Joint Stock Company “State Scientific Center – Research Institute of Atomic Reactors”

ROSATOM STATE NUCLEAR ENERGY CORPORATION

CAPABILITIES AND PROSPECTS FOR DEVELOPMENT OF JSC “SSC RIAR”

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JSC «SSC-RIAR»

NIIAR

ROSATOM STATE NUCLEAR ENERGY CORPORATION

State Scientific Center – Research Institute of Atomic Reactors

State Scientific Center – Research Institute of Atomic Reactors (SSC RIAR) is one of the largest nuclear centers in Russia hosting several research reactors, large hot material testing and radiochemical laboratories

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Background

- **The history of Research Institute of Atomic Reactors goes back to March 1956, when the USSR Government decided to construct a pilot power plant in the Melekess city, Ulyanovsk region so as to provide a technical support for the development of a wide range of atomic reactors for nuclear power engineering. In 1959, Research Institute of Atomic Reactors was established on the basis of test and experimental reactors, facilities and laboratories being under construction that time.**

Some more history

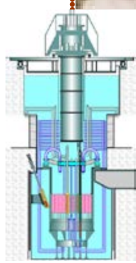
- **For the first ten years, several reactor facilities of different types were constructed at the RIAR's site. By 1986, RIAR operated material testing, radiochemical and chemical&technological research facilities. In 1994 RIAR got a status of State Scientific Center.**
- **Since the time of its establishment and till now, JSC "SSC RIAR" is one of the largest research centers in the world that carries out both fundamental and applied research in the wide range of issues related to nuclear power engineering.**

Key RIAR's activities

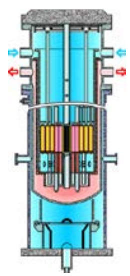
- **The unique multi-field experimental capabilities allow RIAR to carry out fundamental and applied research related to basic scientific trends of nuclear power engineering:**
- **□ Development and pilot demonstration of empowering nuclear technologies;**
- **□ Rendering of science intensive services;**
- **□ Transfer of nuclear technologies in other branches of industry, including nuclear medicine, industry and their application for solving environmental problems.**

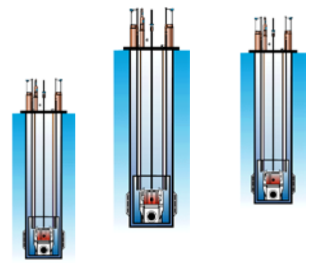
RIAR Experimental Facilities

BOR-60 Fast
reactor



VK-50 (BWR)
Reactor





RBT-10/2

MIR Test
reactor

RBT-6 test
reactor

RBT-10/1

SM High
Flux

Post Irradiation Examination
Complex (Hot lab)

RIAR's Reactor Facilities

All reactors are successfully operated and no failures were registered for the last 10 years.

The last modernization of the SM reactor was completed in 1993 and it can be operated till, at least, 2050.

The MIR M1 reactor is being successfully modernized (without shutdown) to prolong its lifetime till 2025 as minimum.

Experiments and calculations are carried out to justify the extension of the BOR-60 operation till 2015 and work is underway on to prolong its lifetime till 2020.

Characteristics of RIAR's Research Reactors

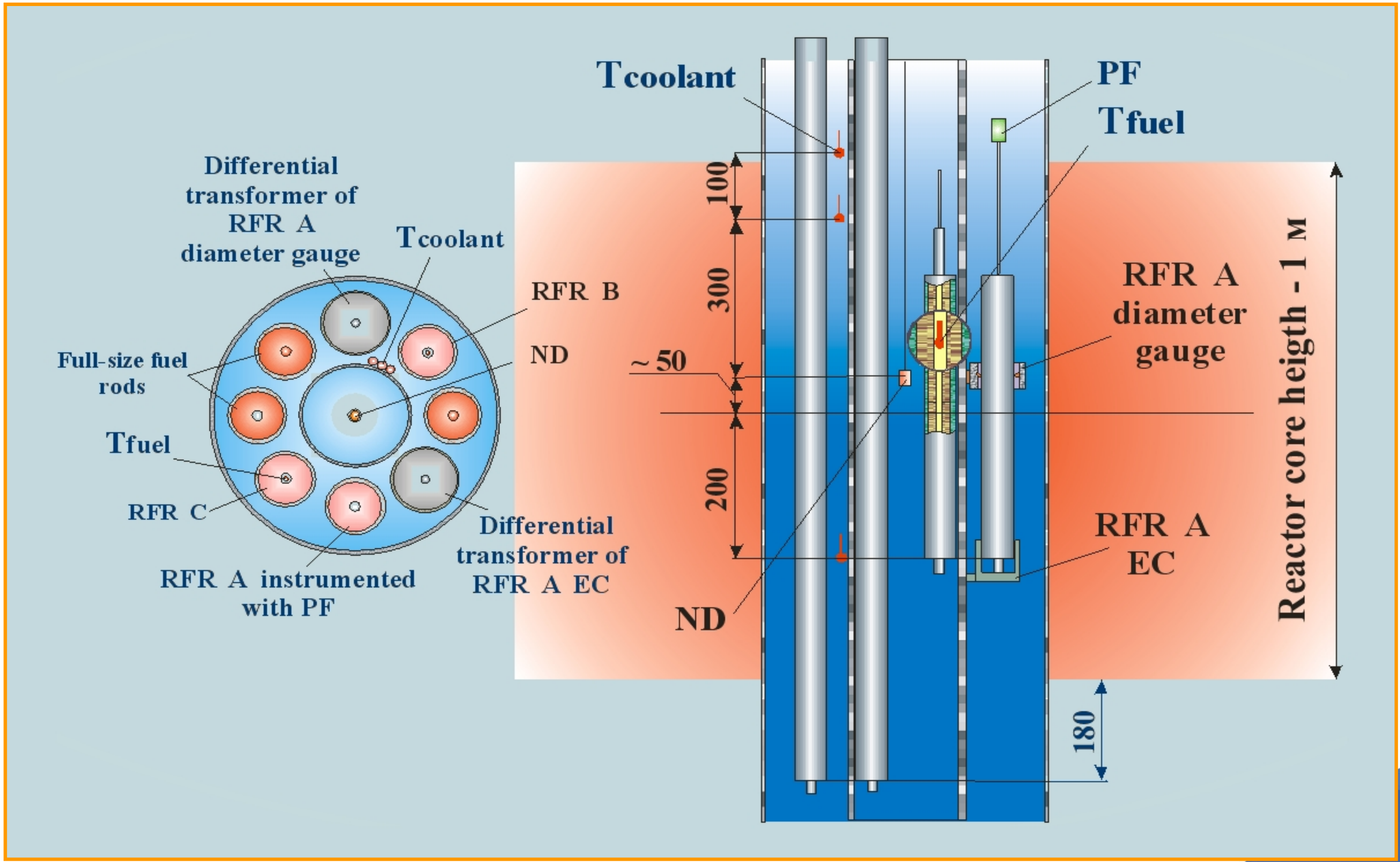
Parameters	Reactors				
	SM	MIR	BOR-60	RBT-6	RBT-10
Thermal capacity, MW	100	Up to 100	Up to 60	6	10
Max neutron flux density, $cm^{-2} \times s^{-1}$	5×10^{15}	5×10^{14}	3.7×10^{15}	1.4×10^{14}	1.5×10^{14}
Fuel	UO_2, 90% enriched in ^{235}U	UO_2 in aluminum matrix, 90% enriched in ^{235}U	MOX-vibro	SM SNF	SM SNF
Moderator	Water	Be+ water	–	Water	Water
Reflector	Be	Be	–	Water	Water + Be
Coolant	Water	Water	Na	Water	Water

Characteristics of RIAR's Research Reactors

Parameters	Reactors				
	SM	MIR	BOR-60	RBT-6	RBT-10
Coolant T, °C:					
at core inlet;	50	40	330	60	60
at core outlet;	Up to95	Up to100	530	75	75
Coolant flow rate, m^3/h	2400	2500	1100	600	650
Pressure, MPa	4.9	1.5	0.5	0.17	0.18
Coolant	Water	Water	Na	Water	Water
No. of irradiation channels (cells):					
in the core;	Up to50	11	—	8	10
in the reflector;	Up to30	—	—	3	17
in the trap	27	—	—	—	—

