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Development of nuclear research facility concept with multipurpose fast test reactor MBIR

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Purpose and objectives of the MBIR reactor project

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Start of Project: in **2006 : The first Report on the initiative of NIKIET:** "Conceptual design of the MBIR reactor including cost estimation and proposed administration and management of design engineering work"

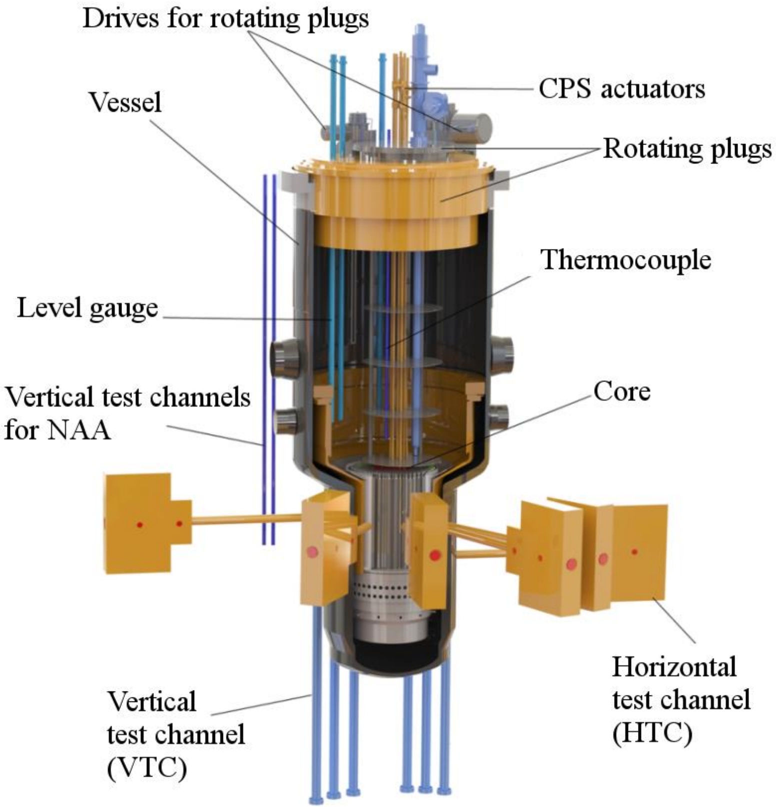
The decision to construct high-flux fast research reactor MBIR was taken on the 22nd November 2007 by the Science and Technology Board #1 at ROSATOM State Atomic Energy Corporation".

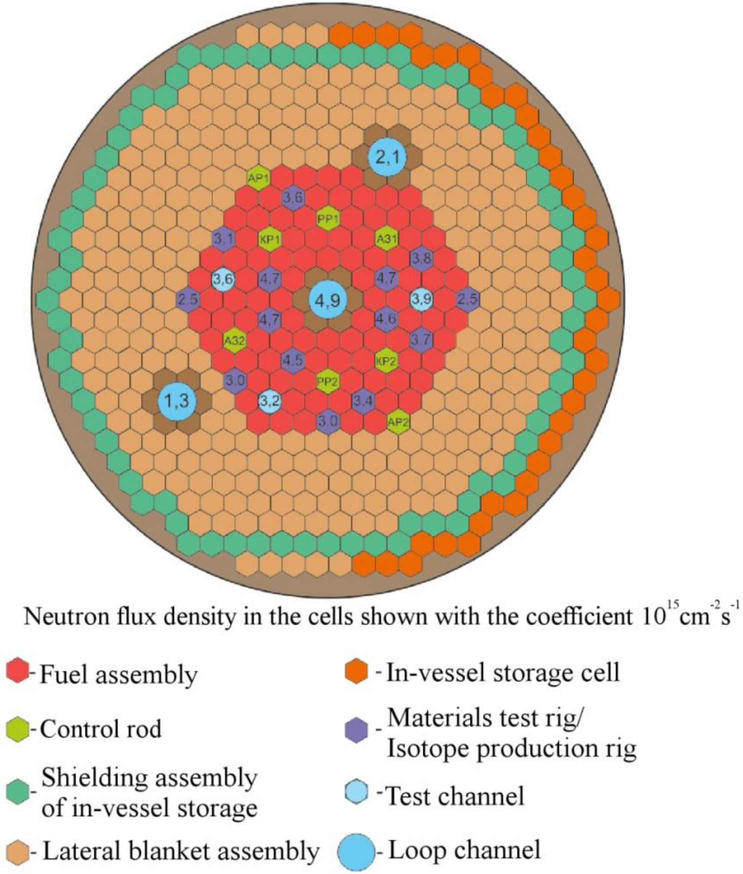
Purpose of MBIR construction: to have a high-flux fast research reactor with unique characteristics attractive to its Consumers, promote and facilitate advances in experimental facilities of nuclear power industry of the Russian Federation.

