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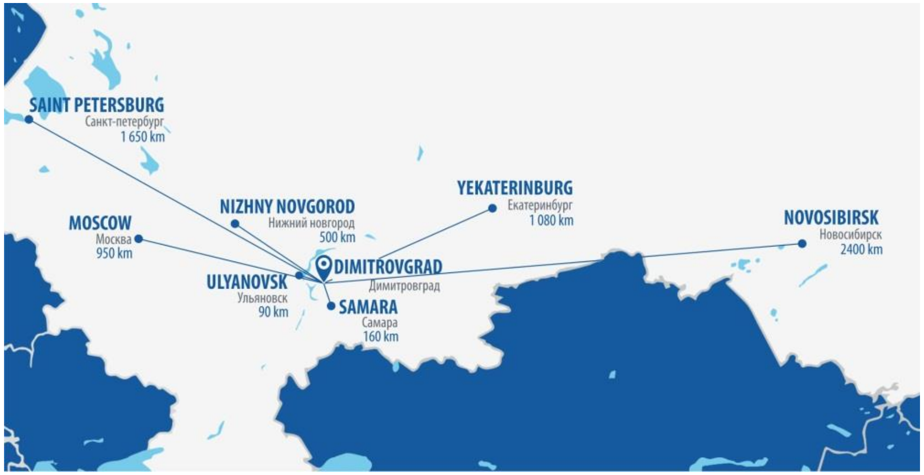
ROSATOM STATE CORPORATION ENTERPRISE

The 18th IGORR Conference
3-7 December 2017, The International Conference Centre,
Darling Harbour, Sydney, Australia

RIAR as IAEA ICERR: Pilot Technical Cooperation Projects and Future Prospects

Alexander TUZOV
JSC “SSC RIAR”, Director

General Information



Foundation: March, 1956

Destination: airports with direct flights to / from Moscow, Saint-Petersburg and other cities - Samara (160 km), Ulyanovsk (90 km)

Number of staff:

- 3 200 persons (incl. ~400 researchers)

Customers: more than **25 countries**

Overseas Portfolio: more than **USD 60 mln.**

RIAR's Overview:

- World's largest fleet of nuclear research facilities (incl. five RRs and two critical stands)
- World's largest complex for post-irradiation examination (incl. full-size fuel assemblies)
- Radiochemical complex to perform NFC-related research activities
- Complex to study properties and produce TRU elements; R&D and production of radionuclides with high specific activity and radiation sources
- Full-cycle infrastructure, incl. nuclear fuel production, spent nuclear fuel and radioactive waste management, treatment of minor actinides

RIAR as IAEA ICERR

Official ceremony of RIAR Designation as IAEA ICERR (IAEA's 60th General Conference, September 26, 2016)

The RIAR's application to IAEA ICERR status was supported by ROSATOM and submitted to the IAEA on **June, 2016.**

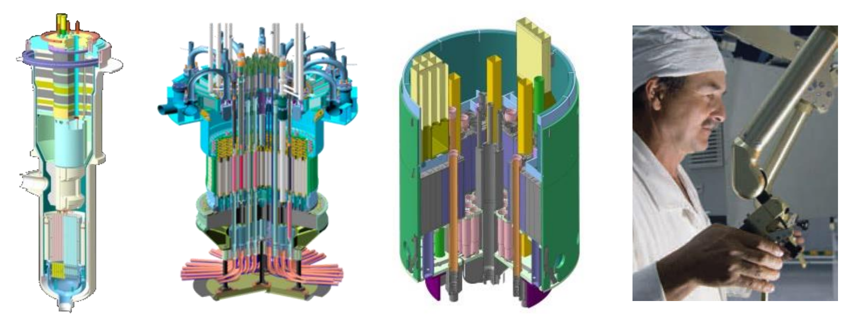
The ICERR Audit Mission team was organized and headed by IAEA's Research Reactor Section, Department of Nuclear Energy.

During the visit to the RIAR's site in **July 2016**, Mr. Andrea Borio di Tigliole (Head of IAEA's Research Reactor Section) noted RIAR's wide experimental capabilities, its great expertise and high level of motivation of its employees.

Designation of RIAR as the IAEA **I**nternational **Ce**ntre based on **R**esearch **R**eactors (ICERR) **confirmed the worldwide recognition of JSC "SSC RIAR"** as a reputable research organization.

Perimeter of RIAR's as IAEA ICERR:

- Sodium-cooled Fast Test Reactor BOR-60
- Multi-Loop Research Reactor MIR.M1
- High-Flux Research Reactor SM-3
- Two critical experimental facilities (the physical mockups of the RRs SM-3 and MIR.M1)
- Reactor Materials Testing Complex