Fuel testing in the MIR reactor

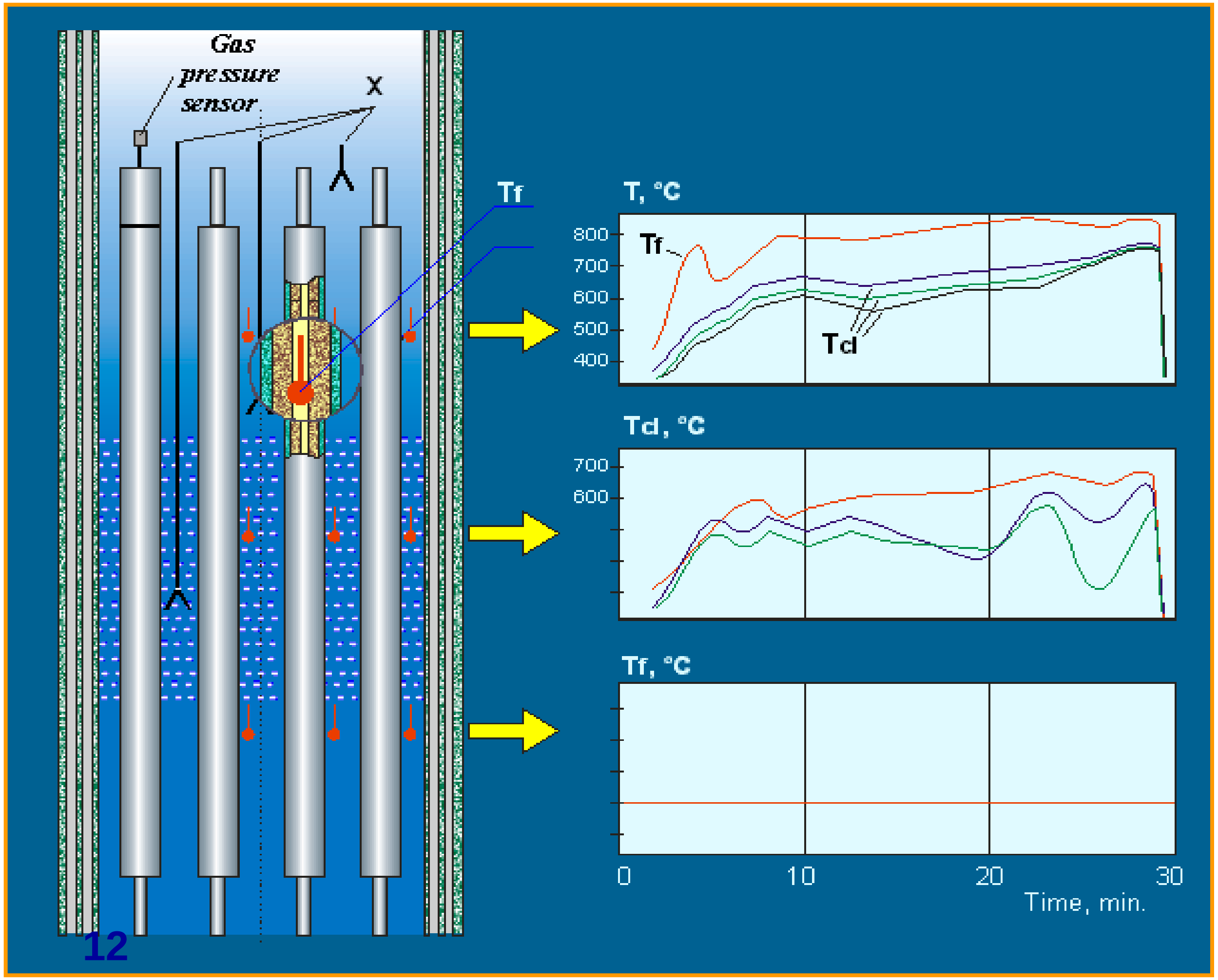
Testing under power ramping conditions



Disposition of fuel rods and sensors in the irradiation device

Fuel testing in the MIR reactor

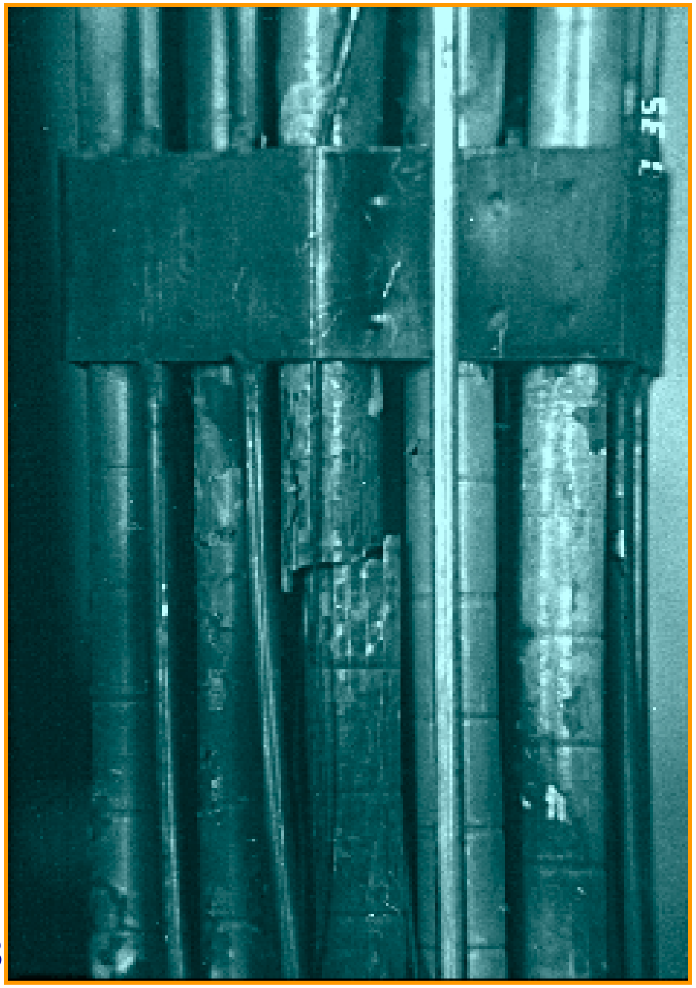
Testing under fuel rod drying, overheating and reflooding conditions (LOCA)

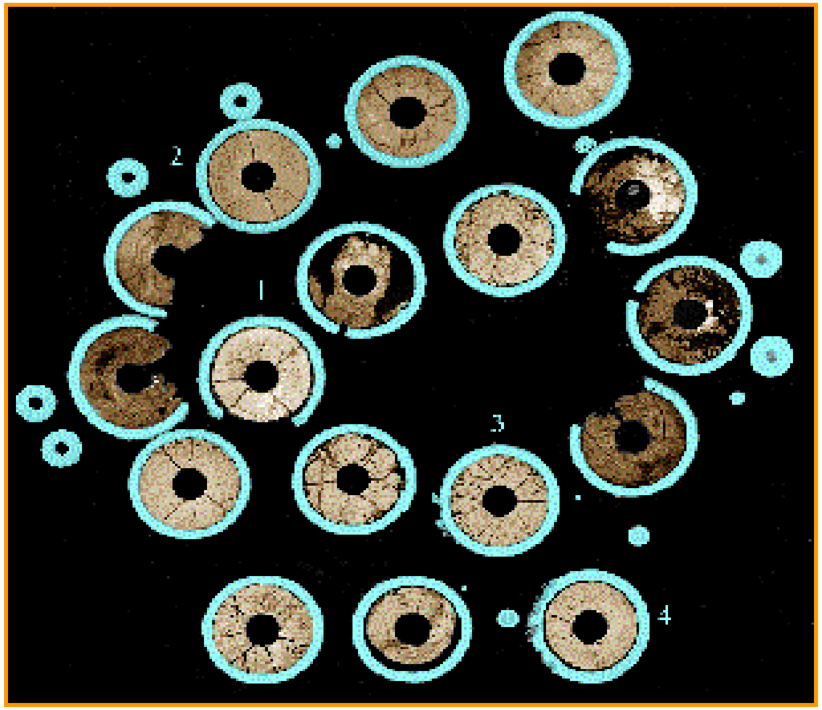


Simulation of loss of coolant and partial core dryout accident (LOCA)

Fuel testing in the MIR reactor

Testing under fuel rod drying, overheating and reflooding conditions (LOCA)

