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RIAR Capabilities and Support of Research and Development of Generation IV Innovative Reactors

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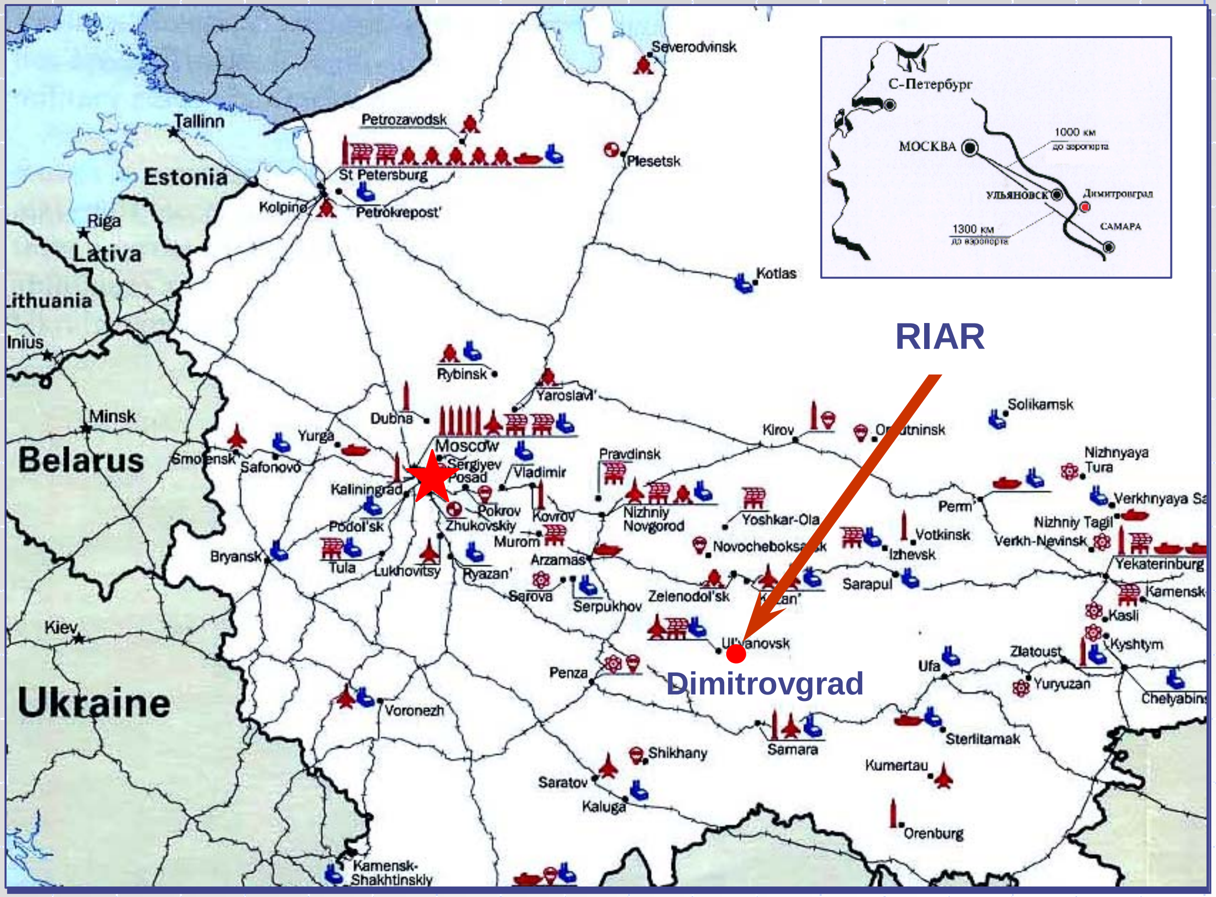
RIAR

Location of the RIAR

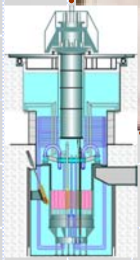
[Dimitrovgrad](#) is situated in the Middle Volga region. The nearest large cities are Ulyanovsk (100 km) and Samara (250 km). It takes 2 hours to get to the airport in Ulyanovsk and 1.5 hours to the airport Kurumoch (Samara) by bus. The river port is in Ulyanovsk. The railway station is in Dimitrovgrad.