BOR-60 **MIR.M1** **SM-3** **Hot Lab**

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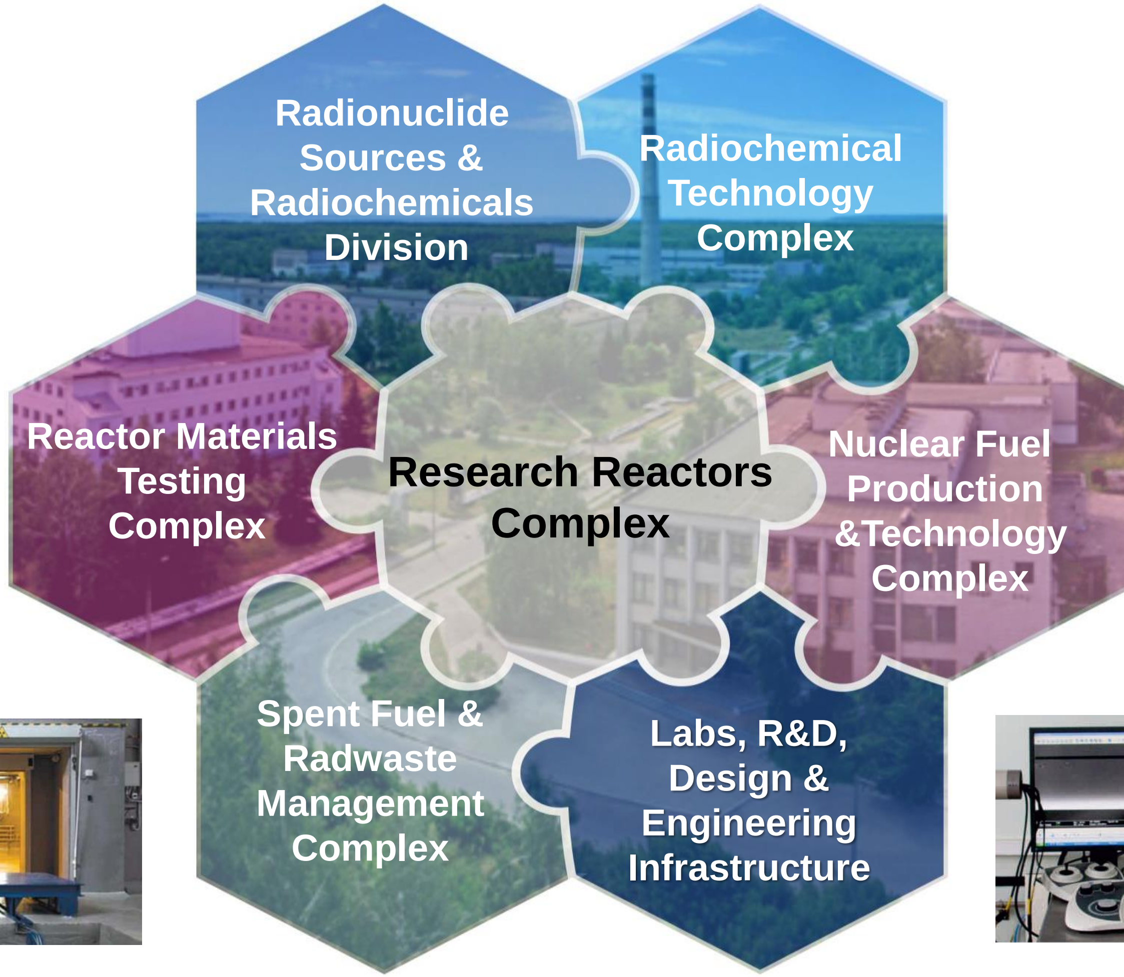
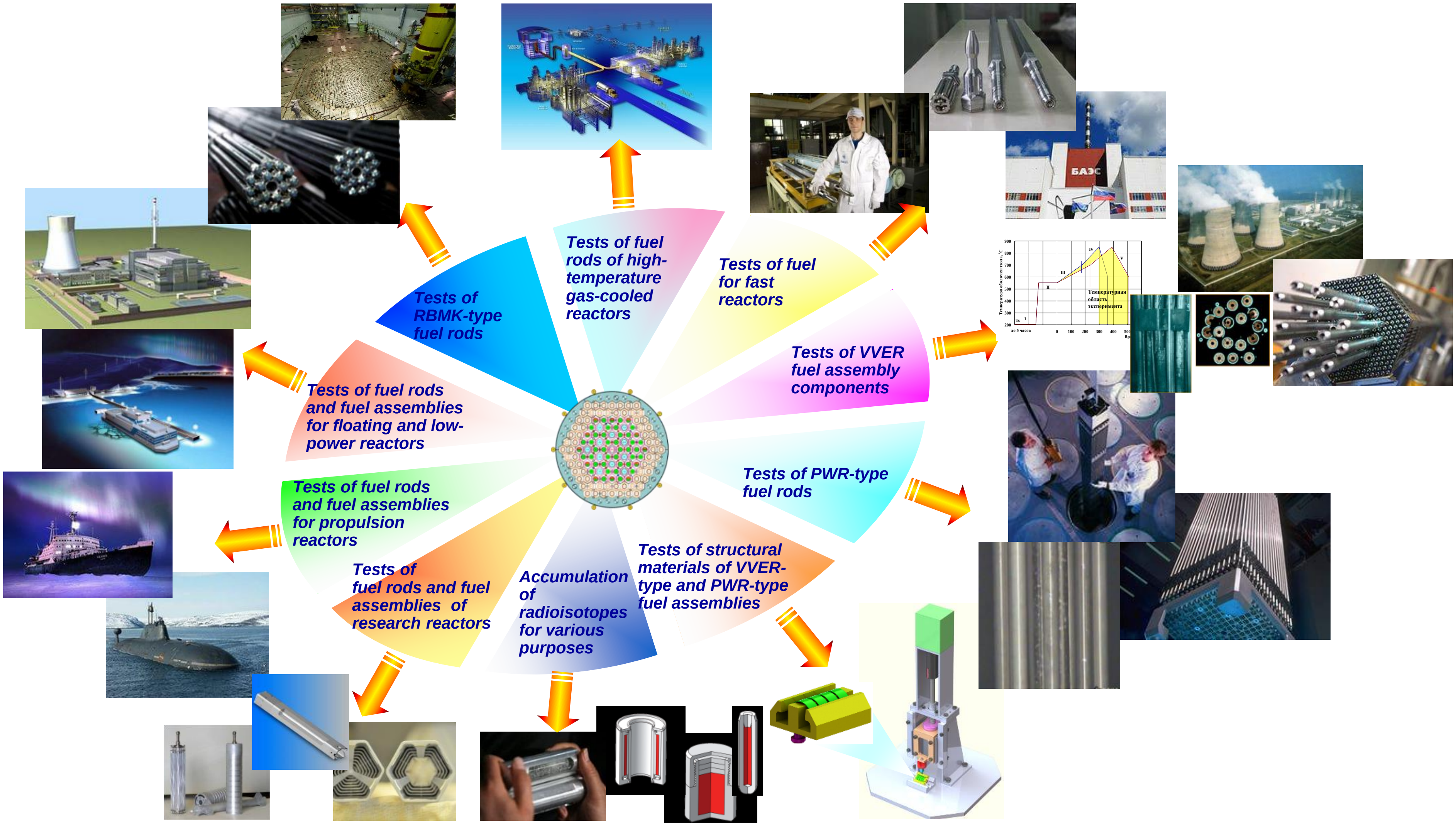
RIAR’s Infrastructure