The MBIR reactor objectives:

- Irradiation experiments and post-irradiation examinations;
- Research & development in support of new production methods for radioisotopes and engineering design configuration;
- Testing of new equipment and engineering design configurations;
- **Related objective:** generation of electric power and heat

Design specifics of the MBIR reactor





Design specifics of the MBIR reactor

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Parameter	Value
Nominal thermal capacity of the reactor, MW	150
Maximum/ average neutron flux density in the core, $cm^{-2} \cdot s^{-1}$	5.3×10^{15} / 3.1×10^{15}
Spacing of elements in the core , mm	75
Number of fuel assemblies in the core, pcs.	93
Number of fuel elements in one fuel assembly, pcs.	91
Number of positions in the core for materials test rigs or isotope production rigs	14
Number of positions intended for test channels	3
Number of positions intended for installing one loop channel	7
Number of loop channels in the core / in the lateral blanket	1 / 2
Fuel for standard fuel assemblies	Mixed uranium-plutonium oxide fuel
Weight content of PuO_2 in the MOX-component of vibropac fuel, %	38.8
Height of fuel column, mm	550
Reactor configuration	Loop-type
Number of loops for heat transfer	2
Number of heat removal circuits	3
Primary and secondary coolant	Sodium
Coolant flow direction in the core	Bottom-upwards
Heat removal from the reactor core	Cooling is done by forced circulation when the reactor is under operation at power / natural circulation when it is shutdown
Protective gas in the gas cavities of the reactor and its containment vessel	Argon
Design lifetime, yr.	50
Reactor operation between refueling operations, EFPD	100
Reactor shutdown period for regularly scheduled outages including refueling operations, d	35 – 45
Reactor availability factor	0.65

Design specifics of the MBIR reactor

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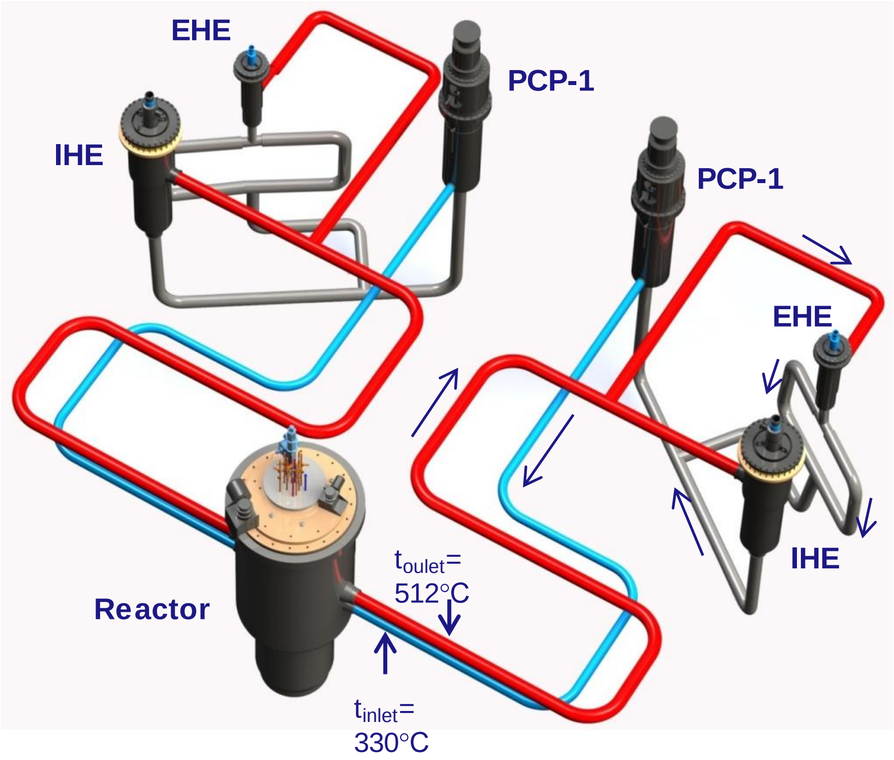
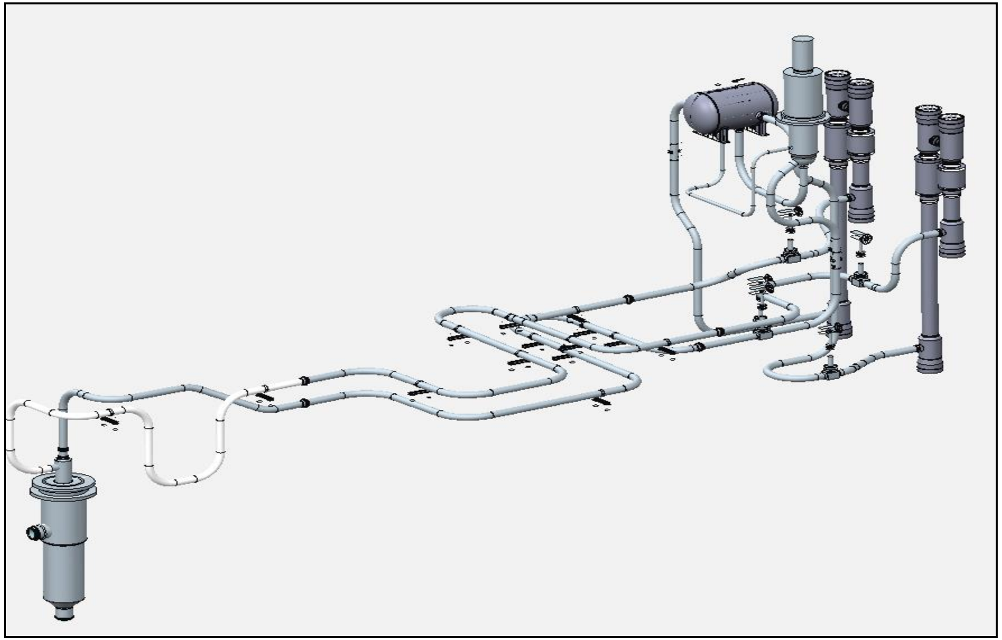
Primary circuit