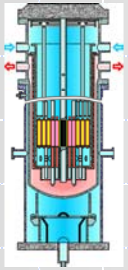
RIAR Experimental Facilities

BOR-60 Fast reactor

Fuel Cycle Facility



VK-50 (BWR) Reactor

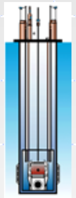


MIR Test reactor

SM High Flux

RBT-6 test reactor

RBT-10/1



RBT-10/2

Post Irradiation Examination Complex (Hot lab)

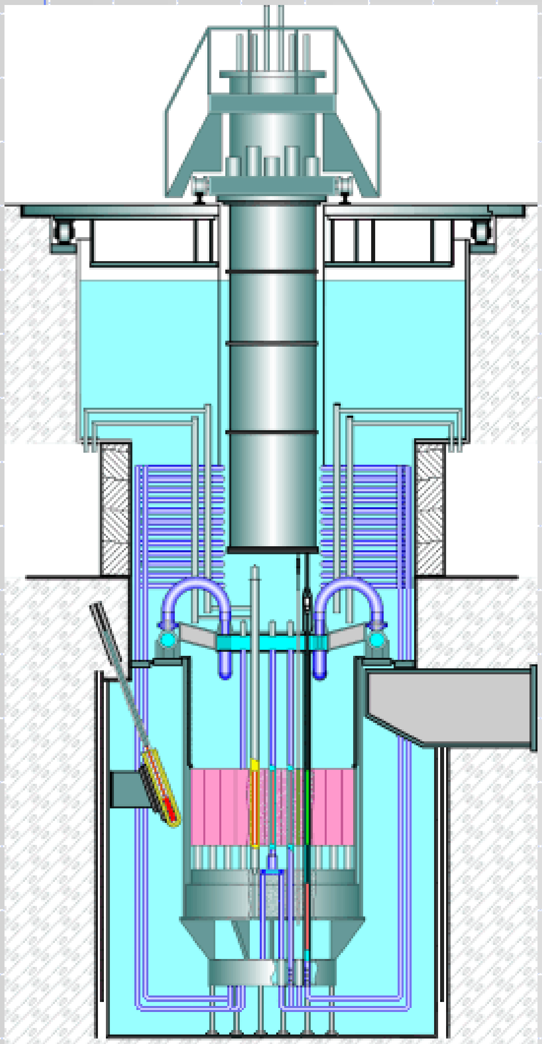
Research Institute of Atomic Reactors (RIAR)

- 7 operated test reactors, included
  - ✓ Sodium cooling fast reactor BOR-60
  - ✓ High flux reactor SM-3
  - ✓ BWR industrial test reactor VK-50
  - ✓ Loop type material science reactor MIR
  - ✓ Pool type reactors RBT-6, RBT-10/1 and RBT-10/2
- The biggest in Europe Material Science Complex for full cycle of PIE for all type of Russian industrial NPP's FAs
- Radiochemical Complex for production of different type of isotopes including market scale batch of Am, Cm, Cf
- Radiochemical Complex for advanced fuel cycle development based of pyrochemical technology of fuel production and reprocessing and vibro-pack technology of fuel pins production
- Technology Complex of Radioactive Wastes Treatment included the unique underground polygon of wastes dipper storage
- 5200 peoples staff

The research reactor MIR is a channel type reactor with water coolant and beryllium moderator and reflector.