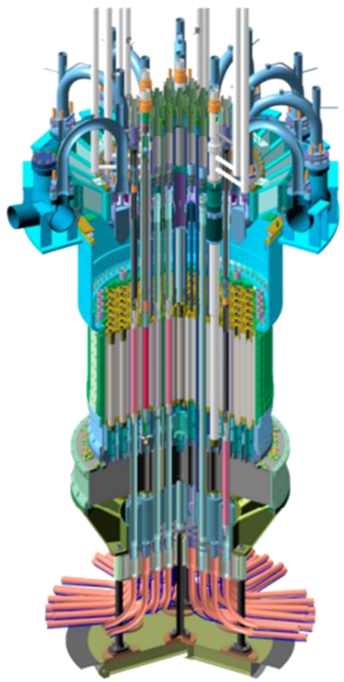
RIAR is **the unique facility**; its self-sufficient R&D and production complex allows providing Customers with full-cycle high tech services and to fulfill all the Customer’s requirements.

MIR.M1 Reactor

Irradiation Capabilities of the MIR.M1



MIR.M1 Reactor
Irradiation Capabilities of the MIR.M1

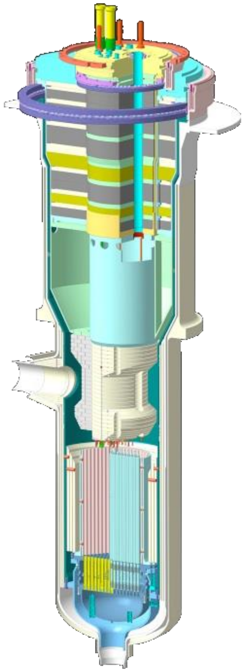


MIR.M1 Key Parameters	
Reactor type	Channel-type water-cooled
Max thermal capacity, MW	100
Max neutron flux density, $cm^{-2} \cdot s^{-1}$	$5 \cdot 10^{14}$
Core height, mm	1000
No of loop channels	11
Effective days per year	230 ÷ 240
Planned life-time	Till at least 2035

Parameter	Loops						
	PV-1	PVK-1	PV-2	PVK-2	PVP-1	PVP-2	PG-1
Coolant	Water	Water, Boiling water	Water	Water, Boiling water	Water, Boiling water, Steam	Water, Boiling water, Steam	He, N_2
Number of channels	2	2	2	2	1	1	1
Max channel capacity, kW	1500	1500	1500	1500	100	2000	160
Max coolant temperature, °C	350	350	350	355	500	550	600
Max pressure, MPa	16,8	16,8	17,8	17,8	8,5	20,0	20,0
Max flow rate through the channel, t/h	16,0	14,0	16,0	14,0	0,7	10,0	-

