Calorimetric measurement of irradiation positions in the core of the LVR-15 reactor

CORE-2025
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Tomáš Melichar, Jaroslav Šoltés, Petr Hájek, Marek Mikloš

CVŘ Research Centre Řež

CICRR Czech International Centre of Research Reactors

UJV Group PEOPLE | INNOVATION | TECHNOLOGY

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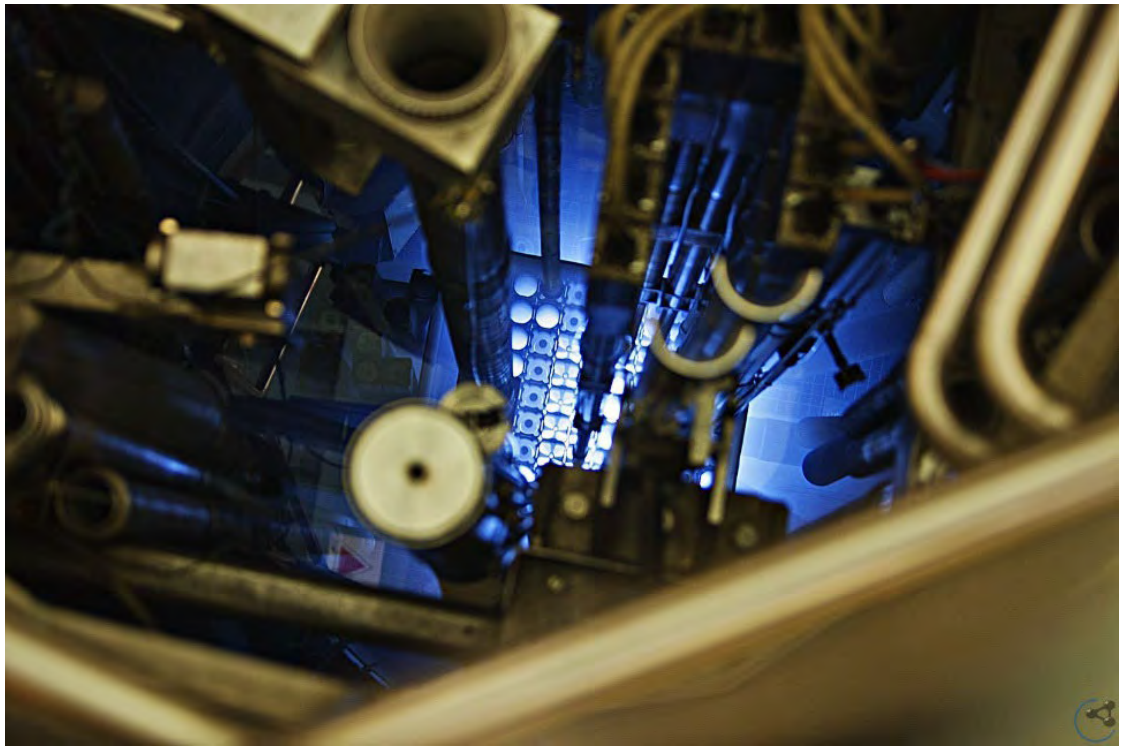
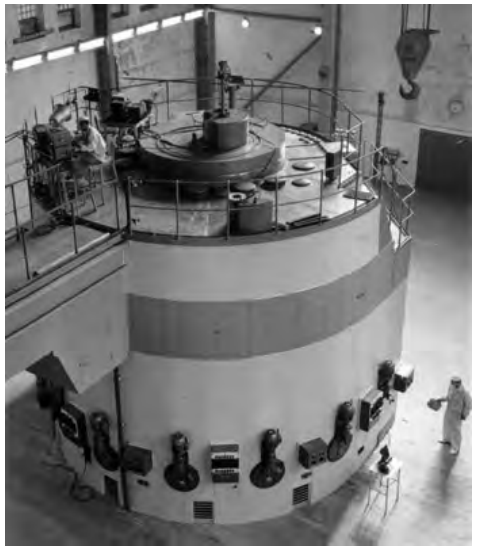
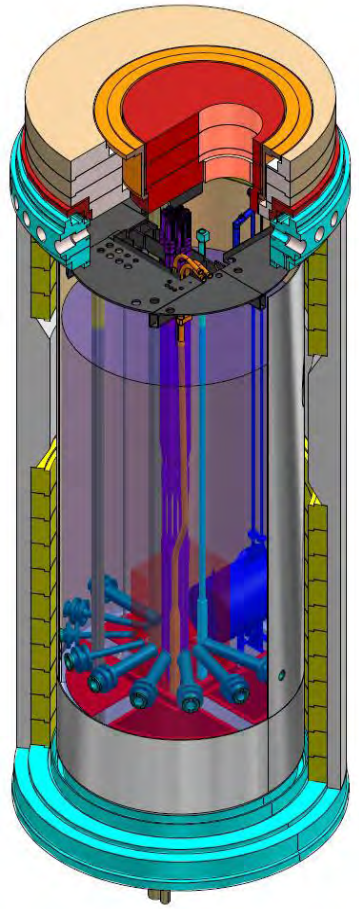