1967 **– Start of operations and beginning of loop tests of fuel rods and assemblies.**

1975 **– Reactor reconstruction, replacement of beryllium blocks.**



Thermal power	*100 MW*
Maximum density of thermal neutron flux in experimental location	$5 \cdot 10^{14}\ sm^{-2} \cdot s^{-1}$
Number of loop channels locations	*11 pcs*
Core height	*1 m*

Loop facilities	*PV-1*	*PV-2*	*PVK-1*	*PVK-2*	*PVP-1*	*PVP-2*	*PG-1*
Number of channels	2	2	2	2	1	1	1
Coolant	water	water	water, boiling water	water, boiling water	water, steam	water, steam	Helium, nitrogen
Max pressure, MPa	16.8	17.8	16.8	17.8	8.5	20	20
Max temptrature, °C	340	340	340	340	500	500	550
Flow rate, kg/h	16000	16000	14000	14000	675	1000	–
Coolant activity, Cu/kg	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	1	1

Major MIR programmes for VVER fuel tests

1994 – 2002 – long-term tests of different modifications and types of fuel rods;

1991 – 1996 – ten experiments of RAMP type with new refabricated and full-size VVER fuel rods;

1997 – 2002 – continuation of RAMP type experiments, program for experiments with "soft" pulse power change at the extended fuel burnup;

1993 – 2000 – eight experiments of LOCA type of the VVER fuel rods with dryout and overheating of fuel rods up to 600 - 1200°C;

1995 – 2004 – further irradiation of full-scale and refabricated fuel rods up to the burnup of 70 MWd/kg U and higher;

1997 – 2005 – tests of the extended burnup fuel at the transient conditions;

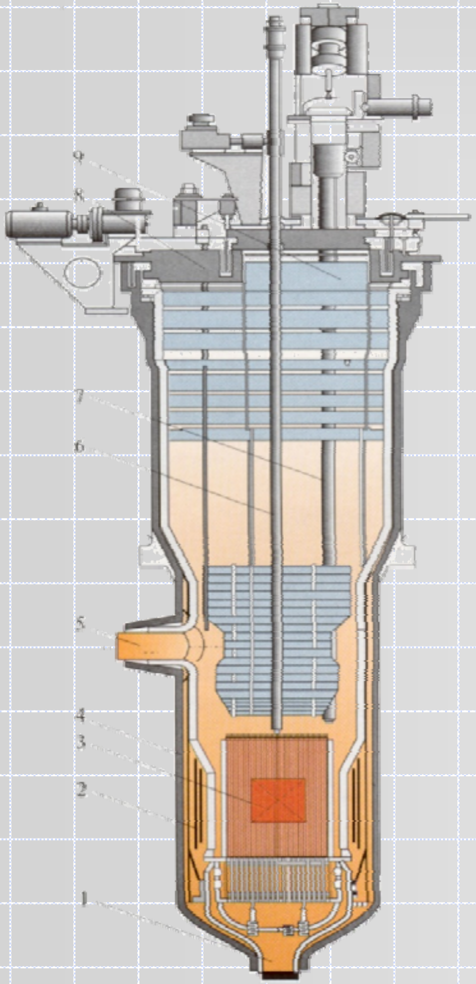
2003 – 2006 – experiments with leaking fuel rods at different burnups and at transient conditions.

2003 – 2007 – SFD (Sever Fuel Damage) type experiments with fuel rods at different burnups.