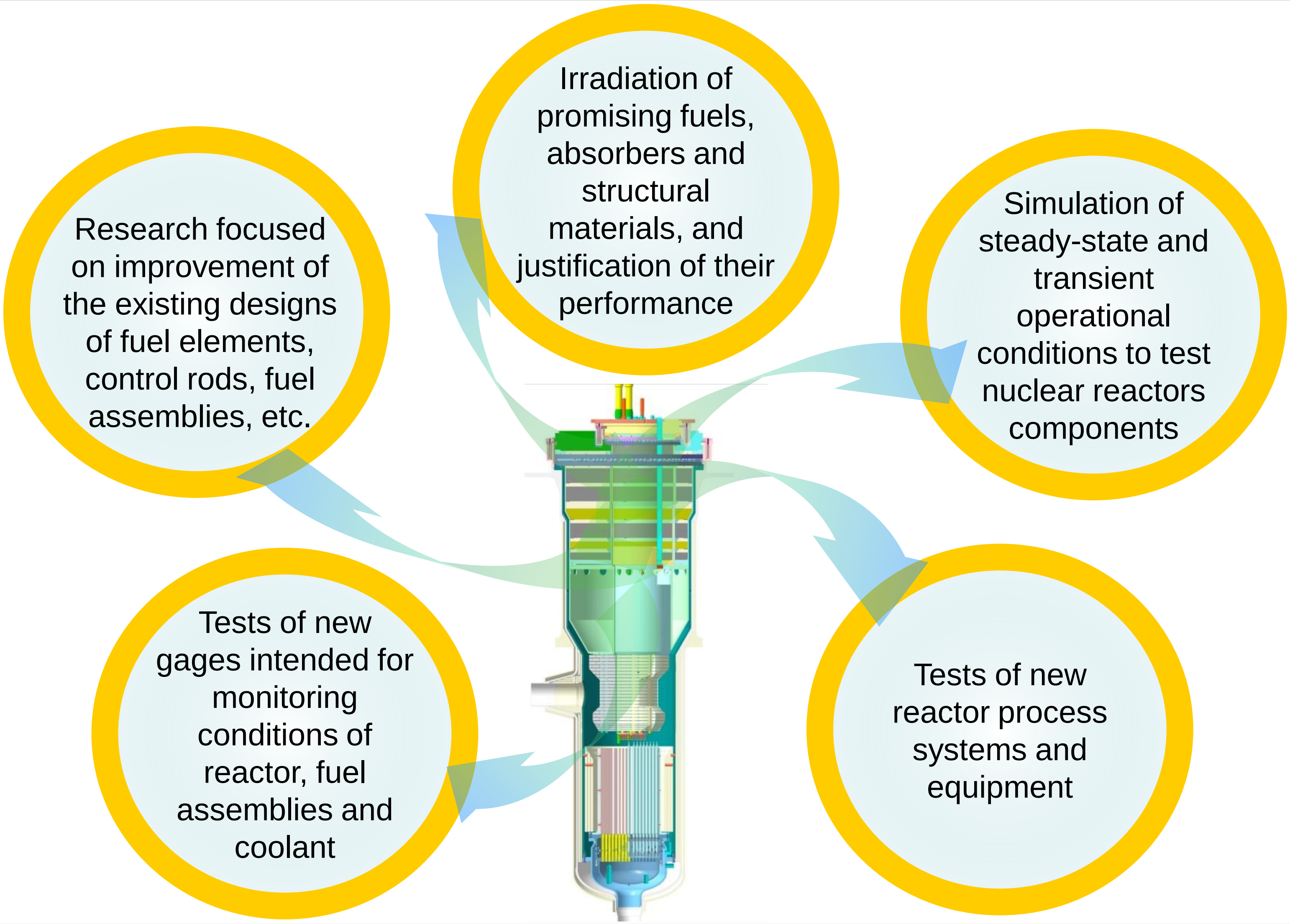
BOR-60 Reactor

Irradiation Capabilities of the BOR-60



BOR-60 Key Parameters	
Reactor type	Fast-neutron sodium-cooled
Max thermal capacity, MW	60
Max neutron flux density, $cm^{-2} \cdot s^{-1}$	$3{,}5 \cdot 10^{15}$
Fuel	UO_2-PuO_2
Enrichment in ^{235}U, %	45 ÷ 90
Enrichment in ^{239}Pu, %	Up to 70
No of experimental cells	12
Effective days per year	230 ÷ 240
Planned life-time	More than 2020

BOR-60 Reactor
Irradiation Capabilities of the BOR-60



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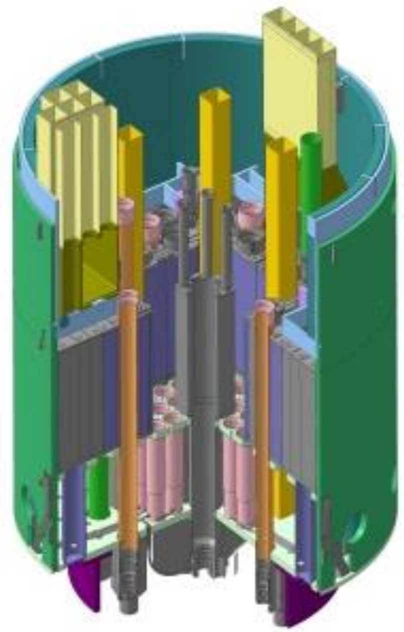
SM-3 Reactor

Irradiation Capabilities of the SM-3



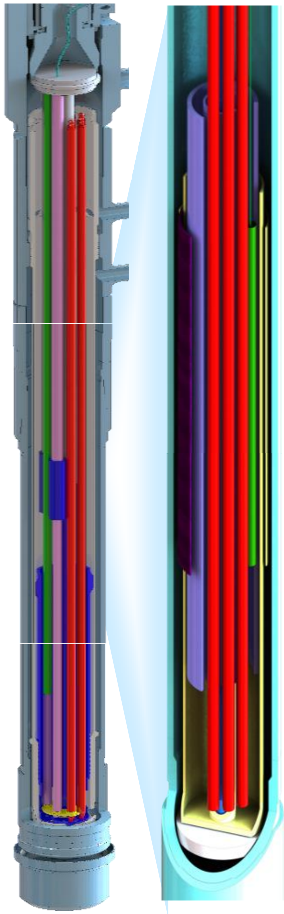
SM-3 Key Parameters	
Reactor type	Vessel-type water-cooled with a trap
Max thermal capacity, MW	100
Max neutron flux density, $cm^{-2}\cdot s^{-1}$	$5\cdot10^{15}$
Core height, mm	350
Effective days per year	230 ÷ 240
Planned life-time	Till at least 2035

Design of irradiation rig	Medium	Testing parameters			
		φ (E>0,1 MeV), $cm^{-2}\cdot s^{-1}$	φ, $cm^{-2}\cdot s^{-1}$	K, dpa/h	Kt, dpa/year
Loop rig in the reflector	Water (300°C, 18,5 MPa)	$10^{13}\div4\cdot10^{14}$	$2\cdot10^{13}\div4\cdot10^{14}$	$3\cdot10^{-5}\div1{,}2\cdot10^{-3}$	0,15÷6,0
Loop rig in the core	Water (300°C, 18,5 MPa)	$1{,}5\cdot10^{15}$	$2\cdot10^{14}$	$\le3\cdot10^{-3}$	15÷18
Ampoule rig in the reflector	Boiling water (up to 320°C), supercritical water, gas (400÷1500°C)	$5\cdot10^{12}\div4\cdot10^{14}$	$2\cdot10^{13}\div4\cdot10^{14}$	$1\cdot10^{-5}\div1{,}2\cdot10^{-3}$	0,1÷6,0
Ampoule rig in the core	Boiling water (up to 320°C), supercritical water, gas (400÷2500°C)	$(1{,}5\div2)\cdot10^{15}$	$(2\div3)\cdot10^{15}$	$\le4\cdot10^{-3}$	16÷25

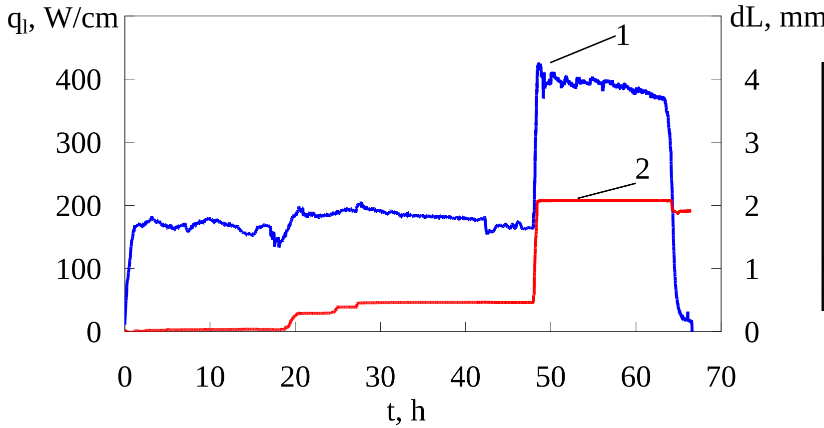
Reactor Testing of Fuel

MIR.M1 Reactor. RAMP Test

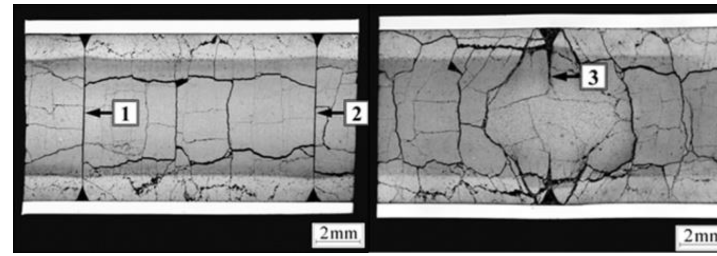
(Proceedings of 2017 Water Reactor Fuel Performance Meeting/ TopFuel 2017, 10-14 September 2017, Jeju Island, Korea, paper A-096, CD)