Research Reactor LVR-15

- Material research, e.g. the irradiation of reactor pressure vessel materials
- Corrosion testing of materials of reactor primary circuit and internals carried out in experimental loops
- Qualification of components in radiation fields (neutrons/gamma)
- Basic research of material properties
- Manufacture of semiconductors by neutron transmutation doping of silicon for the electrical industry
- Production and development of radiopharmaceuticals

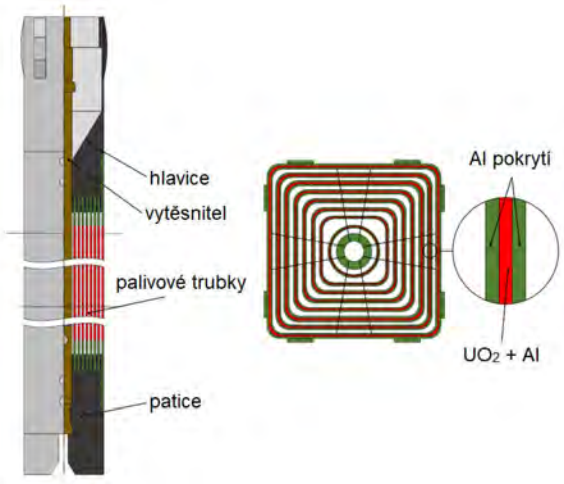


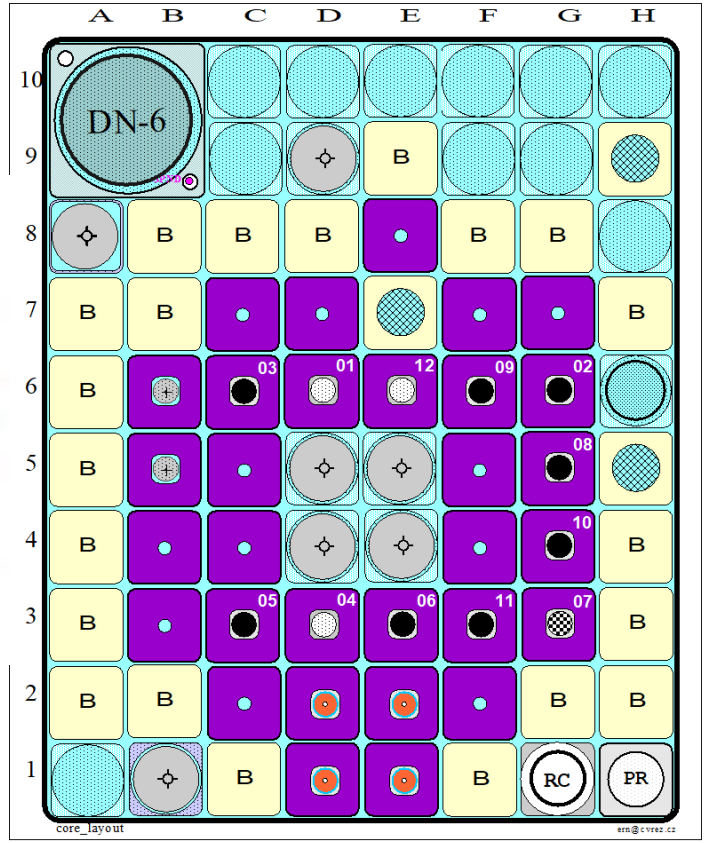


The presented results are obtained using the CICRR infrastructure, which is financially supported by the Ministry of Education, Youth and Sports - project LM2023041.

Research Reactor LVR-15

- In operation since 1989 in place of the former VVR-S reactor (1957 – 1986)
- A research light water moderated reactor with forced cooling water circulation
- Be reflector around the fuel
- Thermal output: max. 10 MW
- Total neutron flux density
  - At core center: up to 4 x 10^{14} n/cm^{2}s
- Maximum thermal neutron flux density
  - At core center : up to 2.5 x 10^{14} n/cm^{2}s
  - In the irradiation channel in the fuel: 1 x 10^{14} n/cm2s
  - In the irradiation channel in the reflector: 3-5 x 10^{13} n/cm^{2}s
- Reactor operation until the end of the decade, further operation extension depends on ageing management and developement in Europe‘s research reactor fleet





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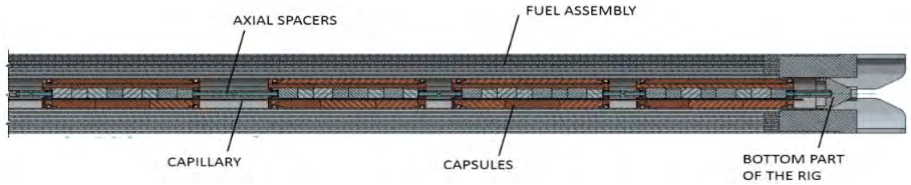
OKaP type rigs

Irradiation rigs designed to achieve high neutron fluences / radiation damage (dpa), to study nuclear fuel cladding and construction materials.

- Rig placed into fuel assembly of LVR-15 reactor
- Temperature reached by interaction of gamma and neutrons with the samples body, online measured by TC's and controlled by proper gas mixture (He+N2)