International cooperation of the MIR reactor

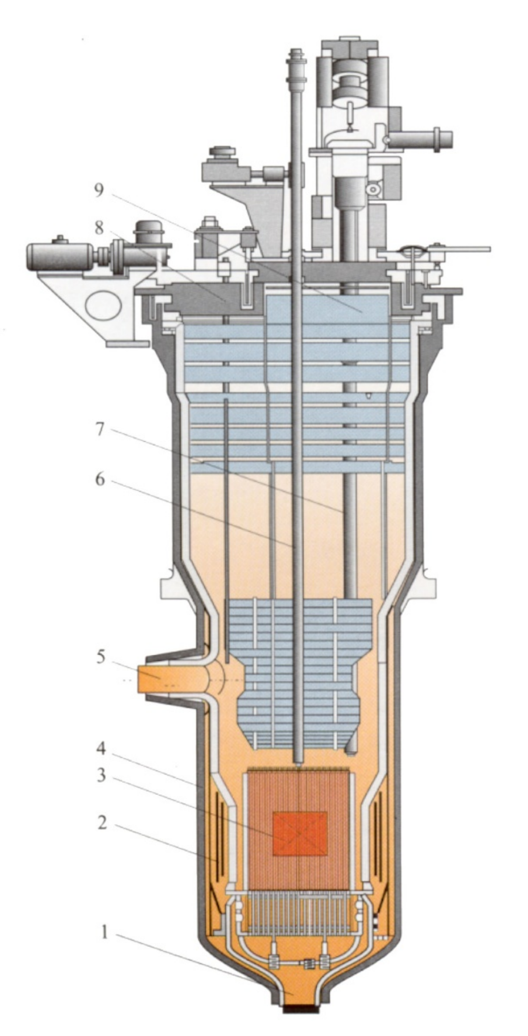
1. *Within the framework of cooperation between CEA and Minatom:* **irradiation of experimental fuel rods in MIR and OSIRIS, exchange of information about the test and PIE results.**
2. *Under contract between with BNFL:* **fuel rods fabricated from BNFL MOX fuel were tested in the high-temperature water loop of the MIR and subjected to PIE, including the fuel dissolution experiments.**
3. *Under contract with KAERI:* **PWR fuel assembly is being tested in MIR.**
4. *Under contract with CIAE:* **the fuel miniplates and the full-scale fuel assembly with low-enriched fuel underwent testing in MIR with subsequent PIE for certification of the CARR research reactor.**
5. *As a part of RERTR program:* **in cooperation between Russian organizations (VNIINM, NIKIET, IRM, NZKHR) and ANL the MIR is involved in testing of low-enriched fuel for research reactors of the Russian origin with a series of PIE.**

The experimental fast sodium liquid-metal-cooled reactor BOR-60



Research fast reactor BOR-60 is intended for testing of a variety of fuel, absorbing and structural materials that are offered for creation of advanced fast, pressurized water, gas-cooled and fusion reactors and serving for substantiation of the VVER and BN-type reactor service life extension

The experimental fast sodium liquid-metal-cooled reactor BOR-60



Reactor heat power	60 MW
Maximum neutron flux density	$3{,}7\ 10^{15}\ sm^{-2}s^{-1}$
Maximum specific power	1100 kW/l
Average core neutron energy	0,45 MeV
Fuel	UO_2, UO_2-PuO_2
^{235}U enrichment	45÷90 %
Fuel burn up rate	up to 6% per year
Neutron fluence per year	$5 \cdot 10^{22}\ sm^{-2}$
Damage dose rate	up to 25 dpa /year
Inlet temperature of coolant	310÷330°C
Outlet temperature of coolant	up to 530 °C
Microcompaign duration	up to 120 days
Reactor generates energy	~265 days per year
Cells quantity - for S/A - for absorbing rods - instrumented cells	265 156 7 3

Main investigation at the BOR-60 reactor

- **Large number fuel element and fuel assembly test in steady, transient and emergency conditions.**
- **Testing of different neutron absorbing materials.**
- **Radiation testing of structural reactor materials.**
- **Testing of electro insulation, magnetic and hard melting materials for fusion reactors.**
- **Investigations on radiation material science**
- **Investigation on radiation material science at temperature from 330 to 1000^{o}C and damage dose up to 200 dpa.**
- **Investigation on fast reactor safety.**
- **Investigation and testing of liquid metal technology: impurities and radionuclides trapping for coolant cleaning and personal dose rate decreasing, impurities control.**
- **Testing of experimental reactor equipment and diagnostic and safety systems**
- **Investigation on transmutation and incineration of long-lived radionuclides from different reactor spent fuel.**
- **Radiation alloying of silicon for radio-electronics.**
- **Generating of high active isotopes for different purposes.**