Parameter	Value
Primary coolant temperature: - At the reactor inlet, °C - At the reactor outlet, °C	 330 512
Sodium flow rate through the reactor, kg/s	650
Pressure in the primary circuit, MPa	No higher than 0.7
Intermediate heat exchanger (IHE): - Thermal capacity, MW	72
Emergency heat exchanger (EHE): - Thermal capacity, MW	3
Primary coolant pump (PCP): - Flow rate, m^3/h	1350

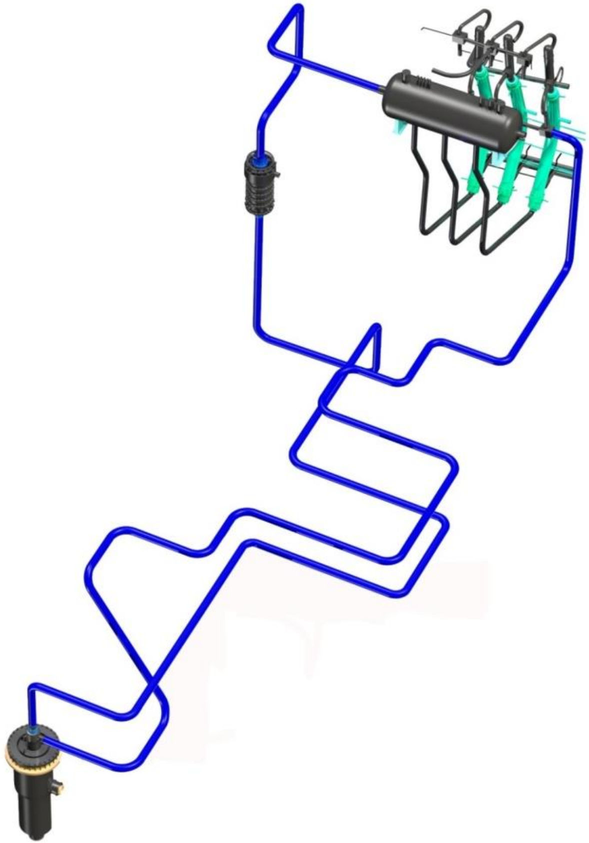
Design specifics of the MBIR reactor

Secondary circuit (Option 1)



Parameter	Value
Secondary coolant temperature: - At the IHE inlet, °C - At the IHE outlet, °C	298 479
Sodium flow rate through IHE, kg/s	310
Steam generator: - Thermal capacity, MW	36 (2 steam generators per loop)
Secondary coolant pump SCP-2: - flow rate, m^3/h	1270
Nominal pressure, MPa	0.64 pressure in the circuit or 0.3 (pump discharge)

Design specifics of the MBIR reactor



Secondary circuit (Option 2)

Parameter	Value
Secondary coolant temperature: - At the IHE inlet, °C - At the IHE outlet, °C	 298 479
Sodium flow rate through IHE, kg/s	310
Modular inverted steam generator (MISG): - Thermal capacity, MW	72 (3 modules of 24 MW each)
Electromagnetic pump (EMP): - Flow rate, m^3/h	1268
Nominal pressure, MPa	0.5

Design specifics of the MBIR reactor

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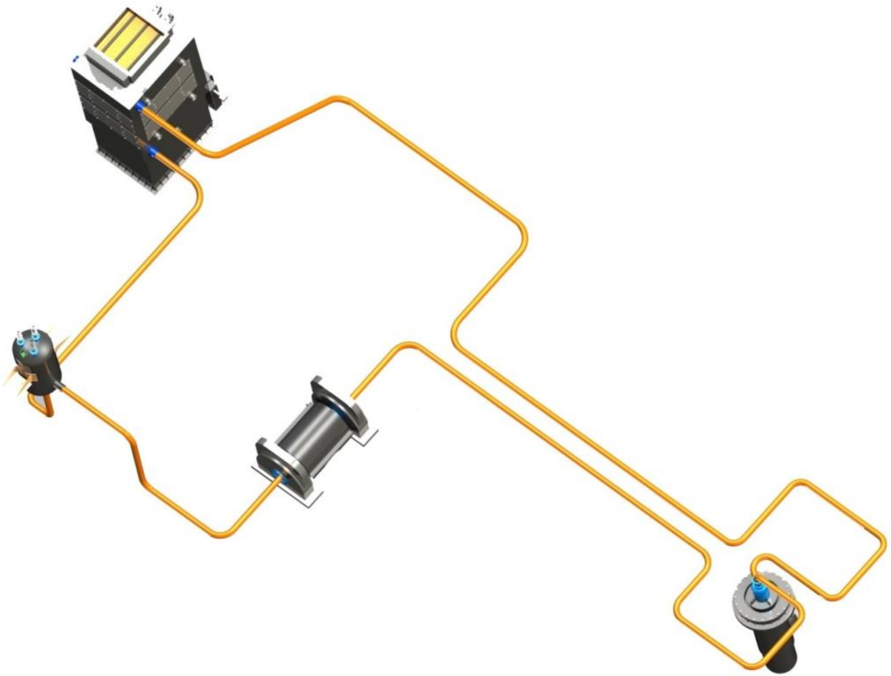
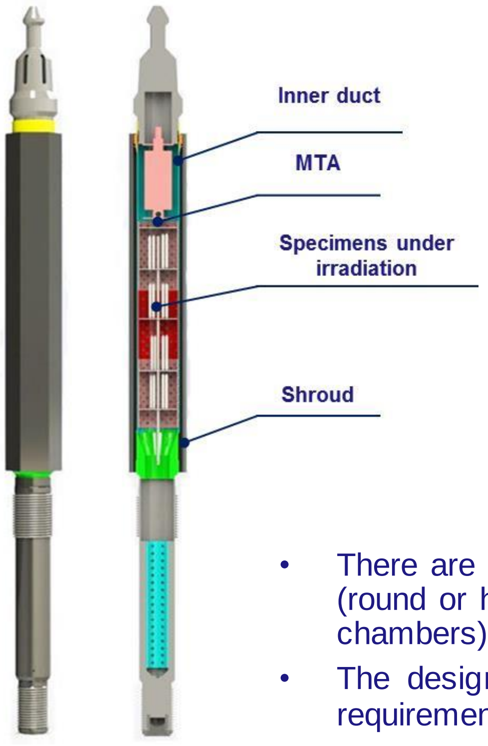
Emergency heat removal system (EHRS)