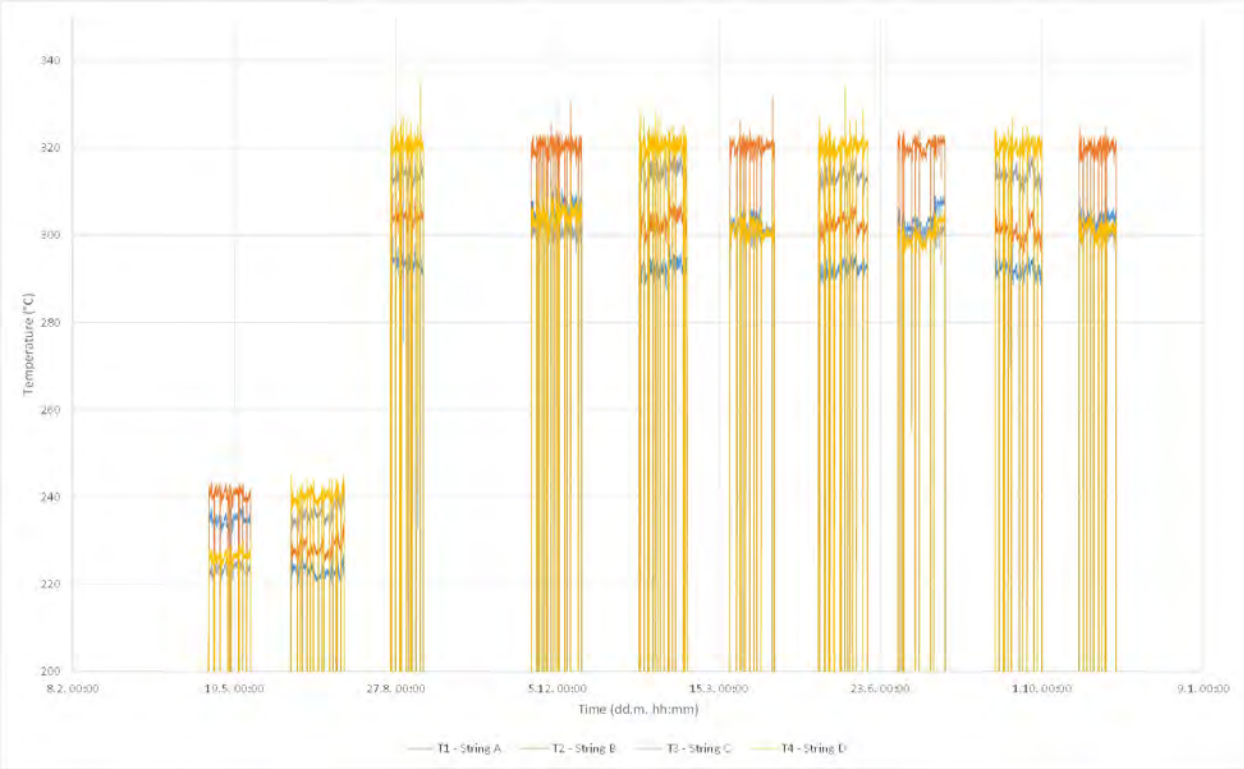


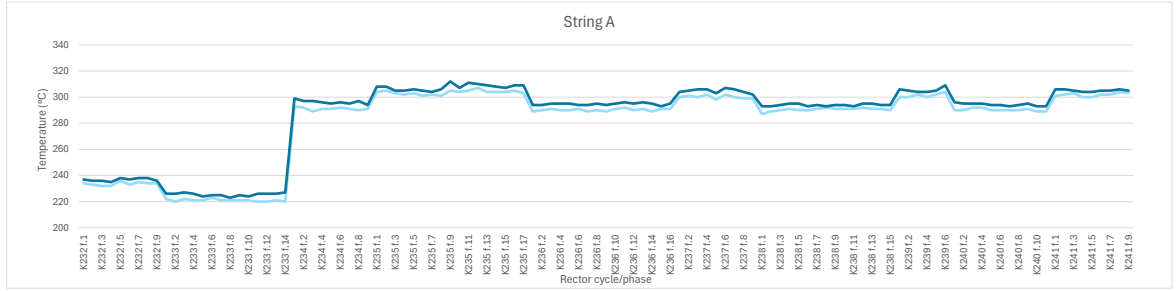
INCA project: In-pile creep studies of ATF claddings

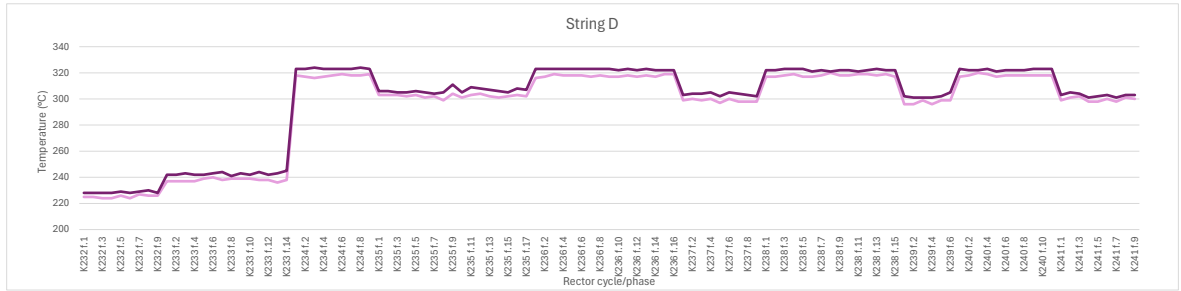
- Under FIDES-II framework
- Timeline: 2021-2030
- First OKaP rig with 4 TCs located in the upper level; non uniform temperatures were generated (need for rig rotation) – inconsistent with the calculation model