International cooperation of the BOR-60 reactor

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1. *Within the framework of contracts with EdF (France):* **the irradiation of ferritic-martensitic steel specimens and their further PIE**
2. *Within the framework of the contract with CEA (France):* **the irradiation of ferritic-martensitic steel specimens and their further post-irradiation material science examination have been conducted.**
3. *Within the framework of the contract with IMF II FZK (Germany):* **the irradiation of ferritic steel specimens and their further post-irradiation material science examination have been conducted.**
4. *Under the contract with the Chinese Institute of Atomic Energy (CIAE):* **the reactor tests of the Chinese absorbing element were performed followed by comprehensive post-irradiation examination for the CEFR research reactor.**
5. *Under the contract with JAEA (Japan):* **irradiations of fuel elements with ODS-claddings have been performed.**
6. *Within the framework of cooperation with CEA (France):* **fuel elements containing mixed uranium-plutonium nitride fuel and MOX-fuel pellets have been tested (BORA-BORA).**

SM-3 high-flux reactor

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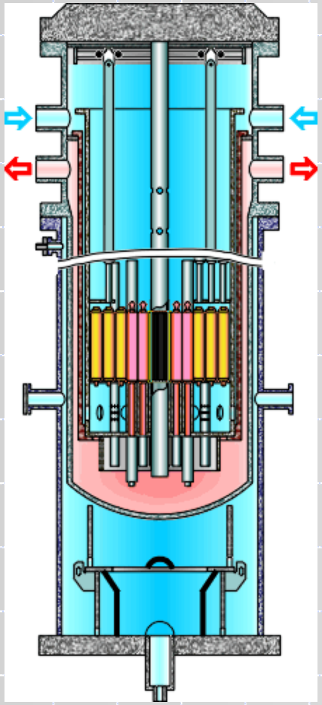
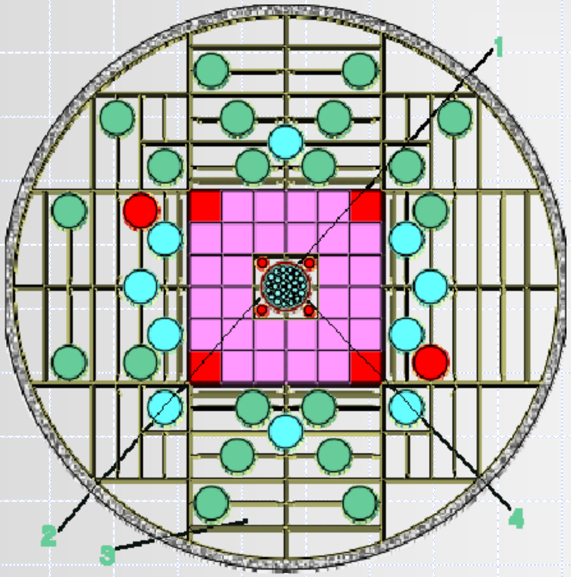


The SM reactor was put into operation in October 1961.

The SM reactor is a vessel-type water-moderated water-cooled intermediate reactor. The median fission energy is 0.1 eV.

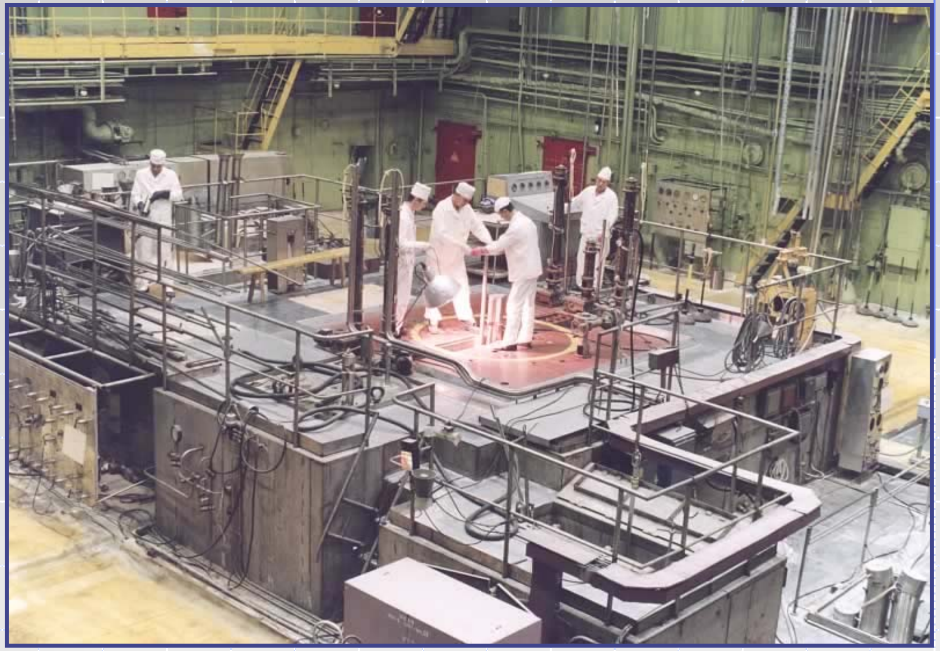
The SM reactor is unique, as it is one of the most high-flux reactors among all research reactors in the world