Parameter	Value
Emergency heat exchanger (EHE): - Thermal capacity, MW	3
EHRS coolant temperature: - At the EHE inlet, °C - At the EHE outlet, °C	 293 486
Sodium flow rate in the EHRS loop through EHE, kg/s	12.12
Air heat exchanger (AHE): - Thermal capacity, MW	3
Electromagnetic pump (EMP) for EHRS loop: - Flow rate, m^3/h	49.5
Nominal pressure, MPa	0.0033

Experimental capabilities– materials test rig (MTR)



Parameter	Value
Width across flats, mm	72.2
Height, mm	2 700.0
MTR usable volume, cm^3	2 280.0
Number of MTR (core)	14
Number of MTR (1^{st} circle of blanket)	No more than 36
Dose rate in the core, dpa/year*)	20÷24
Dose rate (1^{st} circle of blanket), dpa/year*)	14÷17
Maximal neutron fluence, (En > 0.1 MeV), cm^{-2}	1.5×10^{23}

- There are four design options of the materials test assembly depending on the shape of inner duct (round or hexahedral) and sodium circulation at the inlet (from the high-pressure and low-pressure chambers).
- The design engineering of materials test assembly (MTA) is performed based on the technical requirements specified by the Customer to fulfill irradiation test objectives.
- MTR design provides for continuation of irradiation testing launched in the BOR-60 reactor. Two full-size BOR-60 irradiation rigs can be accommodated within the MBIR shroud.

*) *provided that the MBIR capacity utilization factor is 0.65*

Experimental capabilities– Loop test facility (LTF)

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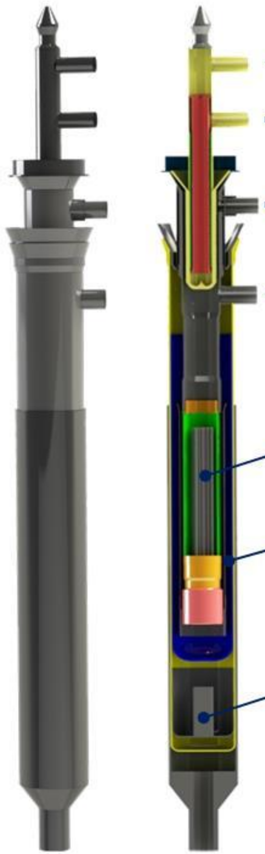
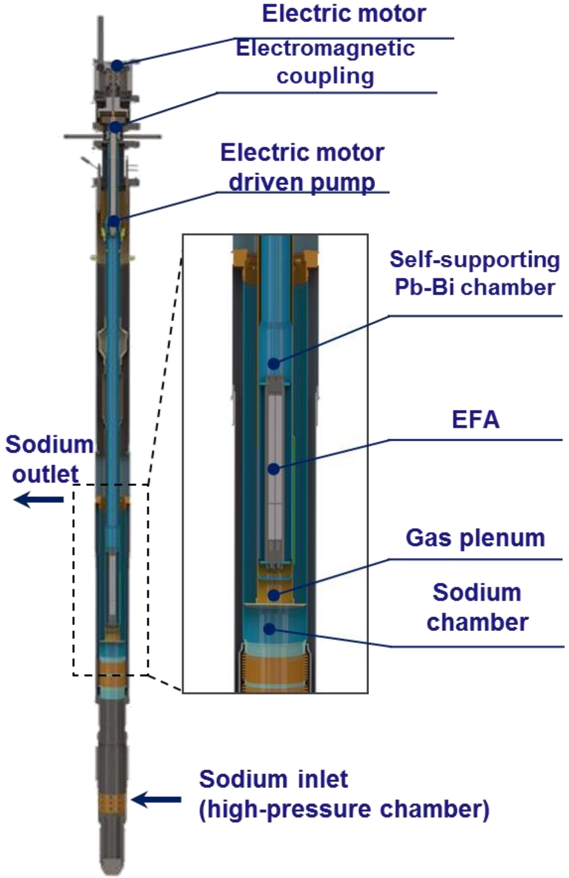


LTF parameter*	Value
Overall height of LTF, mm	11900
Outer diameter of LTF (at the core level), mm	100
EFA coolant temperature (at the inlet/at the outlet), °C	Up to 600 / Up to 900**
Coolant temperature at the LTF outlet, °C	Up to 600
EFA fueled length, mm	550
Sodium flow rate through the EFA, kg/s	Up to 2.85
Sodium flow rate through main circuit of LTF, kg/s	Up to 6.00