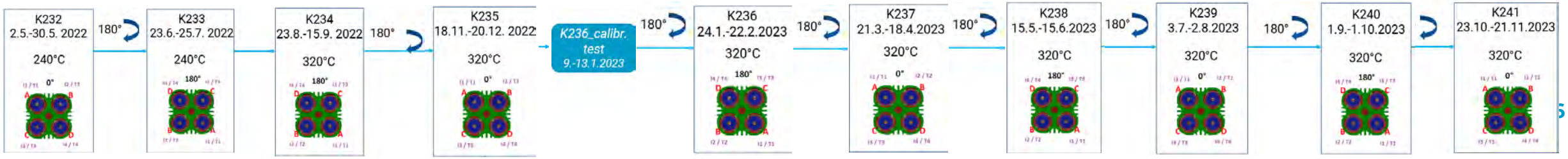
https://www.oecd-nea.org/jcms/pl_70363/in-pile-creep-studies-of-atf-cladding-inca-joint-experimental-programme-jeep

First OKaP rig irradiation experiences



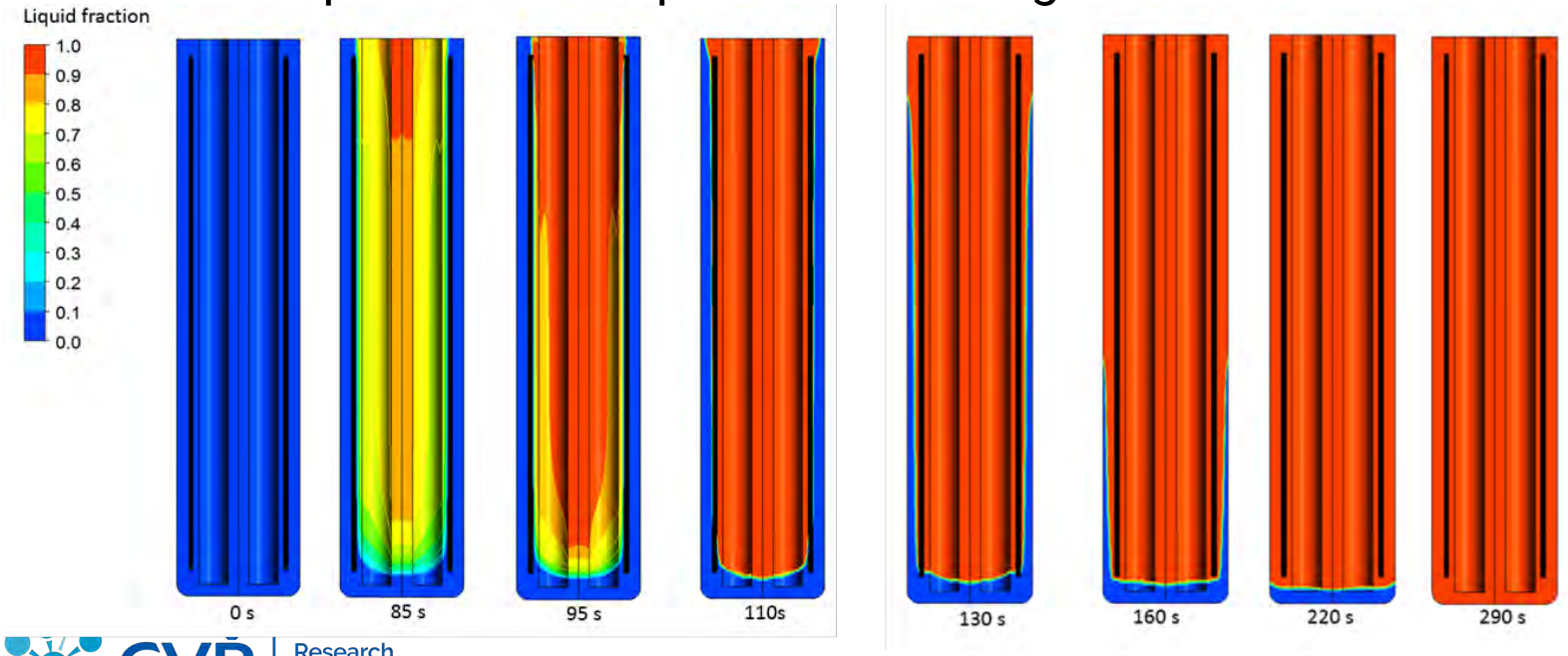


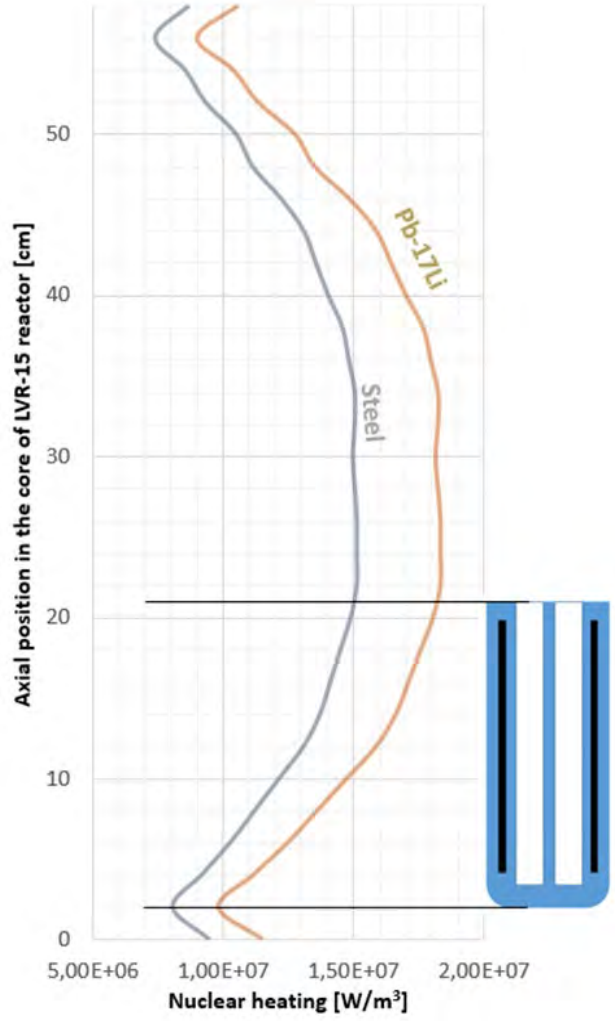




Other irradiation rigs – PbLi rig

- Pb-Li Irradiation rig for tritium permeation barriers testing
- Operational temperature 280 – 450 °C (90% of N2 need; calculation indicated, however, only 50%)
- Melting of Pb-Li in the rig during startup, gamma heating profile needed to predict development of melting