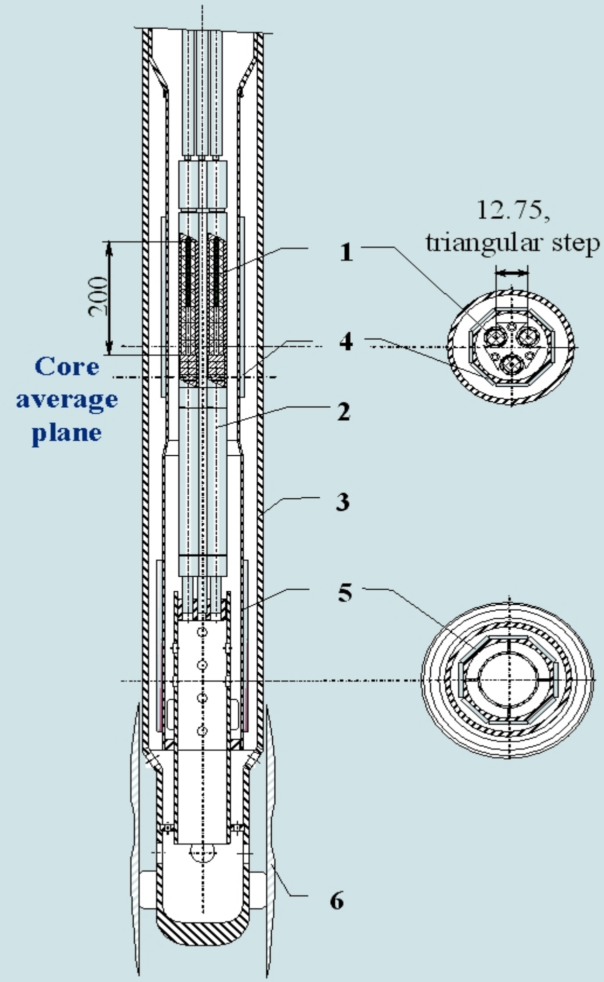


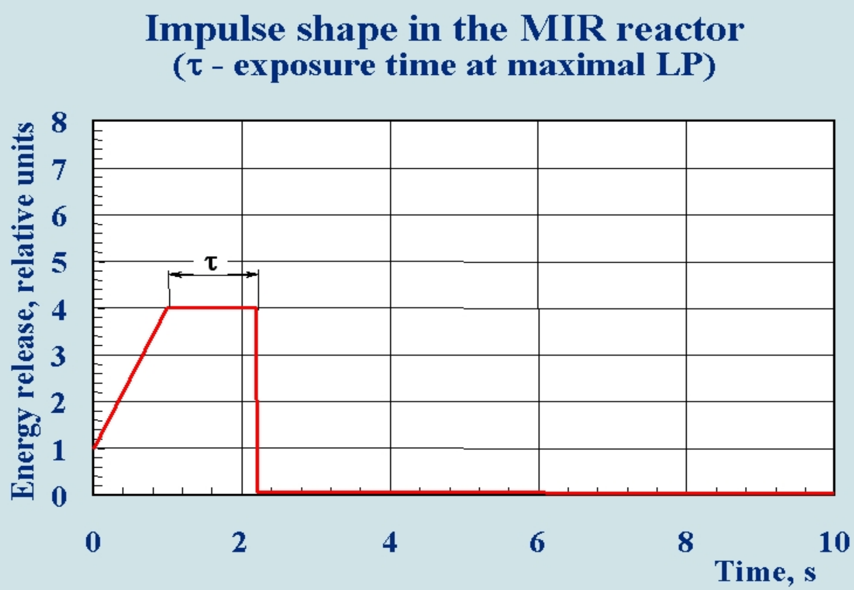


Simulation of loss of coolant and partial core dryout accident (LOCA)

Fuel testing in the MIR reactor

Testing of the high burn-up fuel rods under design-basis RIA conditions

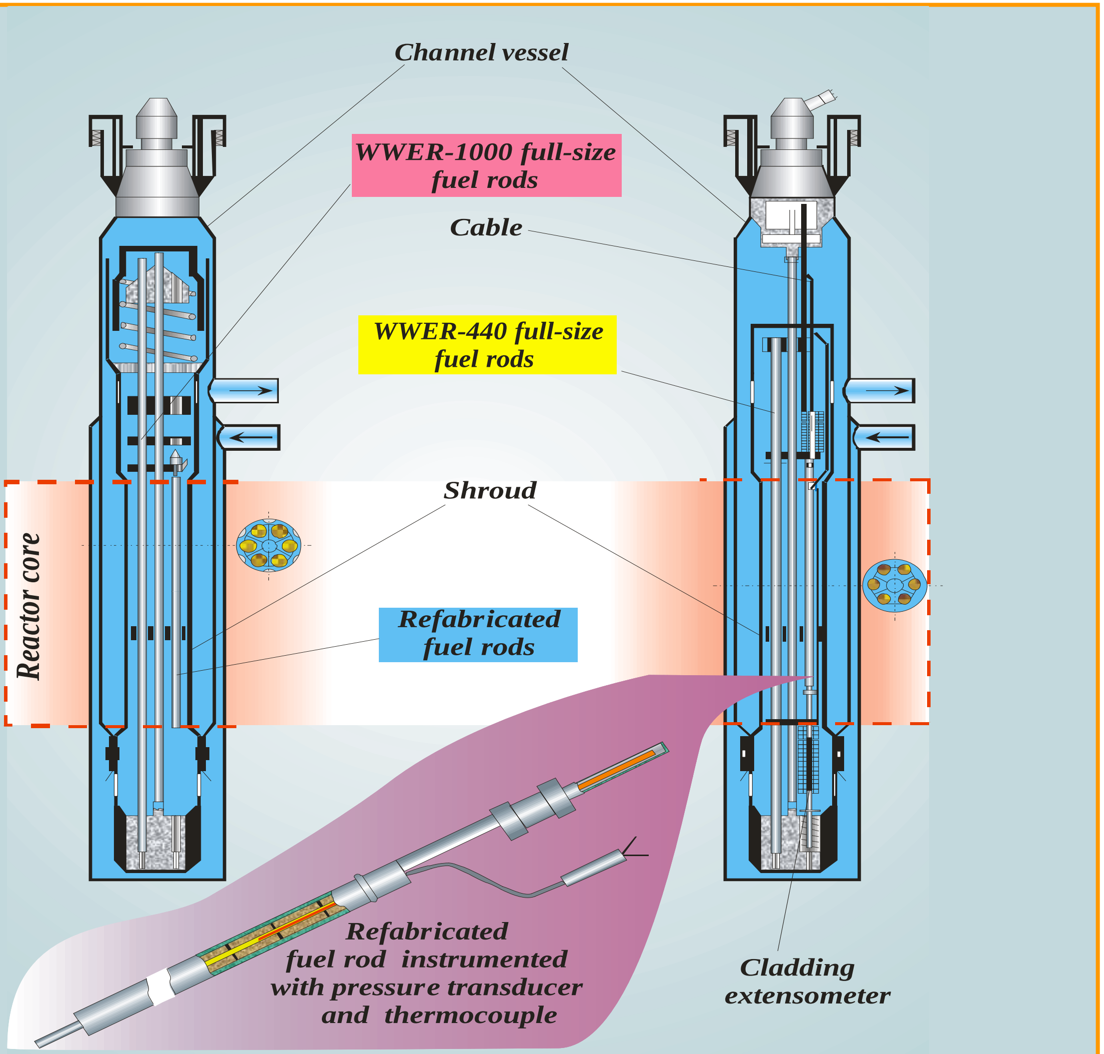




Schematic diagram of the irradiation rig designed for RIA test in the MIR reactor
1 – fuel rods, 2 - conductor pipes, 3 – shroud, 4 –upper shield, 5 –lower shield, 6 – loop channel vessel

