INTERNATIONAL PROJECT ON MBIR REACTOR AS AN INSTRUMENT FOR JUSTIFICATION OF INNOVATIVE NUCLEAR POWER TECHNOLOGIES

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Project Director
ROSATOM
MBIR reactor

MBIR – multipurpose fast neutron research reactor, currently under construction at the RIAR site in Dimitrovgrad. Unique reactor characteristics will be best suited for the materials testing, fuel research, structural materials and coolants studies. MBIR is meant to become the world leader among the high-flux research reactors and provide the nuclear industry with the modern and technologically superb research infrastructure for the upcoming 50 years.

CONSORTIUM IRC MBIR

International Research Center based on MBIR reactor – will become a global international platform for nuclear physics research to justify the development of the two-component nuclear energy.
Yuri Olenin, Deputy Director for Science and Strategy of ROSATOM Yuri Olenin was appointed to lead the implementation of International Research Center based on MBIR reactor.

**Project Composition**

- Poly-Functional Radiochemical Complex (R&D Complex) was incorporated into MBIR project and now available to IRC MBIR Consortium members.
- Consortium members can conduct advanced research in spent nuclear fuel reprocessing, radioactive waste management and closed nuclear fuel cycle straight away.
- Consortium members may have access to BOR-60 and start implementing their research program before the MBIR commissioning.

**Project Schedule**

- In accordance with the Russian Federal Budget Funding Program and the addition of the R&D Complex to the Consortium the schedule for project implementation was set to 2028.
IRC MBIR Consortium members will have a unique opportunity to test the reprocessing equipment and processes along side the fast reactor, which will allow to perform MA burning, multiple cycles of fuel reprocessing, etc.

**PURPOSE AND OBJECTIVES OF THE MBIR REACTOR PROJECT**

**Fuels studies for different compositions, types and burn up rates**

**Structural materials studies for Generation 4 technologies and life-time extension**

**CNCF design, RAW and SNF handling, technologies for multicycle fuel manufacturing**

**R&D activities in independent loop channels – modelling of the FE behavior in the core with different coolants**

**Testing of new equipment and engineering design configurations**

**Safety studies**

**Isotopes production (Lu-177, Cf-252, Co-60, Gd-109:153, Sr-85:89, I-125, Xe-127) and other activities – NAA, silicon doping, NCT**

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### Advanced low-absorbing & corrosion-resistant materials
- Refractory materials
- High-dose irradiation (160÷200 dpa) of new advanced materials

### MOX Fuel burnup
- 17-20%
- Mixed nitride uranium - plutonium fuel burnup 8-12%
- MOX/Nitride/Metal with m.a.

### Metal Fuel
- Thorium based fuel

### Systems of passive protection of the reactor
- Behavior of FEs under transient conditions, including abnormal ones
- Reactor equipment under transient conditions
The draft of the Research Program prepared by Russian scientists is uploaded at http://mbir-rosatom.ru/

If Consortium member is interested in one of the proposed research activities we can together develop a more detailed joined program for more members to join and to promote it within the international organizations for additional funding.

- Research into advanced fuel materials performance
- Research into new and modified liquid metal coolants
- Testing of advanced fuel element materials in transient, power cycling and emergency conditions
- Testing of advanced structural materials
- Testing of absorbing, moderating and composite materials for innovative nuclear systems
- Life tests of new equipment types for innovative nuclear systems
- Conducting of reactor physics, materials, thermal hydraulics and other research for computer code verification
- Applied experimental work, using reactor radiation
POTENTIAL TO UTILIZE MBIR FOR NATIONAL R&D PROGRAMS

Program Goals

Execution of the complex reactor based R&D programs for justification of the innovative materials and structural elements of the core for the Generation 4 reactor technologies, including thorium cycle research.

MBIR provides a wide rage of the R&D experiments for the sodium cooled reactors – starting from the steels irradiation with the possibility to reach very high fluence and extending to research on various fuel compositions and types (nitride, MOX, metal, etc.) in addition to experiments in transient and abnormal conditions in the independent sodium loop channel.

Research on the thorium fuel cycle – demonstration of the U-233 breeding in the blanket and its extraction in R&D complex. In case of the existing interest in such experiments it is possible to start them before the MBIR commissioning on BOR-60 and continue on the existing RIAR’s radiochemical facility.