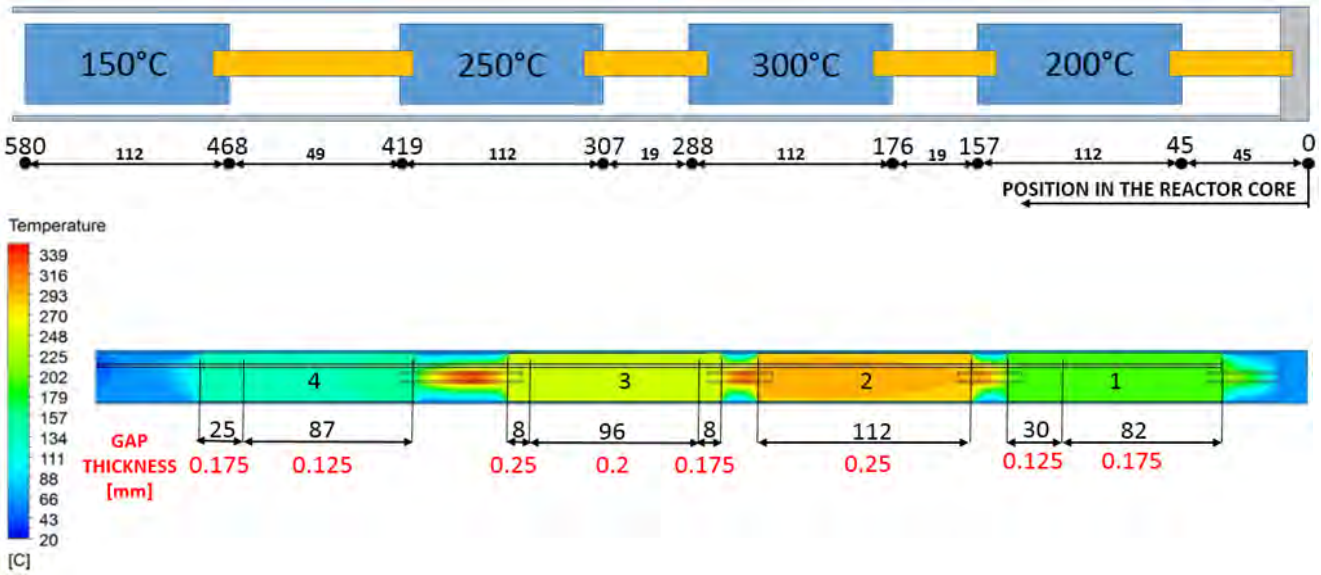




Other irradiation rigs – CuCrZr rig

- Requirement on various temperatures at each axial position / sample
- Precise knowledge of gamma heating profile needed
- Discrepancy between design and measurement

DESIGN



MEASUREMENT	138 °C	244°C	239°C	150°C

Temperature distribution in OKaP rig

Temperature measurement results of the 5-day calibration test.

Measured temperature

	Day 1			
	Pos A	Pos B	Pos C	Pos D
Level 1			344	
Level 2	341	341		
Level 3				307
Level 4	310	320	299	302

	Day 2			
	Pos A	Pos B	Pos C	Pos D
Level 1	366			
Level 2		351		332
Level 3			319	
Level 4	329	325	315	319

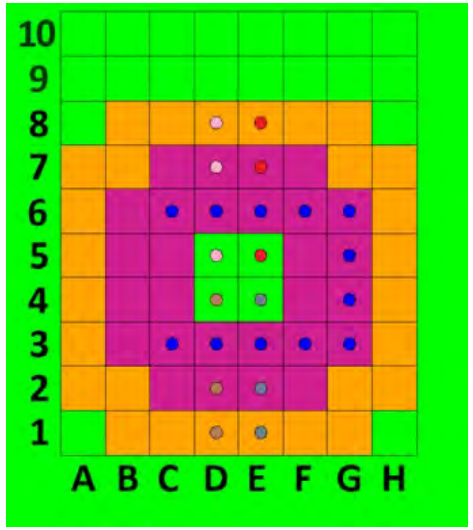
	Day 3			
	Pos A	Pos B	Pos C	Pos D
Level 1		370		
Level 2			327	331
Level 3	326			
Level 4	323	322	310	302