FA parameter	Value
EFA width across flats, mm	47.0
FR length, mm	1245
Power output, kW	Up to 1100

*) *These parameters are given for sodium-cooled LTF.*
**) *Coolant boiling operating conditions.*

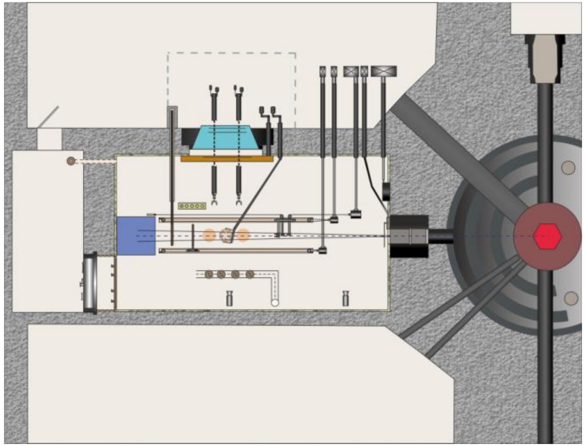
Experimental capabilities– irradiation test rig (TR)



Parameter of Pb-Bi TR	Value
Overall height, mm	10890
Width across flats, mm	72.2
Outer / inner diameter of cylinder-shaped end cap at the level of the core, mm	68.0 / 65.0
Coolant flow rate through the Pb-Bi chamber, kg/s	Up to 6.0
Maximum coolant temperature (in the self-supporting Pb-Bi chamber), °C	390±10
Outer/inner diameter of FA, mm	45.0 / 41.0

- Test rig can be used for conducting the following irradiation experiments:
  - Irradiation testing of structural materials and fuels in the specified medium provided that the irradiation temperature is measured and monitored (320÷1800 ºC);
  - Testing of mechanical properties of structural materials under irradiation.
- The design engineering of instrumented test rigs (ITR) is performed based on the technical requirements specified by the Customer to fulfill irradiation test objectives

Experimental capabilities of the MBIR reactor



Neutron radiography cell

7.1 m (length) × 4.1 m (width) × 2.9 m (height)

Horizontal test channels (HTC)

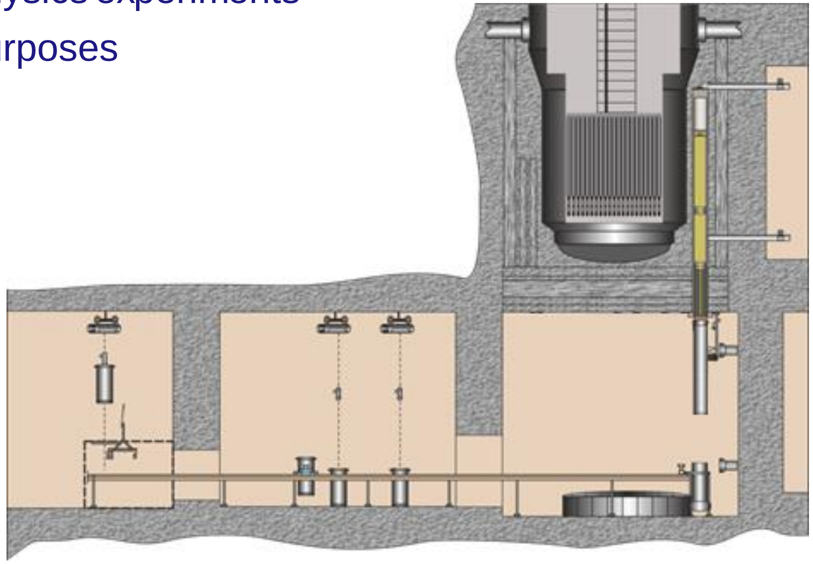
There are 6 horizontal test channels for the following activities:

- Neutron radiography
- Nuclear physics experiments
- Medical purposes

Vertical test channels (VTC)

There are 8 vertical test channels for the following activities:

- Silicon doping (6 VTCs.)
- Neutron-activation alalysis (2 VTCs)



Silicon doping facility

Experimental capabilities of the MBIR reactor

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Irradiation capabilities	Location	Number of TRs	Neutron flux density at the mid-core plane, 10^{15} $cm^{-2}\cdot s^{-1}$	Size, mm
Loop-test facilities Central loop Peripheral	 Core center The 1st and 3rd rings of the lateral blanket	 1 2	 4.9 2.1 / 1.3	D 100, 7 irradiation positions, size width across flats 72.2 each
Instrumented test rigs	Core	3	No higher than 4	Irradiation position, size width across flats 72.2
Irradiation positions for loading materials test rigs and isotope production rigs	Core	14 to a maximum	2.4 – 4.7	Irradiation position, size width across flats 72.2
Vertical test channels	Outside the reactor vessel, within thermal shield at R1675 mm	6	0.0124	D 342
	Outside the reactor vessel, within thermal shield at R2670 mm	2	1.59×10^{9} *	D 34

* The above data are given without regard to 10^{15} $cm^{-2}\cdot s^{-1}$.