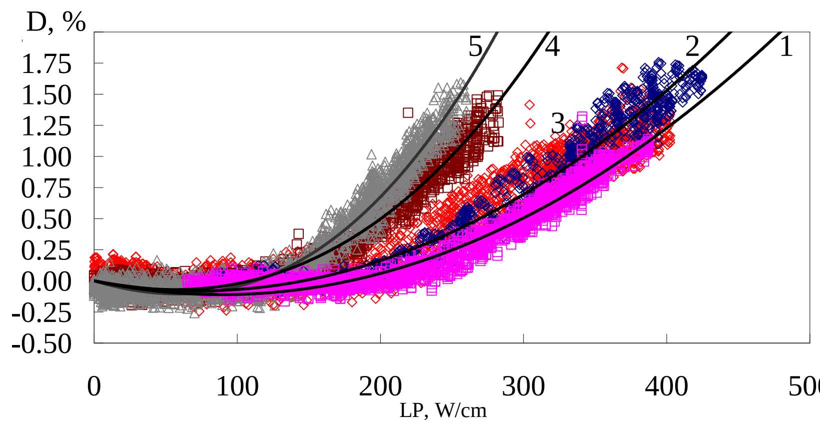
Irradiation rig to test full-size and refabricated fuel rods under RAMP



Change of parameters during RAMP experiment. The maximal LHR (1) and readings of the elongation transducer (2) of FSFR (max burnup 44,5 MWd/kgU)



Structure in the area of large corrugation in the FSFR (max burnup 44,7 MWd/kgU) tested under RAMP

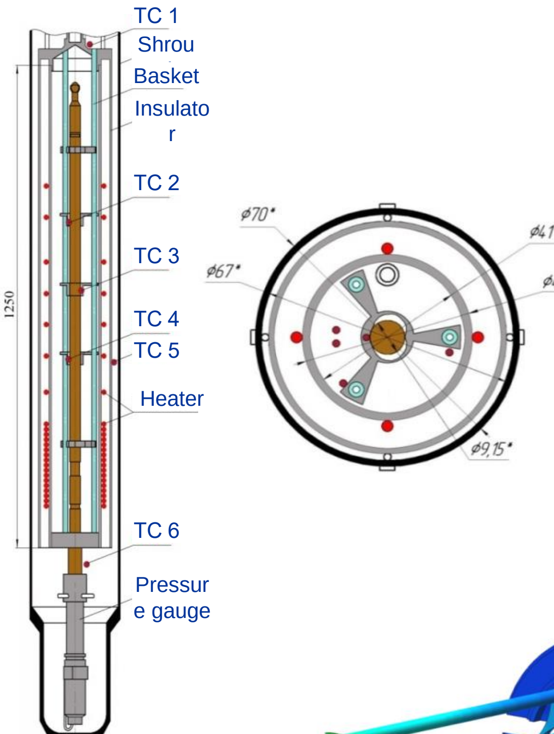


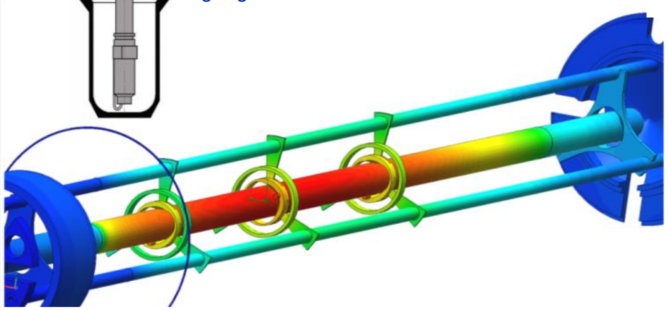
Residual cladding deformation (D) and LHR of fuel rods with different maximal burnups tested under RAMP. 1 - (38,9-44,7) MWd/kgU; 2 – 44,5 MWd/kgU; 3 - 47 MWd/kgU; 4 - 48,4 MWd/kgU; 5 - (56,4-60,9) MWd/kgU

Reactor Testing of Fuel

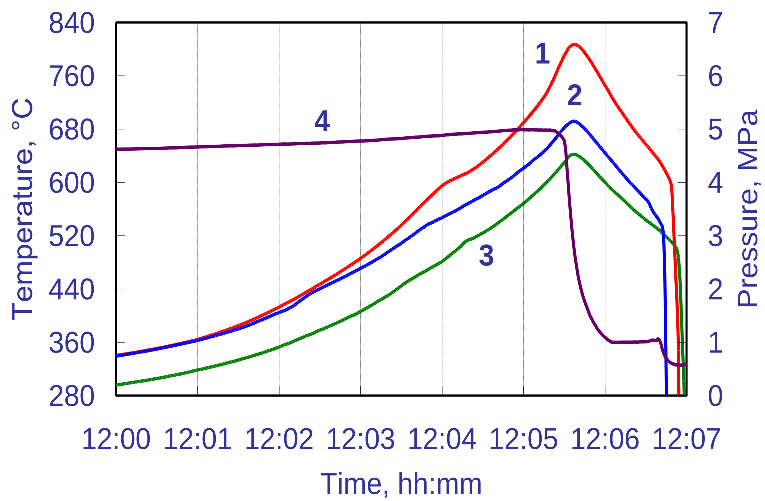
MIR.M1 Reactor. LOCA Test

(Proceedings of 2017 Water Reactor Fuel Performance Meeting/ TopFuel 2017, 10-14 September 2017, Jeju Island, Korea, paper A-088, CD)