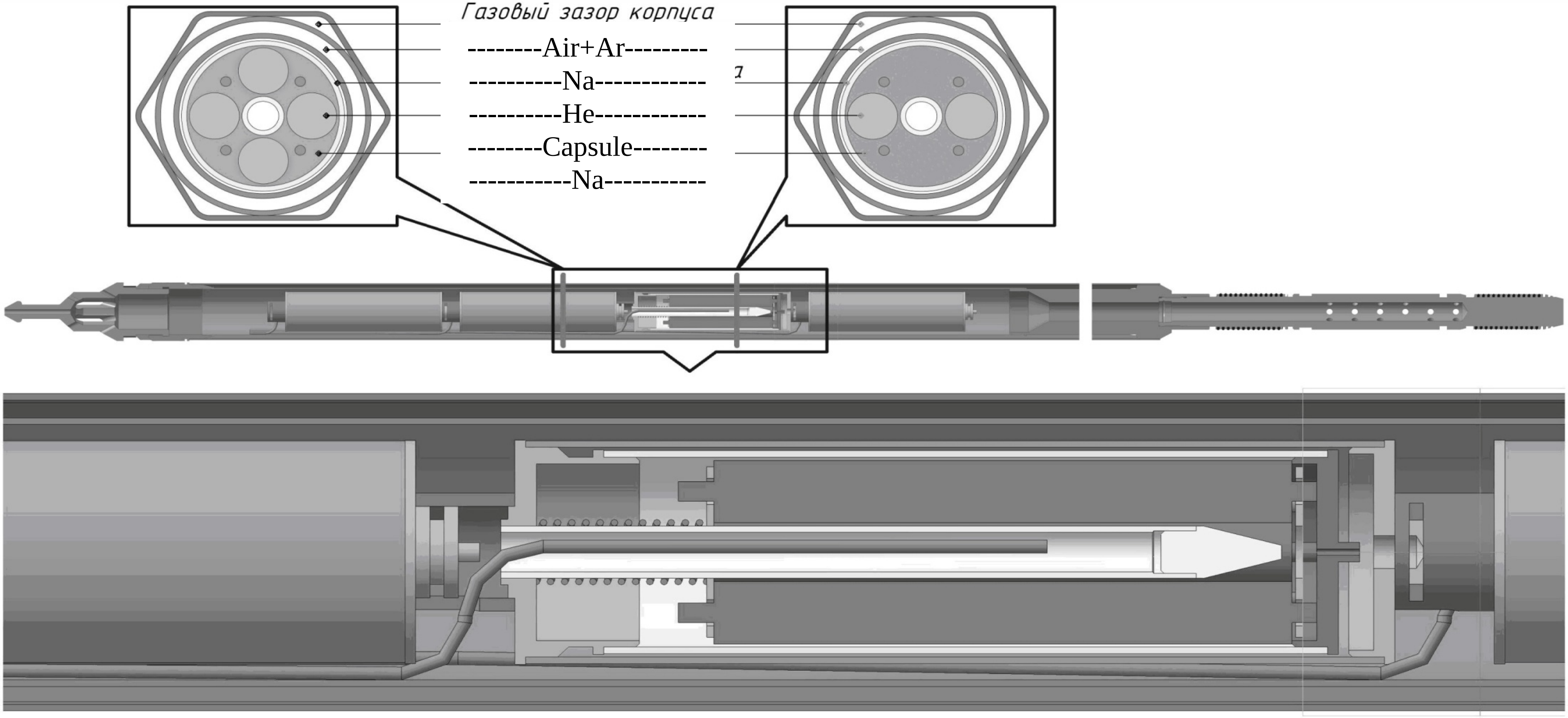
Fuel testing in the MIR reactor

Irradiation of refabricated and full-size fuel rods



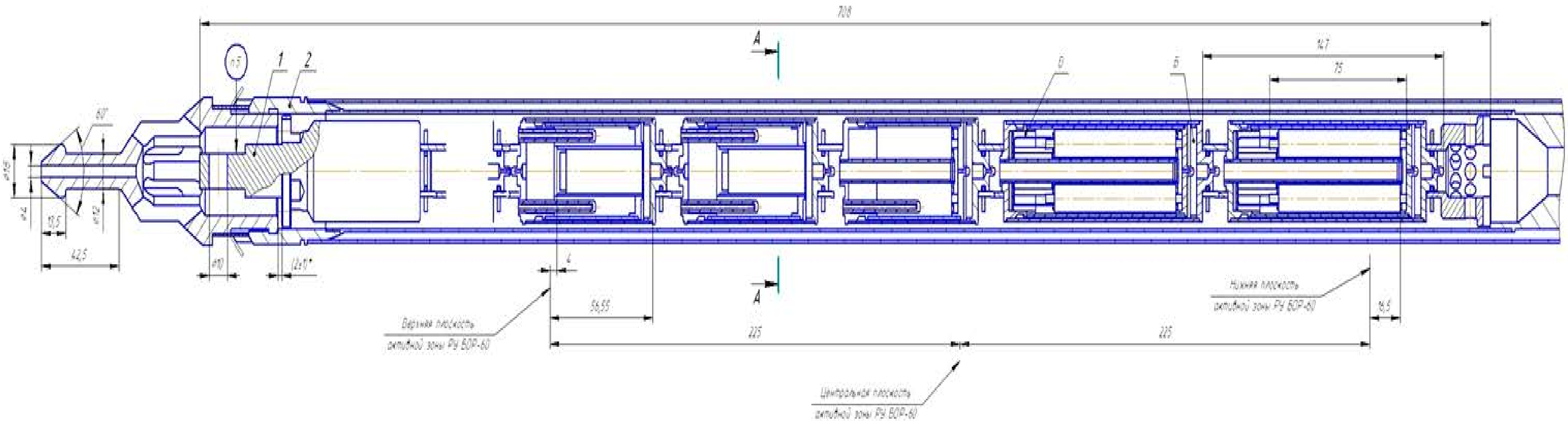
Dismountable experimental devices meant for full-size and refabricated fuel rods testing

BOR-60 irradiation rig for High-T Tests



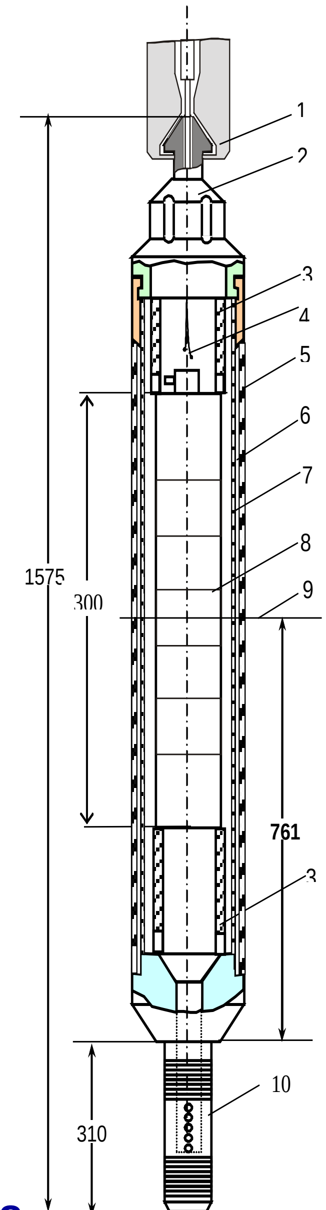
IR design in the cell D23

BOR-60



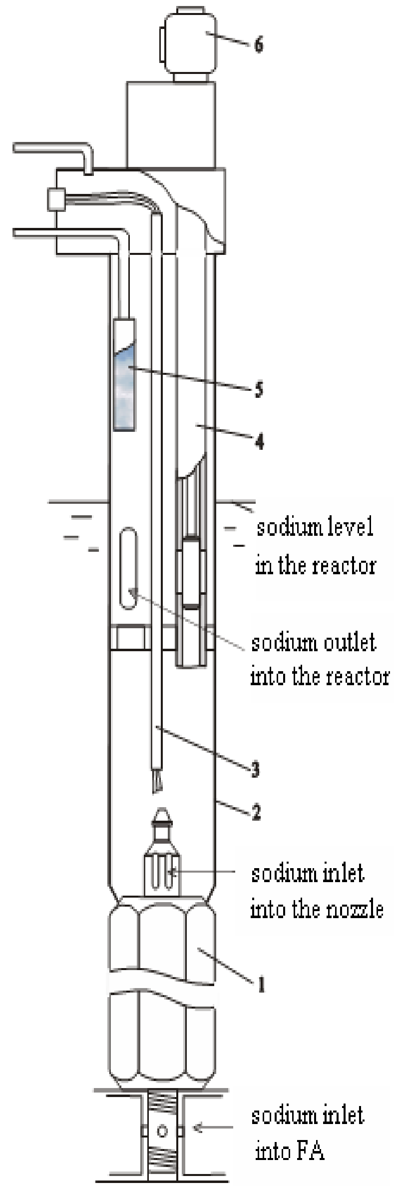
IR with different materials and coolants (Pb, Pb-Bi, Na) in instrumented cell of reactor

BOR-60



1 - thermometric probe;
2 - detachable head;
3 - spacer tubes;
4 - probe thermocouples;
5 - wrapper;
6 - gas clearance;
7 - inner pipe;
8 – capsule assembly;
9 - core center;
10 - fixture

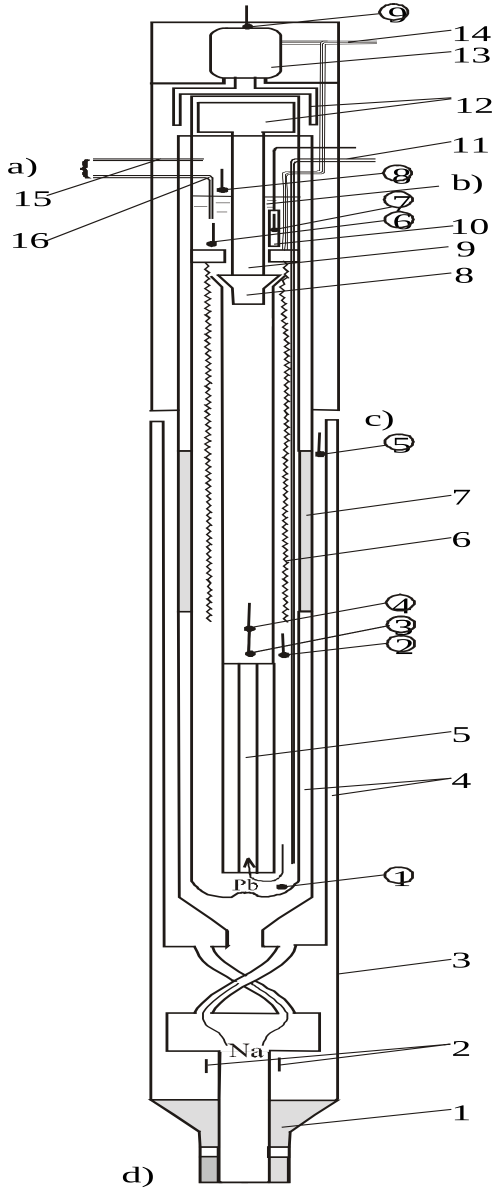
Dismountable assembly for irradiation of structural materials

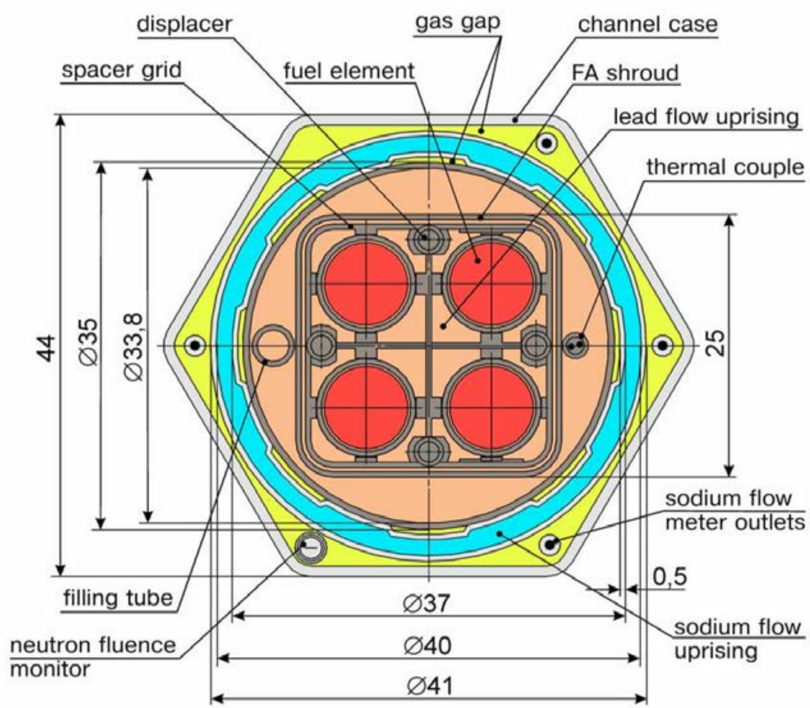


1 - fuel assembly
2 - nozzle body
3 - tube with sensors
4 - flow regulator
5 - sodium vapor filter
6 - electric engine