Experimental capabilities of the MBIR reactor

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Parameters attained at the outlets of MBIR horizontal test channels

Composed function	HTC-1, $cm^{-2} \cdot s^{-1}$	HTC-2, 3, $cm^{-2} \cdot s^{-1}$	HTC-4, $cm^{-2} \cdot s^{-1}$	HTC-5, $cm^{-2} \cdot s^{-1}$	HTC-6, $cm^{-2} \cdot s^{-1}$
Neutron flux density $E>0.1$ MeV	3.28×10^9	9.00×10^8	-	8.36×10^9	3.28×10^9
Neutron flux density 0.01 MeV$<E \leq 0.1$ MeV	2.06×10^9	1.42×10^9	-	8.73×10^9	2.06×10^9
Neutron flux density 0.4 eV$<E \leq 0.01$ MeV	4.51×10^9	2.45×10^9	2.40×10^5	1.38×10^{10}	4.51×10^9
Neutron flux density $E \leq 0.4$ eV	2.38×10^8	6.79×10^7	3.69×10^5	1.34×10^9	2.38×10^8
Channel purpose	Nuclear physics experiments	Nuclear physics experiments	Neutron radiography	Neutron physics experiments	Neutron physics experiments
HTC location	Outside the reactor vessel				
HTC diameter, mm	D180				

MBIR Project implementation

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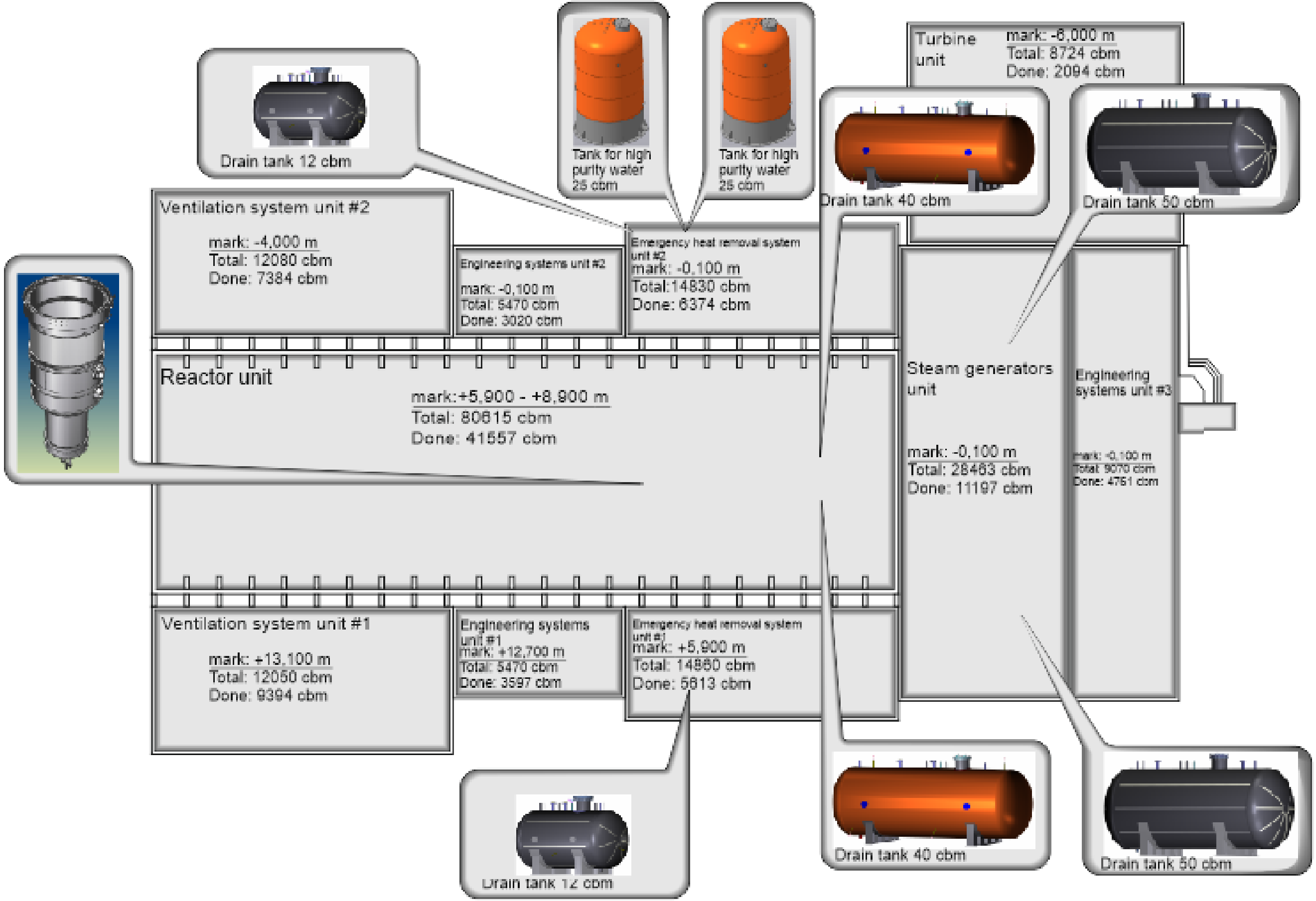
In 2014

Winter 2019

Spring 2021

Current status of concrete pouring work and plans for equipment mounting for 2021