Unique opportunity to test other coolants and material in the independent loop channels (for example, Pb-Bi or molten salt).
IRC MBIR CONSORTIUM MEMBERS CAN START THEIR R&D PROGRAMS ON BOR-60 BEFORE MBIR COMMISSIONING

- It will be possible to select a BOR-60 cell with approximately the same parameters as in MBIR
- The conducted researches confirms possibility to continue BOR-60 irradiation in MBIR
- RIAR has a large experience in transferring samples from one BOR-60 cell into another and continuing irradiation of the samples that were previously irradiated in other reactors.

Currently Research start in BOR-60

From 2029 Continuation of R&D in MBIR reactor
MBIR REACTOR DESIGN FEATURES

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal thermal power, MW</td>
<td>150</td>
</tr>
<tr>
<td>Nominal electric power, MW</td>
<td>55</td>
</tr>
<tr>
<td>Max / average neutron flux density in the core, sm⁻²s⁻¹</td>
<td>5.3 × 10¹⁵ / 3.1 × 10¹⁵</td>
</tr>
<tr>
<td>Fuel</td>
<td>MOX</td>
</tr>
<tr>
<td>Reactor fuel campaigns, not less than, days</td>
<td>100</td>
</tr>
<tr>
<td>Safety systems</td>
<td>Active/Hybrid</td>
</tr>
<tr>
<td>Number of safety systems</td>
<td>2</td>
</tr>
<tr>
<td>Reactor configuration</td>
<td>Loop-type</td>
</tr>
<tr>
<td>Number of loops for heat transfer</td>
<td>2</td>
</tr>
<tr>
<td>Number of heat removal circuits</td>
<td>3</td>
</tr>
<tr>
<td>Coolant Flow</td>
<td>Sodium / Water-steam</td>
</tr>
<tr>
<td>Coolant: I and II circuits / III circuit</td>
<td>до 0,6</td>
</tr>
<tr>
<td>Pressure in the I circuit, MPa</td>
<td>330-512</td>
</tr>
<tr>
<td>Coolant temperature of the I circuit, °C</td>
<td>0,65</td>
</tr>
<tr>
<td>Capacity utilization coefficient</td>
<td>50</td>
</tr>
<tr>
<td>Design lifetime, years</td>
<td>2028</td>
</tr>
<tr>
<td>Commissioning, year</td>
<td>Combination of the internal and external experimental facilities</td>
</tr>
</tbody>
</table>
Neutron Flux is shown with the coefficient $10^{15}$ $\text{sm}^2\text{s}^{-1}$
# EXPERIMENTAL CAPABILITIES OF MBIR

## EXPERIMENTAL DEVICES
- Positions for the material testing assemblies and isotopes productions
- Positions for the material testing assemblies and isotopes productions
- Instrumented irradiation test rigs (ampule channels)
- Independent loop channels with different coolants (Na, Pb, Pb-Bi, gas, molten salt)
- Horizontal Experimental Channel (HEC)
- Vertical Experimental Channel (VEC)