SM-2 reactor core cartogram

- **1**-central block of transuranium targets
- **2**-beryllium gaskets
- **3**-beryllium blocks of the reflector
- **4**-central shim rod

Facilities of the SM high-flux research reactor



- Facility for studying the mechanical properties change of materials under irradiation at different load types and temperatures (uniaxial and biaxial load, temperature up to 700 °C; medium – gaseous, water or steam-water; accuracy of strain gaging – 2-5 μm; time base – up to 10000 h).
- Facility for studying the mechanisms of fission products yield from the fuel under irradiation (temperature up to 2000 °C; analyzed nuclides – solid, gaseous and volatile; determination error of the main parameters – 15-20%; burnup fraction of the studied fuel is unlimited; capsule and loop test variants are possible).
- Capsule boiling-water devices for mass tests of structural material samples (test temperature is 200-300 °C; spread in samples temperature is no more than 2 °C; accuracy of the temperature conditions maintenance – 5 °C; determination error of neutron fluencies is no more than 15%).

Facilities of the SM high-flux research reactor

•Rig for studying corrosion of structural materials in water and water steam (temperature of samples – up to 600 °C; pressure – 2 MPa; load test of samples is possible).

•Rig for studying thermocycling of structural materials.

- Standard center of neutron measurements with a support neutron field, standard facilities for activity measurement and a set of certified maintenance monitors to determine the neutron characteristics of irradiation conditions.
- Section of neutron-activation analysis.
- Facility for certifying the radionuclide preparation samples (absolute activity by the target nuclide, composition of the activated impurity nuclides).

Complex of the RBT pool-type research reactors

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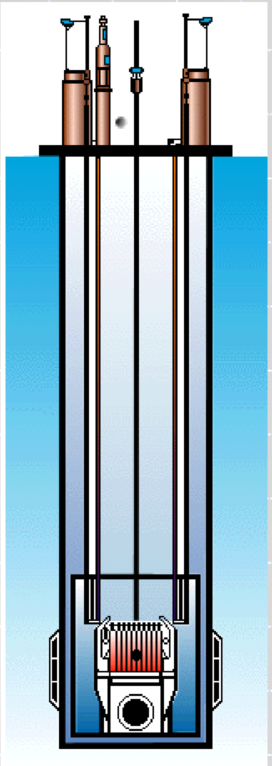
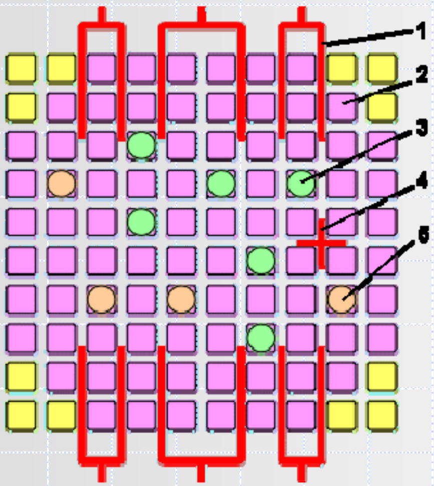