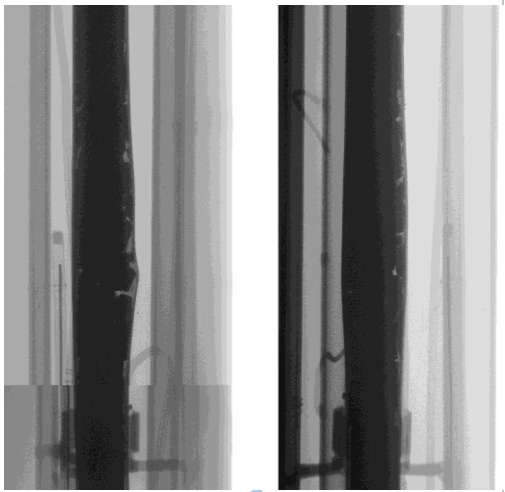




Irradiation rig to test a single fuel rod



Change in the fuel cladding temperature above the central (1), lower (2) and upper (3) spacer grids at 5…50 mm from the upper grid end. Change in gas pressure (4). MIR-LOCA/50 experiment



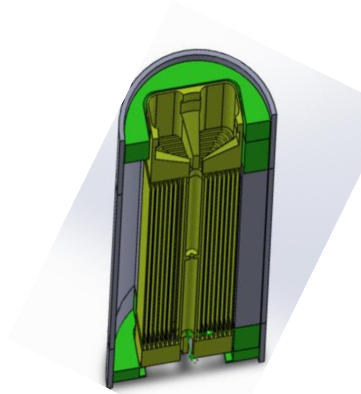
Rotation by 90°

State of the fuel rod after MIR-LOCA/50 experiment (X-ray)

Reactor Testing of Fuel

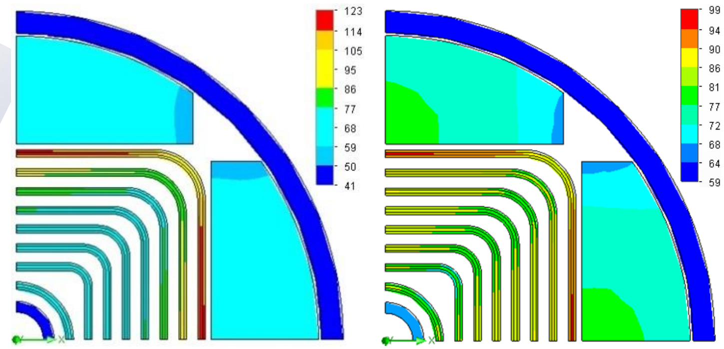
MIR.M1 Reactor. Test of Research Reactor Fuel

(Proceedings of RERTR 2016 - 37th International Meeting on Reduced Enrichment for Research and Test Reactors, 23-27 October 2016, Antwerpen, Belgium, CD)



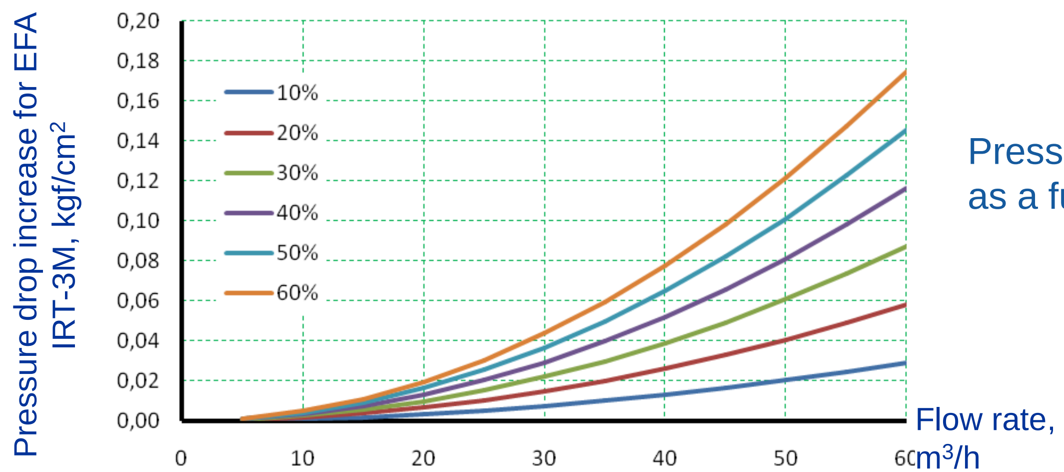
a) *b)*

General view of experimental fuel assembly IRT-3M (a) and experimental channel with EFA (b)



a) *b)*

Temperature distribution in the cross section of EFA IRT-3M and experimental channel a) burnup = 0 %; b) burnup = 60%