Scheme of the instrumented nozzle (D23)

BOR-60 lead loop





ILCC cross-section in the core central plane

Scheme of the lead loop

RIAR Material Testing Complex

ПРЕДПРИЯТИЕ ГОСКОРПОРАЦИИ «РОСАТОМ»

- **The RIAR Material Testing Complex was established in 1964 to solve the tasks of the reactor material science.**
- **Over the years of operation, the Complex has been constantly developed and now it is one of the largest material testing laboratories in the world.**

Reactor Material Testing Complex: Main Research Areas

1. Materials and elements of cores

1.1. Light water reactors
1.2. Sodium fast reactors
1.3. Small reactors
1.4. Gas reactors
1.5. Pb/Pb-Bi-cooled reactors
1.6. Research reactors
1.7. Fusion reactors

2. Technologies for handling SNF from reactors of different purpose

3. Absorbing materials and elements of CPS rods from reactors of different purpose

4. Moderating materials from reactors of different purpose

Reactor Material Testing Complex: Main Research Areas

5. Material science aspects in the extension of the reactor facility lifetime
6. Investigations related to the radiation damage physics, simulation of behavior of nuclear reactor core elements and materials
7. Development of inspection facilities, techniques and equipment for material testing of irradiated materials and products, modernization of engineering systems and basic equipment in the RIAR Material Testing Complex
8. Development and fabrication of experimental irradiation devices, targets for isotope production and other products of nuclear engineering

Goals of the Reactor Material Testing Complex

Level 1 goal

Establishment of the Division as ROSATOM's key experimental base on the reactor material science

Level 2 goal

- **Extension of international cooperation**
- **Enhancement of cooperation with enterprises within ROSATOM and others**
- **Modernization and development of the material and technical base**
- **Development of the effective system for knowledge management**
- **Strengthening of the role of the Center of Excellence**
- **Active participation in the FTP "Nuclear Energy Technologies of New Generation"**

Experimental Base of the Reactor Material Testing Complex

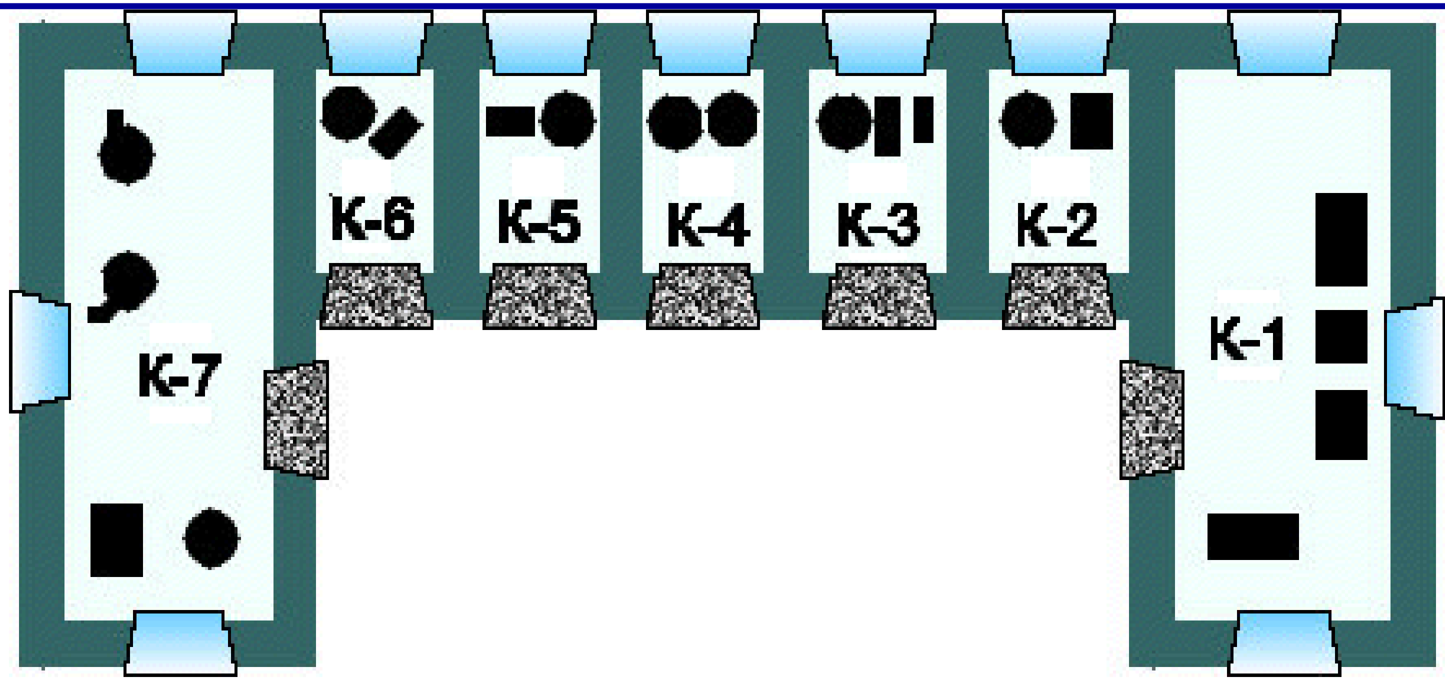
RIAR Material testing complex houses more than 100 hot cells and heavy-duty boxes (up to $2.2{\cdot}10^{16}$ Bq) and consists of two buildings:

● ***for non-destructive analysis of full-scale fuel rods and fuel assemblies***
(measurements of fuel rod parameters; visual examinations; gamma scanning; eddy-current defectoscopy)

● ***for destructive analysis***
(burn-up; fission products release; gamma scanning; metallography and micro-hardness; density and porosity; thermal conductivity and electric resistance; X-ray analysis; dilatometry; TEM, SEM, EPMA, AES, SIMS; mechanical testing (tensile, compression, bending, impact etc.)

Experimental Base of the Reactor Material Testing Complex

Hot Cells for Non-Destructive PIE

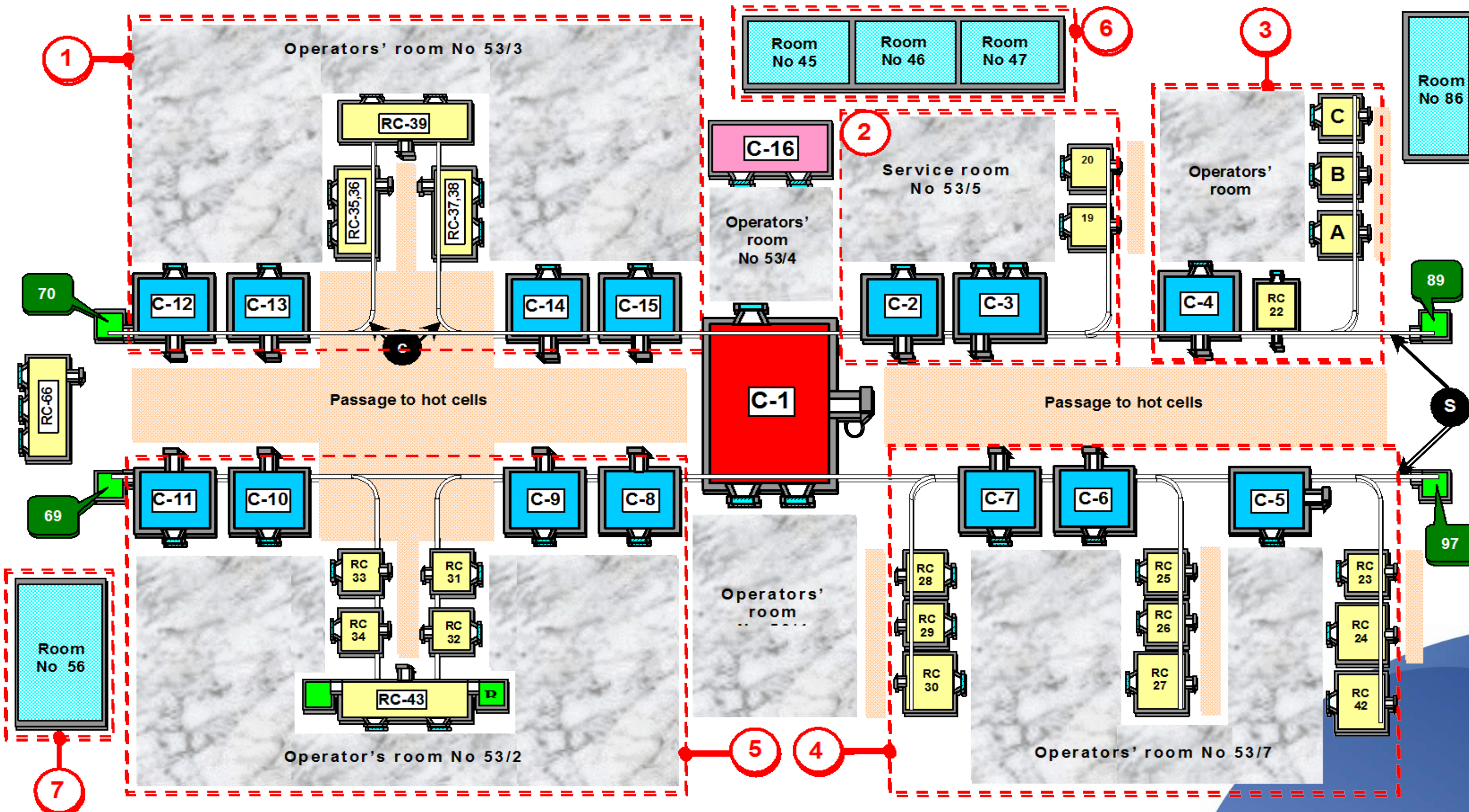


Two big hot cells designed for operations with full-scale fuel assemblies for commercial reactors are 7.5 m long, 4.0 m wide and 7.2 m high.

