of about 6.5 m.

#### **IMPROVING SAFETY LOCALIZATION SYSTEMS**

Hurricanes, tornadoes
Estimated maximum wind speed,
with wind frequency of
1 time per 10 000 years - 56 m/s

Shock wave with front pressure of
30 kPa

Aircraft crash at a speed of 200 m/s

Prevention of yield: nuclides, fission
products from zirconium tubes and
from the reactor vessel and the 1st
vessel coolant.

Flooding at a level with a reliability of



Preparation for surface transportation of the BelNPP melt trap.

It is being built under the reactor.

Serves to localize the core melt of a nuclear reactor, which is possible in severe accidents only. Its weight is about 750 tons.

## INTERNATIONAL CERTIFICATION

The products and services of the Atomenergomash enterprises comply with the quality standards of leading international accreditation authorities for the nuclear industry.









## STRATEGY OF QUALITY

Nowadays Atomenergomash equipment has proven its reliability with many years of accident-free operation at dozens of nuclear power plants around the world.

The company has implemented a quality management system that is consistent with present-day international practice and international standards. Each enterprise undergoes the attestation procedure of national regulatory authorities, as well as certification of manufactured equipment while supplying equipment to foreign NPPs. Control measures are carried out at any production stage from design to supply in which experts from AEM, the customers and their technical authorities take part.

Newest equipment is used for quality control, which allows conducting ultrasound, radiological, thermovision and other types of studies.

Strict quality requirements for products are imposed on external suppliers. AEM experts regularly conduct relevant inspections of enterprises, control purchased blanks, materials, semi-finished products, finished products in order to confirm their ability to supply products and provide the required level of service.



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