- Three RBT-type research reactors (pool-type reactor) were developed, constructed and are successfully operated in the Institute. The time of commissioning: in 1975 - РБТ-6, in 1983 - РБТ-10/1 and in 1984 - РБТ-10/2.
- The RBT type reactors are pool-type reactors, which use spent FA from the SM reactor as fuel. When designing these reactors the following was provided along with a high safety level:



RBT 10/2 reactor core cartogram

- **1** – compensating element
- **2** – working FAs
- **3** – test channels without aluminum displacer
- **4** – automatic control rods
- **5** – test channels with aluminum displacer

International Cooperation using possibilities of the RBT and SM reactors

1. *Within the cooperation between EdF (France) and Minatom (Russia):* vessel materials of power–generating reactors (PWR) were irradiated in the testing facility "Korpus" of the RBT–6 reactor followed by material science examinations.
2. *Within the cooperation with the Institute of Nuclear Research (Czech Republic):* vessel materials of light–water reactors were irradiated in the RBT–6 and LWR-15 reactors followed by post–irradiation examination and exchange of the results obtained.
3. *Thermocyclic testing of first wall and divertor mock–ups was conducted under International project ITER.* Testing of specimens of copper alloys and various types of steels is continued.

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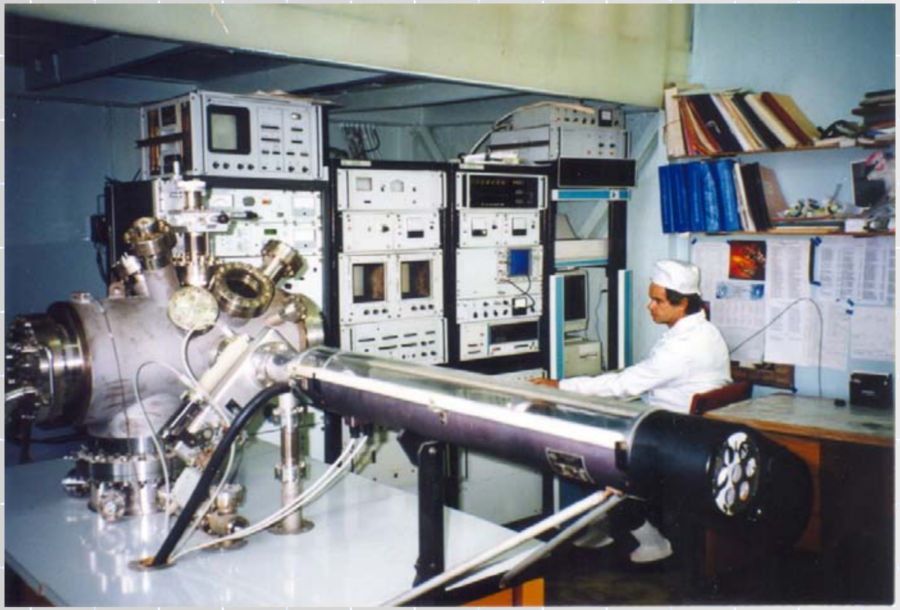
Complex for PIE



Material science examinations

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General characteristics:

- investigations in the RIAR material science complex include pre-irradiation and post-irradiation examination of any materials and nuclear fuel;
- transport operations (shipping/acceptance): fuel assemblies, control rods, NPP fuel rods can be transported in containers weighing up to 50 t with the maximum item length of 4.3 m and the total content of U and Pu up to 125 kg;
- experimental samples, including the instrumented ones, are fabricated for reirradiation.