Another five hot cells are 5.0*1.8*2.6 m in size.

Experimental Base of the Reactor Material Testing Complex

Hot Cells for Destructive PIE



Types of researches

Structural materials

- Mechanical properties
  - Short-term
  - Long-term strength
  - Heat resistance
  - Crack growth resistance
- Macro and microstructure
- Swelling
- Radiating growth
- Radiating and thermal crip
- Thermal conduction and temperature conductivity

Fuel

- Macro and microstructure
- Swelling
- Production and diffusion of fission products
- Crip
- Thermal conduction and temperature conductivity
- Porosity
- Density

Types of researches

Fuel rod

- Change of geometry
- Mechanical and physical-chemical interaction “fuel-cladding”
- Gap “fuel-cladding”
- Change of length of a fuel column
- Corrosion of an outside and internal surface of an cladding
- Axial and radial distribution of fission products
- Fission gas release under an cladding
- Amount and structure of deposition
- Condition of welded connections
- The reasons of damage

Fuel Assembly

- Change of geometry
- Corrosion of constructional materials
- Condition of welded connections
- Presence, size both arrangement of damages and defects

The Test Equipment of the RIAR's Material Testing Complex

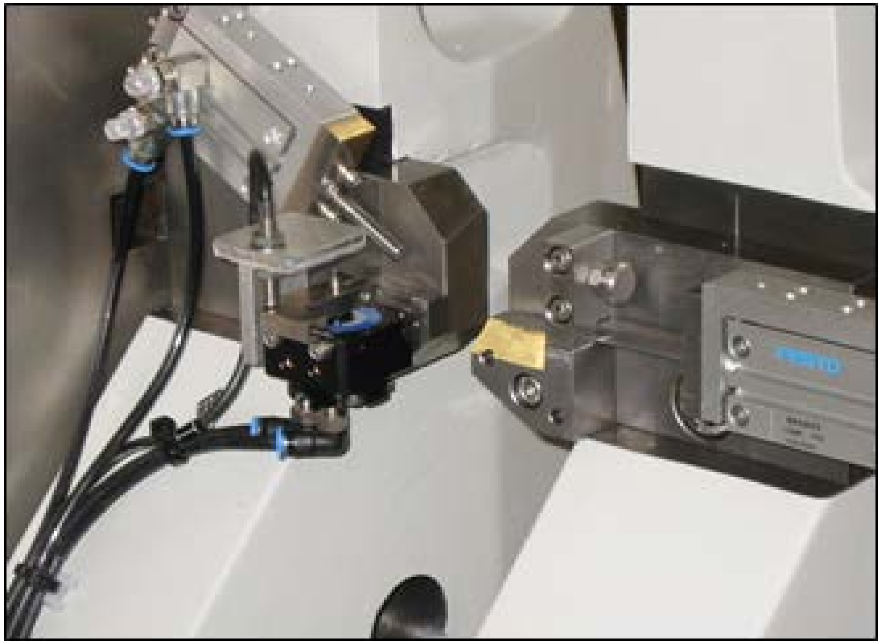
EXAMINATION	TECHNIQUE IN BRIEF
Visual inspection	Photographing and video (color and black-and-white)
Bending measurement	Device to measure fuel rod length and FA wrapper size and shape
Determination of gas amount and composition in a fuel rod	Cladding puncturing, mass-spectrometry, chromatography
Cladding-to-fuel gap measurement	Deformation of cladding by mechanical loading before covering the fuel meat
Eddy-current test	Amplitude-phase analysis
X-raying	Tomography
Optic metallography	Optical microscopes MIM-15, UMSD, TELEATOM-4
Measurements microhardness density and porosity gas content thermal conductivity electrical conductivity	Hardness meters Density meters UVA-100Pa Gas analyzer ON-900 Mass-spectrometer MI-1201 Pulse heating technique Potentiometers

The Test Equipment of the RIAR's Material Testing Complex

EXAMINATION	TECHNIQUE IN BRIEF
Burn-up measurement	Gamma- and mass-spectrometry(TRITON)
X-ray analysis	Micro-diffractometer KED-1, remote diffractometer s DARD, DRON-7.
Chemical analysis	LPS «Spectroflame Modula S», OPTIMA 2100
Scanning and transmission microscopy	Electronic microscopes JEM 2000 FX; Philips FX 30 ESEM-TMP; Zeiss Supra 55VP
Micro-X-ray analysis	Micro-analyzers MAR-3, MAR-4
Laser micro-analysis	Laser atomic-fluorescent analyzer LAFA-1
Auger spectrometry	Differential scanning Auger spectrometer ESO-3 UM, ESO-5 UM
Ion-probe micro-analysis	Secondary-ion mass-spectrometer MS-7201M, MC-7202M
Measurement of mechanical characteristics	Testing machines Instron 1362-DOLI, RKP-450, Zwick 5113

Examples of the Test Equipment

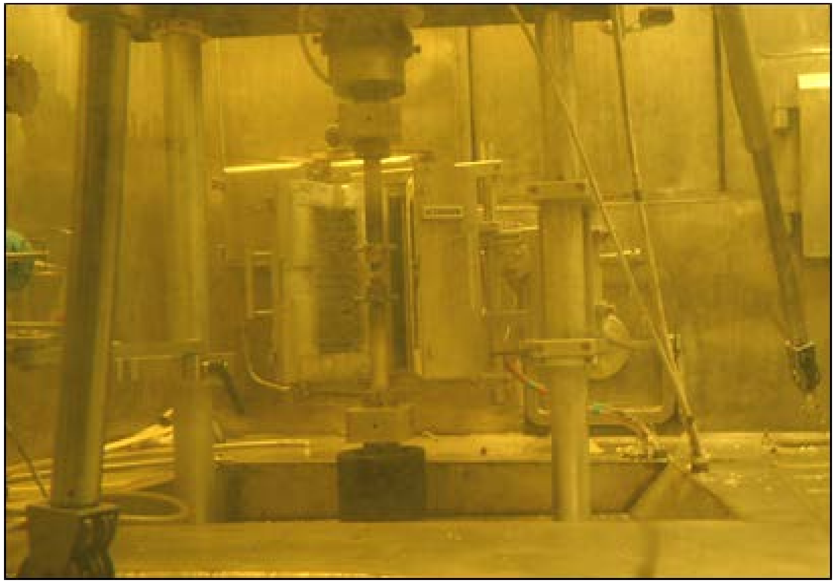
Zwick 5113 impact testing machine



temperature range from – 190 up to +680°C

Examples of the Test Equipment

Instron 1362-DOLI



Tensile tests and low–cycle fatigue tests, temperature range from +20 до +800°C

Scanning electronic microscope Phillips XL 30 ESEM-TMP

accelerating voltage: from 0,2 to 30kV;
bundle current: from 0,4 pA to 4 µA;
maximum achievable resolution: 3.5nm at 30kV and 25nm at 1kV;
maximum magnification: 100000x.

Transmission electronic microscope JEM 2000 FX II

The National Programs

1. Federal Programs

1.1 National Technological Base

1.2. Nuclear and Radiation Safety

1.3. Nuclear Energy Technologies of New Generation

2. Program of PIEs of the VVER and RBMK FAs for 2011 -2015

3. Navy and Space

The International Programs

- Tests of FAs for CMAR reactor (KAERI, South Korea)
- Tests of materials for PWR internals "BORIS", "SAMARA" (EDF, France)
- Tests of materials for PWR vessels "KORF" (EDF, France)
- Tests of materials for ADS systems "ALTAIR" (CEA, France)
- Tests of mock-ups and FAs for CARR reactor (CIAE, China)
- Tests of RAFM - steels for DEMO reactor "ARBOR" (KIT, Germany)
- Tests of fuel pins with ODS claddings (JAEA, Japan)
- Tests of fuel pins with different fuel compositions "BORA-BORA" (CEA, France)
- Tests of absorber elements for fast reactors (Marubeni, Japan)
- Tests of model zirconium alloys (EPRI, USA)
- Investigation of the thermal stability zirconium alloys (EDF, France)
- PIE of BN-600 vibropacked MOX fuel pins (JAEA, Japan)

Examples of the Experience of Work: *The Circuit of Tests and Researches of the VVER Fuel at RIAR*

Experimental justification of SNF handling technologies

Fabrication of irradiated mockup fuel rods

Examination of FAs from NPPs

Reactor Complex

Testing & examination of absorbing & structural materials

Material Testing Lab

Testing & examination of full-size fuel rods & mockup fuel rods & FAs

Examples of the Experience of Work: *“BORA-BORA”*

Two irradiation stages were performed in the BOR-60 reactor as well as PIE after each irradiation of the experimental fuel pins. The purpose of the experiment was to get data on the state of fuel pins with the increased plutonium content in different fuel compositions after irradiation in the fast reactor.