## LOCATION

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>NUMBER OF TRS</th>
<th>Size, mm</th>
<th>NEUTRON FLUX IN CELL, SM².S⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>Up to 14</td>
<td>One regular cell width across flats – 72,2</td>
<td>Max – 5,0 · 10¹⁵ Average – 3,1 · 10¹⁵</td>
</tr>
<tr>
<td>Core, blanket</td>
<td></td>
<td>Limited by blanket size</td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>Up to 3</td>
<td>One regular cell width across flats – 72,2</td>
<td>(3,2÷4,0) · 10¹⁵</td>
</tr>
<tr>
<td>Core central channel, blanket</td>
<td>5 Up to 3 simultaneously</td>
<td>Seven regular cells Ø 100</td>
<td>5,0 · 10¹⁵ 1÷2 · 10¹⁵</td>
</tr>
<tr>
<td>Outside the reactor vessel</td>
<td>6</td>
<td>200</td>
<td>0,5 · 10¹⁴</td>
</tr>
<tr>
<td>Outside the reactor vessel</td>
<td>Up to 8</td>
<td>~ 350</td>
<td>0,5 · 10¹⁴</td>
</tr>
<tr>
<td>PARAMETER / LOOP NAME</td>
<td>LCh-Na</td>
<td>LCh-Pb</td>
<td>LCh-Pb-Bi</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------</td>
<td>----------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Coolant</td>
<td>Sodium</td>
<td>Lead</td>
<td>Lead-bismuth alloy</td>
</tr>
<tr>
<td>Neutron fluence in LCh, cm$^{-2}$-s$^{-1}$</td>
<td>$\geq 3 \cdot 10^{15}$</td>
<td>$2 \cdot 10^{15}$</td>
<td>$(2\pm3) \cdot 10^{15}$</td>
</tr>
<tr>
<td>Power, MW</td>
<td>Up to 1.0</td>
<td>$\geq 0.3$</td>
<td>Up to 0.8</td>
</tr>
<tr>
<td>External diameter, mm</td>
<td>$\geq 190$</td>
<td>$\geq 190$</td>
<td>$\geq 190$</td>
</tr>
<tr>
<td>Fuel length</td>
<td>MBIR core height</td>
<td>MBIR core height</td>
<td>MBIR core height</td>
</tr>
<tr>
<td>$T_{in}/T_{out}$ of working fluid, °C</td>
<td>320/550</td>
<td>Up to 350/ up to 750</td>
<td>Up to 350/ up to 500</td>
</tr>
</tbody>
</table>
POLYFUNCTIONAL RADIOCHEMICAL COMPLEX (R&D COMPLEX) - NEXT GENERATION NUCLEAR LAB

Full lifecycle research – from FA to new fuel and RAW treatment

Real FR SNF - up to 600 kg SNF per year

- any FA existing and planned (up to 4 m length)
- any composition (oxide, metal, other)
- any burnup and cooling time (up to 7 kW residue heat allowed per FA)

Full scale demonstration provides for all kinds of RAW – decrease implementation risk

All RAW treatment can be done by R&D Complex

Widest experimental range

- from natural U – to 6-month cooling SNF
- any actinides (Pu, Np, Am, Cm)
- from test-tube – to real prototype
- from several gram – to full-scale demonstration (1 FA at once, up to 127 kg SNF)
- from bench-top to heavy hot cell (1.3 m concrete wall, 15 kg SNF at operation)

15-years long experiment with matrix (glass, ceramic, other) with real RAW allowed
FINANCING STATUS OF MBIR AND R&D COMPLEX PROJECTS

**MBIR Reactor**

Russian government has decided to increase the share in MBIR CAPEX and include IRC MBIR into Russian Federal Budget Funding Program. The State share will amount to 71.7 bln Russian rubles (~1 bln USD)

- **Federal Budget** 62%
- **International users** 16%
- **Bank Loan** 18%
- **Rosatom** 2%
- **Russian investors** 2%

**R&D Complex**

R&D Complex has all the CAPEX financing covered by Federal Budget of Russian Federation and Rosatom

- **Federal Budget** 90%
- **Rosatom** 10%
- **Bank Loan** 0.2 bln $
ROSATOM calls for international cooperation & research partnership based on MBIR reactor

International experience demonstrates that future breakthrough R&D requires powerful research reactors, which leads to very high cost of such research reactors

50% of MBIR reactor resource is intended for the Russian national research program for new reactor technologies research and studies on increase of nuclear industry efficiency

50% of MBIR reactor resource can be used by international partners by participating in IRC MBIR Consortium

Similar or comparable research reactors currently do not exist

- Operating the reactor
- Liabilities, Operation & Maintenance
- R&D program execution
- Laboratory assist

- R&D program administration
- Joint activities management
- Managing of joint financing
- Development and maintenance of the research infrastructure
- Formation of the reactor research market and promotion of the advanced Generation 4 technologies and CNCF
CONSORTIUM IRC MBIR MISSION

- Broad international scientific platform for solving current problems & topical issues in the field of innovative nuclear technologies on the basis of the MBIR and R&D complex
- Full cycle of high-tech knowledge-based services: pre-, under- and post-irradiation research of nuclear materials and elements of active zones of prospective nuclear reactors

CONSORTIUM IRC MBIR OBJECTIVES

- Chance to entry in free with subsequent compensation of costs through the implementation of joint scientific programs
- Development of the experimental and rig base for the implementation of international projects and multilateral research programs
- Market formation and promotion of promising technologies for Gen4 and close nuclear fuel cycle
- Best practices and examples of engineering culture in the field of planning, conducting and supporting experiments
- Creation of new demand outlets for promoting the developments and competencies of the scientific platform to the world markets
- Global center of competence for fast reactors tech under the aegis of the OECD NEA and IAEA
- Broad scientific collaboration with the participation of the best international experts
CONSORTIUM MANAGEMENT STRUCTURE AND TYPES OF PARTICIPATION