Basic material science techniques

Examination	Brief description
Measurements:	
❖ micro hardness;	Hardness testers
❖ density and porosity;	UVA-100PA-based density gage
❖ gas content in materials;	Gas analyzer ON-900, Mass- spectrometer MI-1201
❖ thermal conductivity;	Pulse heating technique (developed by RIAR)
❖ electrical conduction	Potentiometry
Burnup determination	Gamma and mass -spectrometry
X-ray structural analysis	Microdiffractometer KED-1, remote diffractometer DARD
Thermal analysis	Differential-thermal method

Basic material science techniques

Examination	Brief description
Visual examination	Photographing, video storage (color or white-and-black), developed by RIAR
Measurement of dimensions and bending characteristics	Facility for measuring fuel rod length, dimensions and shape of the fuel assembly wrapper (developed by RIAR)
Determination of volume and gas content in fuel rod	Cladding puncturing, mass spectrometry, chromatography (developed by RIAR)
Measurement of the gap size between fuel and cladding	Cladding deformation by mechanical loading until its contact with the fuel column (developed by RIAR)
Gamma-scanning	Quantitative (developed by RIAR)
Eddy-current defectoscopy	Amplitude-phase analysis (developed by RIAR)
X-ray examination	Tomography
Optical metallography	Optical microscopes

Basic material science techniques

Examination	Brief description
Measurements:	
Dilatometry	Developed by RIAR
Scanning and Transmission Electron Microscopy	Electron microscope IEM 2000 FX; Philips FX 30 ESEM-TMP
X-ray Microspectral Analysis	Microanalyzers MAR-3, MAR-4
Laser microanalysis	Laser atomic-fluorescence analyzer LAFA-1
Auger-spectrometry	Differential scanning Auger electron spectrometer ESO-3 UM, ESO-5 UM
Ion-probe microanalysis	Secondary ion mass-spectrometer MS-7201M, MS-7202M
Measurement of mechanical characteristics	Testing machines, micro rupture machines, fatigue crack growth facilities

Hot cell facility for MOX fuel production and reprocessing and dry technology tests

Basic research on radiochemistry

Production of radionuclides for medicine and industry

Application of RIAR research reactors for radioactive isotope production

Regular production of reactor and other isotopes: P-33, Fe-55, Co-60 (high active), Ni-63, Se-75, Sr-89, I-131, Ba-133, Gd-153, W-188(Re-188), Ir-192, Np-237, Am-241, Am-243, Cm-244, Cf-252.

New technologies for production:Mo-99(Tc-99m), Sn-117m, I-125, Cs-131, Lu-177m

Production for special orders: P-32, Cr-51, Mn-54, Fe-59, Cd-109, Ag-110m, Sn-113(In-133), Sn-119m, Pu-242, Cm-248, Bk-249, Cf-249,

New Russian Sodium Fast Research Reactor – Multi-functional Fast Test Reactor (MFTR)

(Proposed location – RIAR site)

Characteristic	Value
Maximum flux Φmax, n/cm2·sec	~ $6.0 \cdot 10^{15}$
Thermal power, MWth	~ 150
Electric power, MWe	~ 50
Number of independent experimental loops (~1 MWth, sodium, heavy metal and gas coolant + salt coolants)	3 (+1 behind reactor vessel)
Driven Fuel	Vi-pack MOX, (PuN+UN)
Core height, mm	400-500
Maximum heat rate, kW/l	1100
Fuel Cycle	Full Scale Closed FC based on Pyro Processes
Test Fuel	Innovative Fuels, MA Fuels and targets
Maximum fluence in one year, n/cm2	~ $1{,}2 \cdot 10^{23}$ (up to 55dpa)
Design lifetime	50 year
RR creation time (no more than, years)	**2018**

RIAR Education and Training Centre
RIAR Information Centre

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Training center for operators of Research reactors and Fuel cycle facilities

- Experience on education personal from other Russian research reactors
- Experience on education of operational personal for CEFR (China) and from FBTR (India)

Informational (Crisis) Centre on Russian Research reactors

- Collection and analysis of information on accident and problems of RRR
- Collection and analysis of information on spent fuel and wastes from RRR

Production of unique type of fuel and radioactive isotopes:

- Joint studies with Japan, France, Korean specialists
- Some joint studies in the frame of ISTC, CRDF and other foundations

Thank you for attention!

State Scientific Center of Russian Federation “Research Institute of Atomic Reactors”,

Dimitrovgrad, 2008