Fuel compositions	**B max, %**
40% PuN+60% ZrN	19,4
40% PuO_2 + 60% MgO	19,0
45% PuO_2+55% UO_2 (pellets)	12,4
45% PuO_2+55% UO_2 (vipac)	12,8
45% PuN+55% UN	9,4
60% PuN+40% UN	12,1

All fuel rods retained their cladding integrity, no anomalies were found.

The obtained results showed that the increased content of Pu in the oxide fuel didn’t cause any new phenomena in the fuel rods during irradiation and special features in their state after irradiation.

Examples of the Experience of Work: <u>*ODS Claddings*</u>

Three series of irradiation tests have been successfully conducted.

Excellent potential performance of the ODS cladding fuel pins was confirmed up to burn-up of 11.9 at% and neutron dose of 51 dpa.

Examples: Collaboration on «BORIS» Experiments

(1995-2005)

EDF (France)

Post-irradiation examinations of austenitic steels irradiated in the BOR-60 reactor up to damage 120 dpa at a temperature of 330-340°C for reactor internals were carried out.

Examples: Collaboration on "*ARBOR*" Experiments

(2002-2010)
(KIT, Germany)

* Post-irradiation examinations of ferritic-martensitic steels irradiated in the BOR-60 reactor up to damage 70 dpa at a temperature of 330-340°C for DEMO were carried out

* The examined materials included RAFM 7-10%Cr-WVTa steels, ODS EUROFER, boron doped heats and technological weld specimens

* In general, the obtained results demonstrate a favorable possibility to use the RAFM steels in a fusion reactor of special design within a temperature range of 350-550°C for the primary wall and the blanket

Irradiation Test and the PIE of Experimental

Examples: Collaboration on LEU U-Mo fuel elements Experiments

(2002-2012)

ANL (USA)

*The objective of this examination is to estimate the in-pile performance of metallic fuel and non-fuel core component, and to confirm their integrity during the irradiation test

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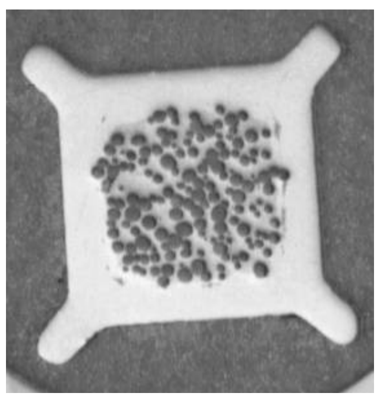
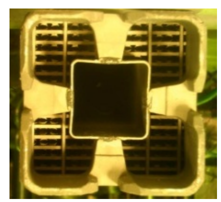
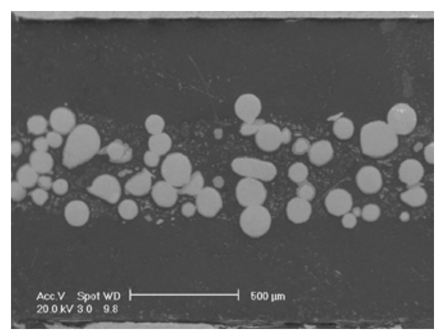
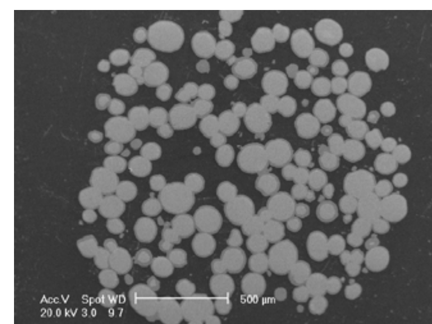


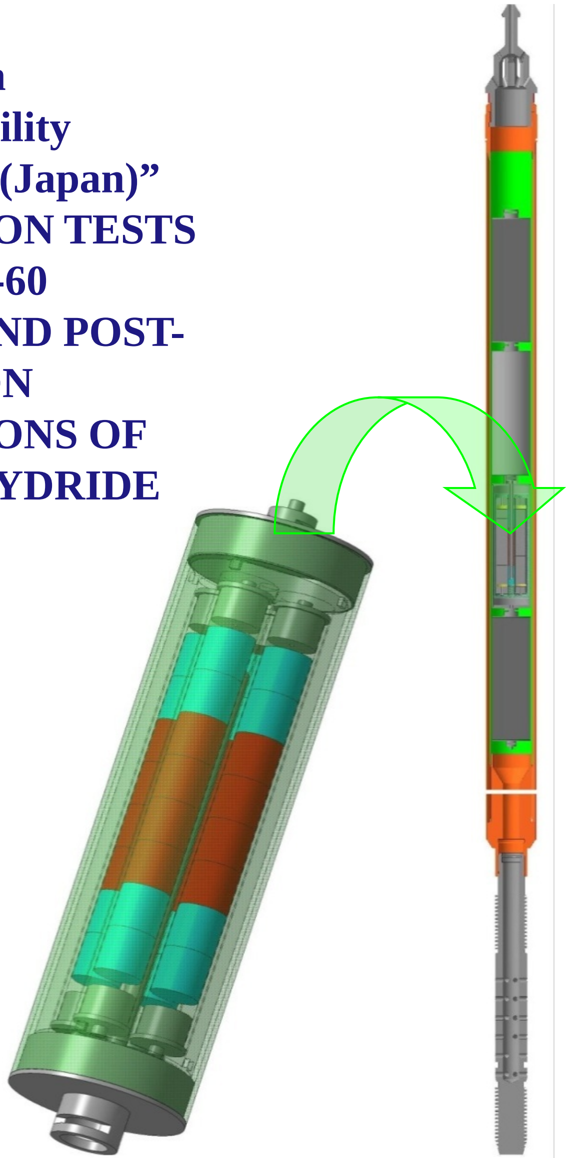






Examples: Collaboration on Hafnium Hydride Experiments (2009 – 2012)

Contract with "Marubeni Utility Services, Ltd. (Japan)" "IRRADIATION TESTS IN THE BOR-60 REACTOR AND POST-IRRADIATION EXAMINATIONS OF HAFNIUM HYDRIDE SAMPLES"



IRRADIATION TESTING CONDITIONS

Environment - Na

T = 500-600°C

Damage dose up to 15 dpa

POST-IRRADIATION EXAMINATIONS

- **Visual examination and photography**
- **Measurements of pellets mass, geometrical sizes, density**
- **Metallographic examinations**
- **X-ray investigation**
- **Determination of hydrogen content**
- **Measurement of HfHx pellets mechanical strength**
- **Scanning and transmission electronic microscopy**

Materials Proposed for Gen IV Reactors

Reactor	Coolant	Max T, °C	Core materials		
			Fuel	Cladding	Absorber
GFR fast	He	850	(U,Pu)C/SiC composite ceramic, fuel particles with ceramic coating	ceramics(?)	High-temperature boron-based ceramics (metal carbides or borides) with isotopes ^{10}B up to95% - $^{10}B_4C$, $W^{10}B_2$, $Hf^{10}B$ $Dy_2O_3 \cdot HfO_2$, $Dy_2O_3 \cdot HfO_2 + B_4C$*
LFR fast	Lead or lead-bismuth	500÷800	U-Pu (U,Pu)N	Ferritic-martensitic steel (9…12% Cr) ceramics	
SFR fast	Na	550	U-Pu-Zr U-Pu-Zr + actinides $(U,Pu)O_2$ $(U,Pu)O_2$+ actinides	Ferritic-martensitic steel (9…12% Cr) ODS vanadium alloys with coatings	
SCWR fast (thermal)	Water of super critical parameters	550 (P=25 MPa)	$(U,Pu)O_2$ dispersed (UO_2)	Ferritic-martensitic steel (9…12% Cr) Fe Ni Cr Ti ODS Inconel 690, 625,	
MSR epithermal	Molten salt	750÷800	salt	—	—
VHTR thermal	He	1000	TRISO UOC in graphite matrix with ZrC coating	Graphite with ZrC – coating $^{11}B^{15}N$ $^{11}B^{15}N + ^{11}B_4C$*	Boron carbide with pyrocarbon treatment

New Concept:

DOVITA

1992

- Dry technologies
- Oxide fuel with MA
- Vi-pack
- Integrated disposition same site with the reactor
- TA Transmutation of Actinides

DOVITA-2

2007+

- **D**ry technologies
- **O**n-site reprocessing
- **V**arious type of fuel with MA
- **I**ntegration of MA recycling into FR Closed Fuel Cycle
- **TA** - Transmutation of Actinides

DOVITA-2

Fuel type/ Stages	Oxide vi-pack	Oxide pellet	Nitride vi-pack	Metal	Molten salt
Concept Studies	+	+	+	+/-	+
R&D	+	-/+	+/-	-	+
Fuel Production	+	-	-	-	-
Irradiation Testing	+	-	-	-	-
PIE	+	-	-	-	----
Reprocessing	-/+	-	-	-	+/-

DOVITA-1

Reasons and plans of upgrading

The International Community proposed 6 types of Gen IV innovative reactors, four of them are fast reactors. The operating parameters (temperature, environment, pressure) and requirements to safety, reliability and lifetime of core components are higher as compared to the existing facilities.