- There will be different forms of participation and conditions based on the access to the core or lateral blanket and participation in the financing of the reactor construction. The general research program, including the distribution of participants’ resources and the formation of multilateral programs, will be formed by the Advisory Council, which will include representatives of the founding members of the IRC, permanent participants of multilateral programs, representatives of the operating organization and independent experts representing leading scientific institutions and industry-specific regional and international organizations.

- The consortium agreement defines the relationship between the members and secures a share in the reactor resource (neutron flux), depending on the member’s contribution amount. Associate and main members have to join the Consortium by signing the Consortium Agreement and accept its rules in order to conclude an irradiation services contract. IRC MBIR Consortium Leader is responsible for financing the difference between the cost of the reactor and the raised funding from the members of the Consortium, federal budget and ROSATOM.
KEY REASONS TO JOIN IRC MBIR CONSORTIUM

Reactor complex MBIR is a unique tool for the technologies of the future and also for the experimental studies for improving the technologies of the present.

The Main Members will have the opportunity to define the configuration of the reactor core, prioritize the research equipment (independent loop channels) and chose the cells in the core which suit best its R&D goals.

Merging financial and scientific resources guarantees the best price per quality ratio vs the national research centers and ensures savings on national research infrastructure.

Joining the Consortium as a Main Member at the construction stage guarantees a significant discount on the commercial price of the MBIR reactor resource.

There are no restrictions for the Main Members to further cell the MBIR reactor resource to other users.

Establishment of the wide scientific platform with the participation of the leading Russian and international experts.

Opportunity for International partners to ensure the continuity of their R&D (in case of absence or temporal shut down of their own research reactors) and additional experimental possibilities and reactor resource for justifying strategic decisions on development of the national nuclear research programs.

RIAR - the operator with 60-years of research reactor managing experience and on-site supporting facilities guaranty safe and due performance of the reactor and highest quality of experiments execution.
ROADMAP TO JOIN IRC MBIR

STEP 1
Letter of Intent with research program directions

STEP 2
To sign a Memorandum of Understanding & non-disclosure agreement
To decide on your scientific program
To select representatives to Consortium management bodies

STEP 3
To sign the terms of participation
To conclude a consortium Agreement
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APPENDIX
**EXPERIMENTAL CAPABILITIES – MATERIALS TEST RIG (MTR)**

<table>
<thead>
<tr>
<th>Value</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.2</td>
<td>Width across flats, mm</td>
</tr>
<tr>
<td>2700.0</td>
<td>Height, mm</td>
</tr>
<tr>
<td>2280.0</td>
<td>MTR usable volume, cm³</td>
</tr>
<tr>
<td>14</td>
<td>Number of MTR (core)</td>
</tr>
<tr>
<td>No more than 36</td>
<td>Number of MTR (1st circle of blanket)</td>
</tr>
<tr>
<td>20/24</td>
<td>Dose rate in the core, dpa/year*</td>
</tr>
<tr>
<td>14/17</td>
<td>Dose rate (1st circle of blanket), dpa/year*</td>
</tr>
<tr>
<td>1.5×10²³</td>
<td>Maximal neutron fluence, (En &gt; 0.1 MeV), cm⁻²</td>
</tr>
</tbody>
</table>

* provided that the MBIR capacity utilization factor is 0.65

The design engineering of materials test assembly (MTA) is performed based on the technical requirements specified by the Customer to fulfill irradiation test objectives.

There are four (4) 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).

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.