Pressure drop increase for EFA IRT-3M as a function of burnup range

MIR.M1 Reactor Capabilities for the ATF Development and Justification

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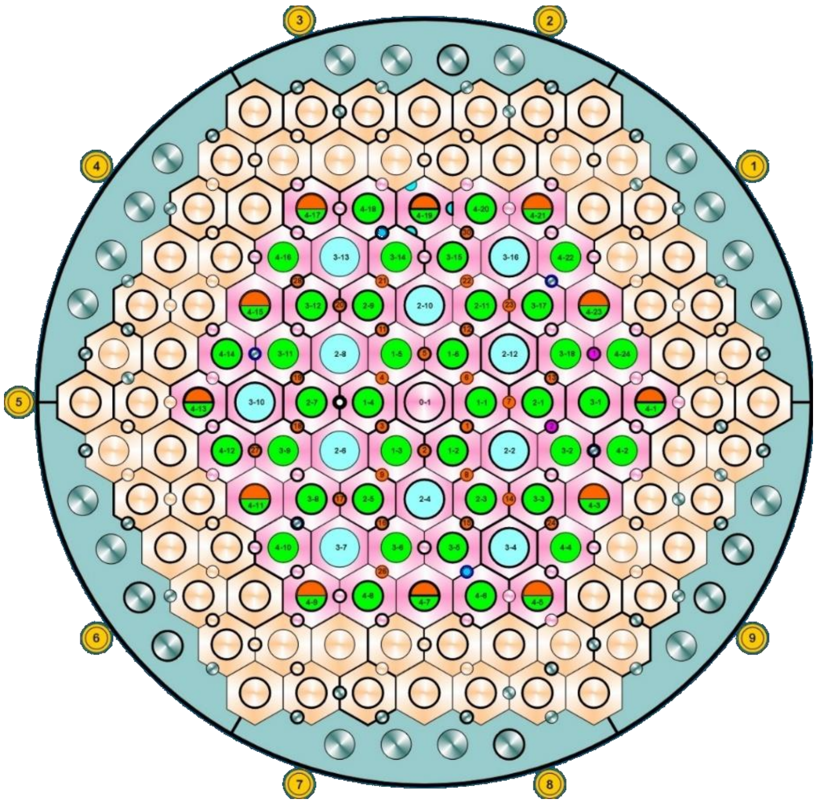
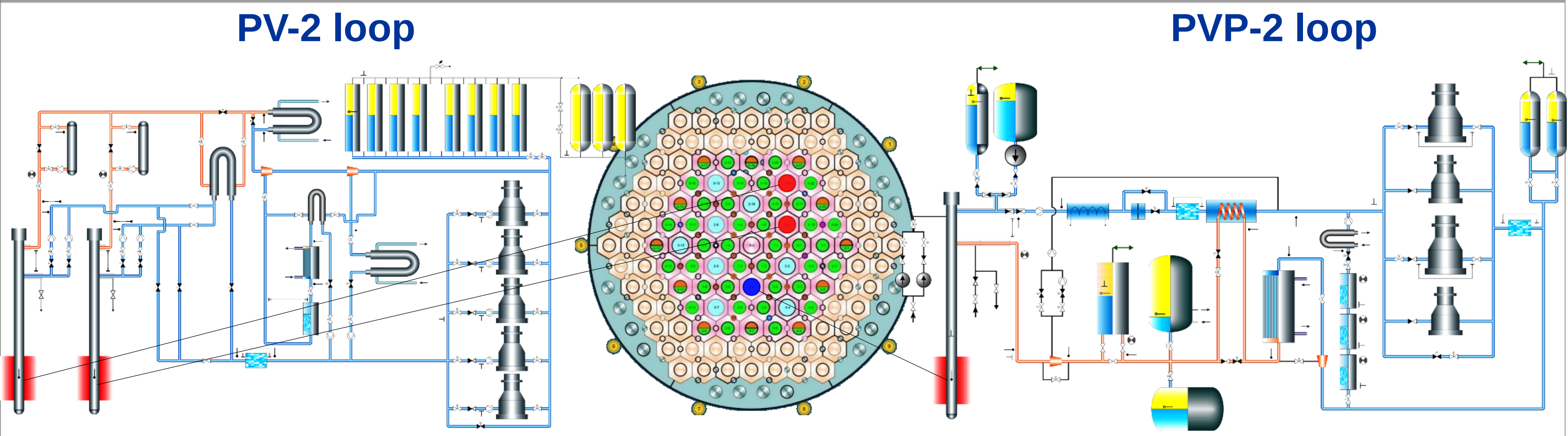


- – operating FA channel
- – experimental channel
- – combined operating FA with absorber
- – control rod channel

Cells for irradiation	up to 49, height - 1100 mm	Neutron flux, $cm^{-2} \cdot s^{-1}$		Kt, dpa/year
		φ (E>0,1 MeV), $cm^{-2} \cdot s^{-1}$	φ, $cm^{-2} \cdot s^{-1}$	
Core	11 cells for loop channels, ∅ ≤ 148,5 mm	$2{,}0 \cdot 10^{14}$	$5{,}0 \cdot 10^{14}$	1,5
Core	38 cells, ∅ ≤ 34 mm	$3{,}0 \cdot 10^{14}$	$5{,}0 \cdot 10^{14}$	5,0

MIR.M1 Reactor Capabilities for the ATF Development and Justification

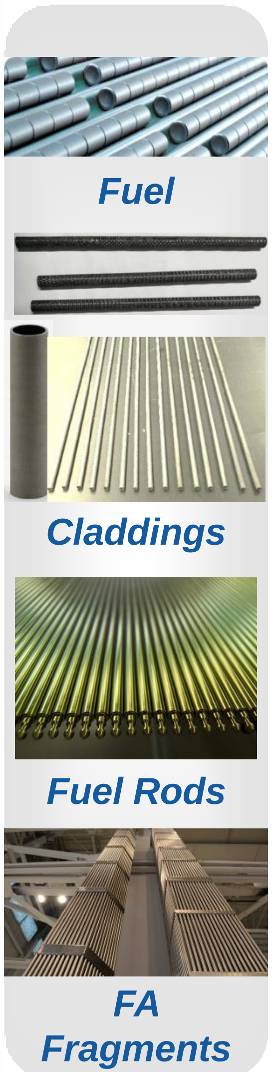


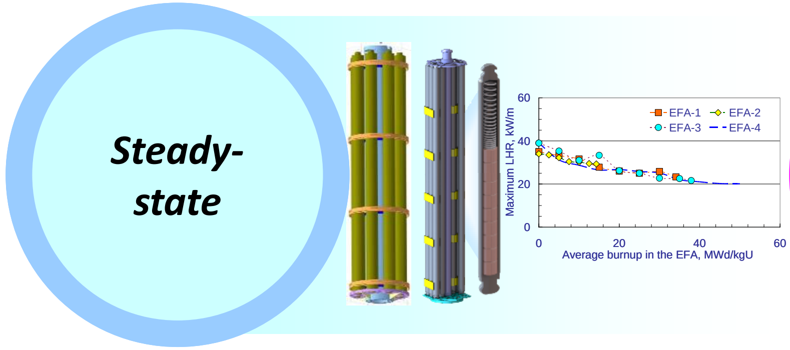
PV-2 Loop	Key Parameters	PVP-2 Loop
1500	Max channel capacity, kW	2000
350	Max coolant temperature, °C	550
17,8	Max pressure, MPa	20,0
16,0	Max flow rate through the channel, t/h	10,0