To perform PIEs, the equipment that allows to investigate fuel, structural and absorbing materials at the new level is needed. For this purpose, the RIAR Material Testing Complex is modernized, including putting into operation new test machines and devices.

The technical upgrading program is accepted and implemented of the Material Testing Complex up to 2020 with a total cost of 100 million $.

Scanning electron microscope Zeiss SUPRA55VP

Super-high resolution field-emission scanning electron microscope Zeiss SUPRA55VP (Carl Zeiss AG, Germany): energy-dispersive spectrometer Inca Energy 350 (a), wave-dispersive spectrometer Inca Wave 500 (b) and HKL EBSD Premium system for registration and analysis of backscatter electron diffraction (c).

Examples of upgrading

Basic technical parameters of the research unit

Spatial resolution:

- resolution in secondary electrons	1nm (at 15 kV)
- resolution in secondary electrons	1.7nm (at 1 kV)
- resolution in secondary electrons	4.0 nm (at 100 V)
- resolution in backscattering electrons	1.3 nm
- resolution under STEM mode	0.8 nm
- HKL CHANNEL 5 system (phase)	25nm
- accelerating voltage range	100V – 30kV
Magnification range:	12x - 900 000X
Low vacuum range:	1-133Pa

The in-built low vacuum system allows non-conductive specimens to be examined.

Examples of upgrading

In the near future it is planned to modernize the entire complex for non-destructive examinations, as well as metallography, TEM, EPMA and physical-chemical analysis areas.

For example:

- transmission electronic microscope «Tecnai G2 20 S-TWIN»;

- Spark optical emission spectrometer «FOUNDRY-MASTER UVR» (OXFORD Instruments);

- ICP- optical emission spectrometer «Ultima 2» (HORIBA);

- gas determinator «OH-900» (ELTRA GmbH);

- scanning electron microscope «VEGA 3 RXMU» (TESCAN);

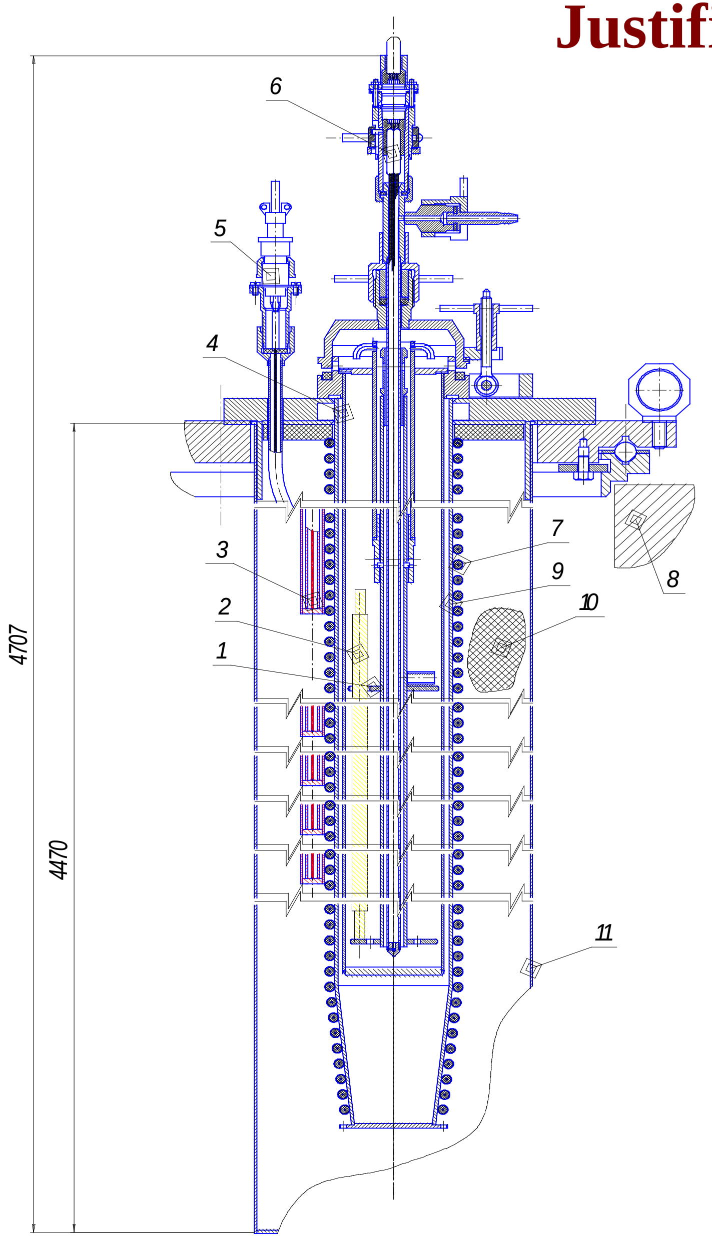
- electron-probe microanalyzer «Cameca SX 100R».

RIAR R&D International Cooperation in the Field of Advanced FC

	Fuel production		Repro-cessing	P&T	Advanced	Cladding materials	Concept Studies	Funda-mental Studies
	MOX	other						
France	-	MA oxide	-	Am/Cm recovery	Pyro	+	FS	Cm
INPRO	-	-	-	-	-	-	CPP FINITE	-
Japan	MOX vibro	-	MOX	MA/REE separ.	Pyro/ Fluorex/ MoO_4^{2-}	ODS	FS	MA
Korea	-	MA met. ?	Metalliz./ vibro-DUPIC	MA/REE separ.	Pyro	+	-	-
US	TRU fuel		UREX+1	TRU fuel	-	-	-	RTIL's
EU	-	MA nitride	-	-	MSR fuel	-	-	Cm

Red color – DOVITA-1/2 activities

Justification of “dry” storage of spent VVER-1000 FAs from Zaporozhye NPP



Electric heater:

1-rack; 2-fuel rod; thermocouple on a heater;
4-capsule; 5-joint;
thermocouples in capsule;
heater;
8- cell well; 9-body;
10-insulation; 11-jacket; 12-rack channel.

Capabilities:

- **Test temperature range - 300-600°C.**
- **Remote loading-unloading of fuel rods.**
- **Simultaneous test of 18 full-size VVER-1000 fuel rods in three independent modules.**
- **Simultaneous simulation of several SNF storage modes (both temperature and gas environment).**
- **Periodical gas sampling from any module;**
- **Temperature field profiling along the fuel rod height;**
- **Thermo-cycling– simulation of either daily or seasonal variations of the environmental temperature.**

MBIR Irradiation Programs

- Irradiation testing of promising structural materials for different types of nuclear reactors, including fusion facilities, under intensive neutron irradiation with the flux density of up to $(2\text{-}5)\cdot10^{15}$ sm^{-2} s^{-1}.
- Examination of new radiation-resistant materials for FAs providing a minimal change in form and the required mechanical properties up to a high fuel burn-up. Among them, examination of ferritic-martensitic steels retaining their performance at 650-750°C, as well as special heat-resistant and high-temperature materials retaining their performance at temperatures > 900°C.
- Examination of various promising fuel types at high and super-high burn-ups.

MBIR Irradiation Programs

- Investigation of issues related to closed fuel cycle and burnout of long-lived radioactive elements.
- Investigation of FAs and fuel rod behavior under transient, cycling and accident conditions.
- Corrosion testing of the core elements and study into the laws of the fission products transfer in the loop circuit under the close-to-real dynamic conditions.
- Testing of various technologies for preparation of the coolant under the reactor conditions.

Types of researches

Structural materials	Fuel
Mechanical properties - Short-term - Long-term strength - Heat resistance - Crack growth resistance	Macro and microstructure
Macro and microstructure	Swelling
Swelling	Production and diffusion of fission products
Radiating growth	Crip
Radiating and thermal crip	Thermal conduction and temperature conductivity
Thermal conduction and temperature conductivity	Porosity
	Density

Types of researches

Fuel rod

- Change of geometry
- Mechanical and physical-chemical interaction “fuel-cladding”
- Gap “fuel-cladding”
- Change of length of a fuel column
- Corrosion of an outside and internal surface of an cladding
- Axial and radial distribution of fission products
- Fission gas release under an cladding
- Amount and structure of deposition
- Condition of welded connections
- The reasons of damage

Fuel Assemble

- Change of geometry
- Corrosion of constructional materials
- Condition of welded connections
- Presence, size both arrangement of damages and defects

TRANSPORTATION

A very complicated topic:

- **Depends on national and international regulations and agreements**
- **Needs compatibility between a cask and facilities**
- **Specific content needs specific agreement on a cask**
- **A different company to transport to each country**
- **Can delay the program**
- **Takes time and money**

LEGAL ASPECTS

Prepare an agreement between the parties

- Objectives
- Financial contributions
  - Can be subject to appropriate national funding
  - In kind contribution
  - Financial contribution, accounting schedule
- Management
  - Contact persons, exchange of information, meetings
- Intellectual Property, Rights of use
- Specific conditions
  - For example, consider a long-term shutdown of the reactor
- Technical Annex
  - Technical program, Post Irradiation Examination
  - Distribution of tasks
  - Due dates

CONCLUSION

At present, the reactor irradiation program and PIE possibilities are harmonized.

The existing experimental base of the Material Testing Complex and its future upgrading make it possible to state with certainty that the Complex can effectively operate as a part of the MBIR-based Center of Excellence.

Thank you for attention!