Inner duct

MTA

Specimens under irradiation

Shroud

The design engineering of materials test assembly (MTA) is performed based on the technical requirements specified by the Customer to fulfill irradiation test objectives.
**EXPERIMENTAL CAPABILITIES— LOOP TEST FACILITY (LTF)**

<table>
<thead>
<tr>
<th>Value</th>
<th>LTF parameter*</th>
</tr>
</thead>
<tbody>
<tr>
<td>11900</td>
<td>Overall height of LTF, mm</td>
</tr>
<tr>
<td>100</td>
<td>Outer diameter of LTF (at the core level), mm</td>
</tr>
<tr>
<td>Up to 600 / Up to 900**</td>
<td>EFA coolant temperature (at the inlet/at the outlet), °C</td>
</tr>
<tr>
<td>Up to 600</td>
<td>Coolant temperature at the LTF outlet, °C</td>
</tr>
<tr>
<td>550</td>
<td>EFA fueled length, mm</td>
</tr>
<tr>
<td>Up to 2.85</td>
<td>Sodium flow rate through the EFA, kg/s</td>
</tr>
<tr>
<td>14/17</td>
<td>Sodium flow rate through main circuit of LTF, kg/s</td>
</tr>
</tbody>
</table>

* These parameters are given for sodium-cooled LTF

** Coolant boiling operating conditions.

<table>
<thead>
<tr>
<th>Value</th>
<th>FA parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>47,0</td>
<td>EFA width across flats, mm</td>
</tr>
<tr>
<td>1245</td>
<td>FR length, mm</td>
</tr>
<tr>
<td>Up to 1100</td>
<td>Power output, kW</td>
</tr>
</tbody>
</table>

** Coolant inlet to EFA

** Coolant inlet

** Coolant inlet at sodium cooler

** Coolant outlet at sodium cooler

** Coolant outlet

** EFA

** Removable section of LTF/a

** Core trap
**EXPERIMENTAL CAPABILITIES– Pb LOOP TEST FACILITY (LTF)**

<table>
<thead>
<tr>
<th>Value</th>
<th>LTF parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coolant</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Lead</strong></td>
<td></td>
</tr>
<tr>
<td>650</td>
<td>Max temperature of the fuel element cladding, °C</td>
</tr>
<tr>
<td>Up to 420 /</td>
<td><strong>EFA average coolant temperature</strong> (at the inlet/at the outlet), °C</td>
</tr>
<tr>
<td>Up to 535</td>
<td></td>
</tr>
<tr>
<td>Up to 420</td>
<td>Linear heat flux density on EFA fuel elements, W/cm</td>
</tr>
<tr>
<td>Up to 500</td>
<td>Output power flow, kW</td>
</tr>
<tr>
<td>Up to 35.0</td>
<td>Pb flow rate, kg/s</td>
</tr>
<tr>
<td>3,5</td>
<td>Max neutron flux density at main loop of the core level</td>
</tr>
<tr>
<td>350</td>
<td>Air temperature at the inlet to air heat exchanger of Pb LTF, °C</td>
</tr>
<tr>
<td><strong>Forced</strong></td>
<td>Circulation of the cooling circuit</td>
</tr>
<tr>
<td>Up to 20</td>
<td>Power of electric heaters, kW</td>
</tr>
</tbody>
</table>

- **Forced**

- **Up to 20**
### EXPERIMENTAL CAPABILITIES – IRRADIATION TEST RIG (TR)

**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 °C);
- 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.

<table>
<thead>
<tr>
<th>Parameter of Pb-Bi TR</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall height of LTF, mm</td>
<td>10890</td>
</tr>
<tr>
<td>Width across flats, mm</td>
<td>72.2</td>
</tr>
<tr>
<td>Outer / inner diameter of cylinder-shaped end cap at the level of the core, mm</td>
<td>68.0 / 65.0</td>
</tr>
<tr>
<td>Coolant flow rate through the Pb-Bi chamber, kg/s</td>
<td>Up to 6.0</td>
</tr>
<tr>
<td>Maximum coolant temperature (in the self-supporting Pb-Bi chamber), °C</td>
<td>390±10</td>
</tr>
<tr>
<td>Outer/inner diameter of FA, mm</td>
<td>45.0 / 41.0</td>
</tr>
</tbody>
</table>
EXPERIMENTAL CAPABILITIES – HTC AND VTC

HORIZONTAL TEST CHANNELS (HTC)
There are 6 horizontal test channels for the following activities:
- Neutron radiography
- Nuclear physics experiments
- Medical purposes

Neutron radiography cell
7.1 m (length) × 4.1 m (width) × 2.9 m (height)

VERTICAL TEST CHANNELS (VTC)
There are 8 vertical test channels for the following activities:
- Silicon doping (6 VTCs.)
- Neutron-activation analysis (2 VTCs)

Silicon doping facility