Long-lead equipment

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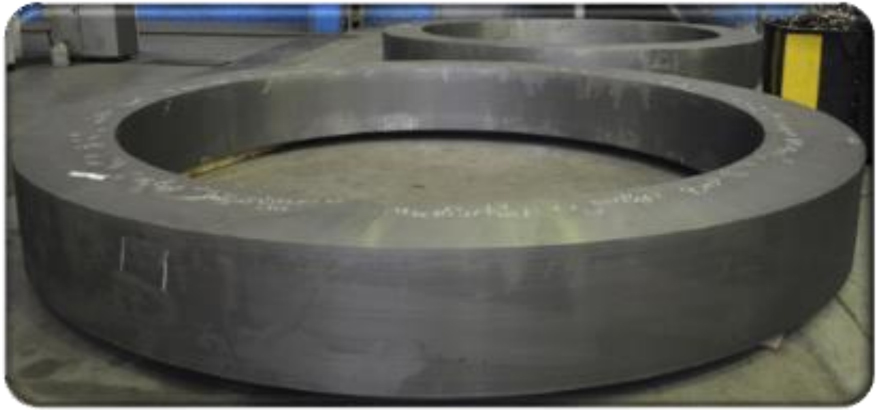
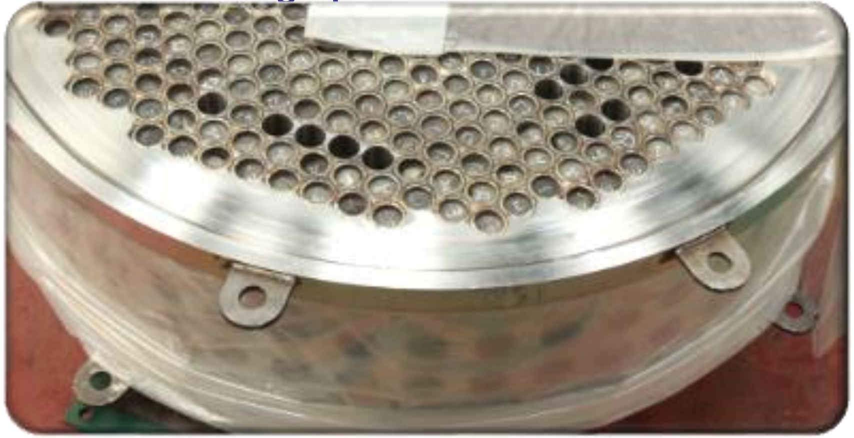


Thermal shield structures

Core barrel

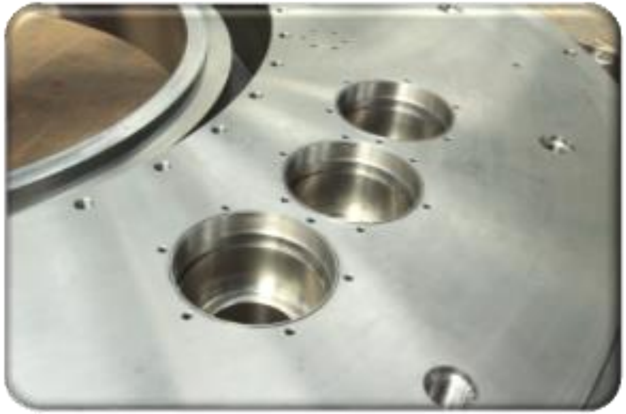
High-pressure section



Long-lead equipment

Guide tube damper

Drain tank of the primary circuit



Large rotating plug

Long-lead equipment

In December 2019 another stage of manufacture was accomplished by Atommash Branch of AEM-Technology JSC in Volgodonsk which is the manufacture of the main reactor vessel as well as large and small rotating plugs. Quality of manufacture was verified by positive results of integrated quality control testing that included hydraulic pressure test, air test and vacuum tests among other things.

Moreover, the hydraulic pressure test and vacuum testing provided for analyses of stress-strained state of the reactor vessel to verify the applied computer codes and obtained strength calculation data to reveal the compliance of calculated stress-strain data and experimental ones.

Long-lead equipment

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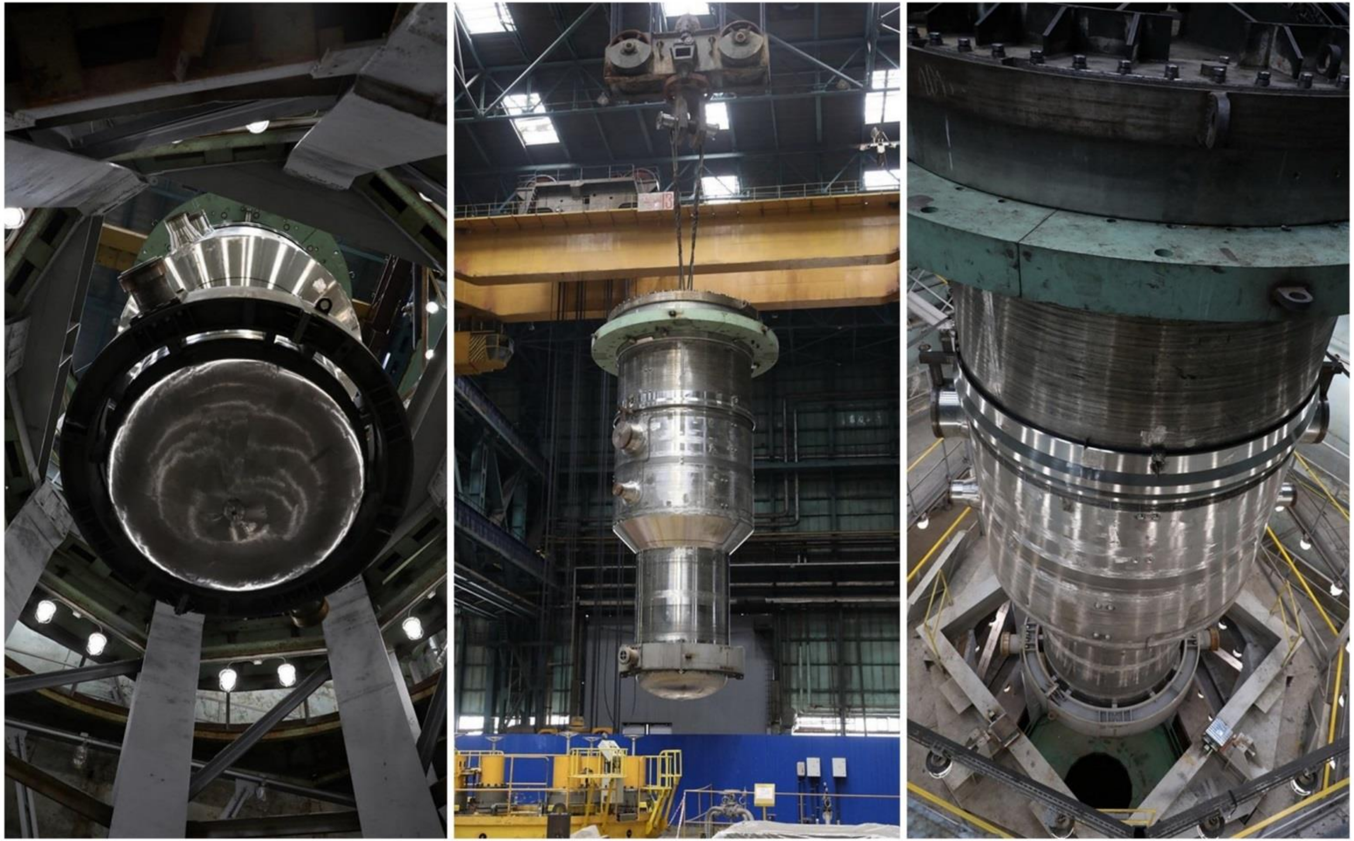