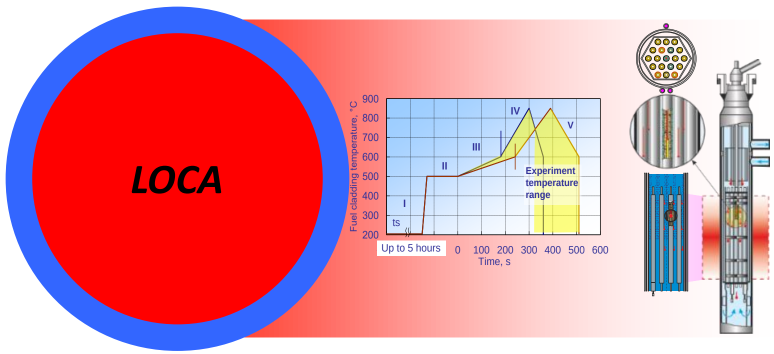
- ✓ Chemistry control and measurement systems of water environment for ampoule rigs
- ✓ Fission products monitoring and measurement facilities
- ✓ Loop systems for simulation of PWR and WWER conditions including water chemistry

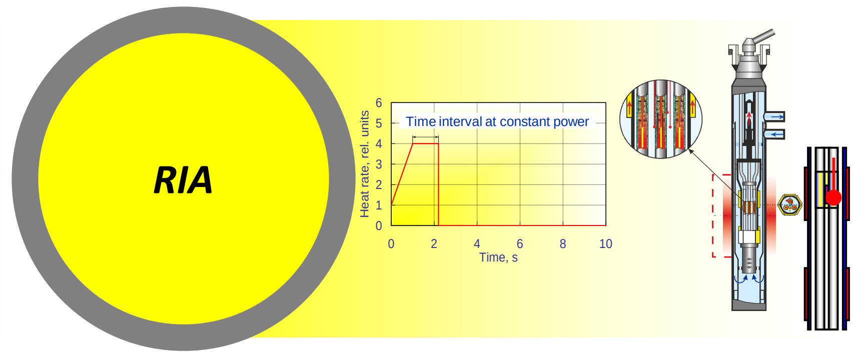
MIR.M1 Reactor Capabilities for the ATF Development and Justification

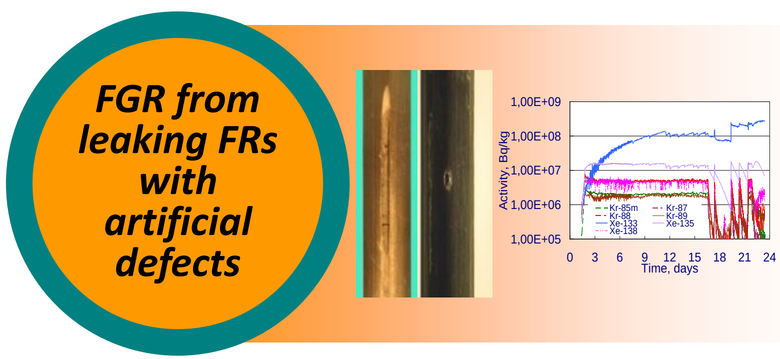
Testing and PIE complex

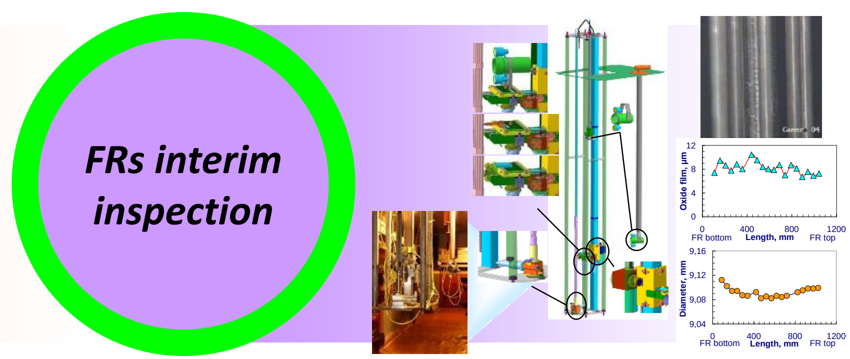












Formation of an International Team of Researchers

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RIAR's Proposal:

Development and implementation of coordinated International R&D Program for Experimental Justification of Accident Tolerant LWR Fuel (using the RIAR's ICERR research infrastructure)

Potential Stakeholders:

- National R&D Organizations (Russia, France, S.Korea, Japan, Argentine, US and others)
- Fuel vendors and NPP's Operators, Regulatory Authorities
- International Organizations (IAEA, OECD NEA etc.)

RIAR's Proposal on International Research Project Approaches:

First step (~1,5 years):

- Evaluation and assessment of the technical capabilities of the MIR Reactor, analysis and selection of the most suitable experimental loop facilities, the design of irradiation rigs, the characteristics of testing fuel rods and their sensors
- Development of coordinated International R&D Program for irradiation tests and PIE of structural and / or fuel materials proposed for the LWR Accident Tolerant Fuel (ATF)

Second step (~2,5 years):

- Implementation of the International R&D Program: Irradiation test (MIR Research Reactor) and PIE (RIAR's Reactor Materials Testing Complex)

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CONCLUSIONS

The designation of RIAR as the IAEA **I**nternational **CE**ntre based on **R**esearch **R**eactors (ICERR) in 2016 marked the worldwide recognition of RIAR’s unique competencies and broadest experimental capabilities and confirmed the readiness of RIAR’s infrastructure and specialists for further expansion of both international and bilateral technical cooperation with foreign partners.

The prospects are marked and certain proposals have been outlined to implement joint research projects based on test reactor MIR.M1.

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Thank you for your attention!

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