Delivery of long-lead equipment

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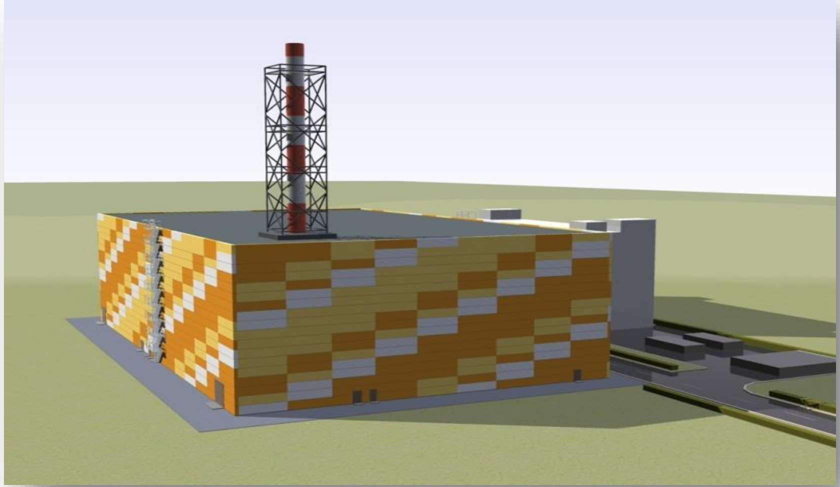
At present time the following large-sized equipment has been delivered to the RIAR's site for the systems important to safety :

- Drain tanks of the primary circuit with volume of 40 m^3 – 2 pcs;
- Drain tanks of the secondary circuit with volume of 50 m^3 – 2 pcs;
- Drain tanks of the EHRS circuit with volume 12 m^3 – 2 pcs;
- Thermal shield structures of the reactor– 1 set;
- Guide tube for the reactor refueling system– 1 set;
- Electric overhear travelling crane for the reactor hall with a lifting capacity of 125/20/1t;
- Railroad grade gates;
- Crown sheet– 1 set;
- Tanks for high purity water with volume of 25 m^3 – 2 pcs;
- A set of CPS guide sleeves;
- A set of jacket covers for level gages;
- A set of thermocouple jackets;
- Thrust ball bearings for large and small rotating plugs;
- Equipment for vent systems of the main reactor building and fallout shelter.

Drain tanks for sodium coolant were installed in project positions.
The reactor vessel is to be delivered to the RIAR's site in 2021.

Prospects

To address the objectives of the National Project targeted at development of technologies for dual-component nuclear power system with fast reactors, establishment and operation of the state-of-the-art test facilities in support of dual-component nuclear power system, special attention is being given to include the Project “Establishment of International Research Center based on Multipurpose Fast Test Reactor MBIR and R&D Complex for Advanced Research in Spent Nuclear Fuel Reprocessing, Radioactive Waste Management and Closed Nuclear Fuel Cycle” in the State Program “ Development of the RF Nuclear Power Industry”.



Conclusion

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At present JSC GSPI has accomplished elaboration of design engineering documents for entire development of the MBIR reactor including its test and support facilities which enable main production activities.

Consideration was given to the possible use of existing infrastructure, unique operating experience and human resources of RIAR JSC at the stage of Project elaboration.

The MBIR reactor construction at the RIAR site will make it possible to achieve a number of targets:

- To preserve and expand experimental capabilities across the globe to support the development of innovation-driven nuclear energy technologies with the focus on new-generation nuclear power plants even though operating fast reactor BOR-60 is to be decommissioned.
- To provide nuclear power industry with experimental capabilities and R&D instruments essential for work under projects in support of innovative and evolutionary technologies.

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Thank you for your attention!

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