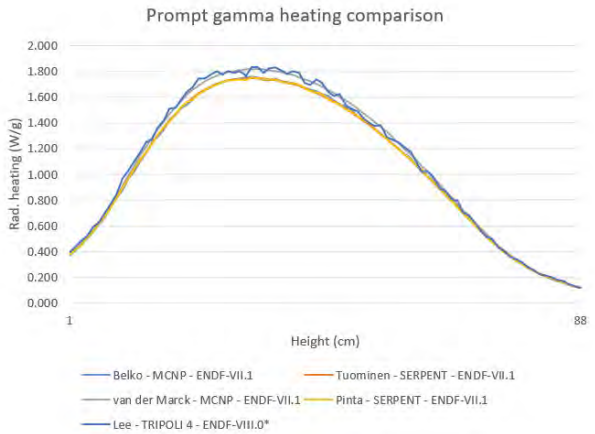
	Day 4			
	Pos A	Pos B	Pos C	Pos D
Level 1				352
Level 2	346		329	
Level 3		328		
Level 4	324	321	301	307

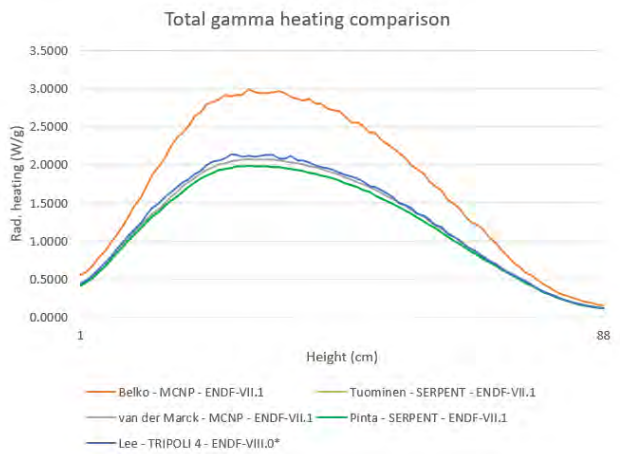
	Day 5			
	Pos A	Pos B	Pos C	Pos D
Level 1	373			
Level 2		356		337
Level 3			320	
Level 4	330	327	315	320

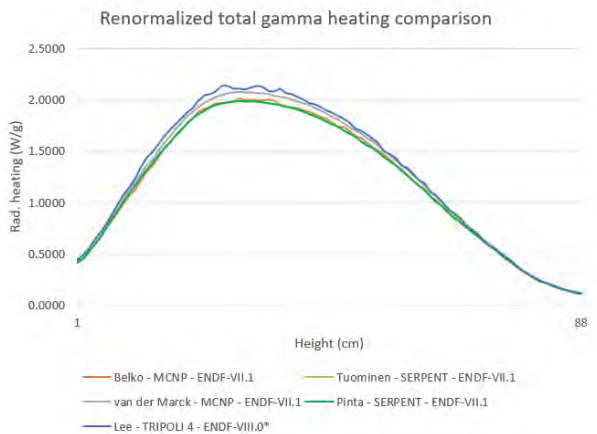
Temperature distribution in OKaP rig

A set of radiation heating calculations from the MCNP code through the whole history was performed. A temperature distribution model for the samples and heaters were prepared -> international Simulation and Modeling Exercise was done under FIDES-II framework (CVR, UJV, VTT, CEA) using the MCNP, Serpent2, TRIPOLI4 codes.









One source of inaccuracy was lifted (overestimated heating), but the axial distribution remained an issue. Therefore, a axial shift calorimetry measurement was proposed

Calorimetric measurement of irradiation positions in the core of the LVR-15 reactor

Collaboration with CEA, where:

- CEA is responsible for design and delivery of calorimeter and ionization chamber
- CVR is responsible for design and manufacturing of the moving system and experimental measurement

Main objectives

- Design and subsequent production of two automatic moving devices.
- Out-of-pile test of the moving device and the ionization chamber/calorimeter.
- In-pile test during the outage to verify the functionality of the entire assembly.
- Measurement and evaluation of gamma heating at positions D2, D1, E7

Measurement and Expected Outcomes

Measurement Activities

- Gamma heating measurements at positions D2, D1, E7.
- Verification of positioning accuracy and repeatability.
- Assessment of torque requirements for ionization chamber and calorimeter movement.
- Evaluation of cable routing and smooth operation.

Expected Outcomes

- Reliable data on gamma heating distribution (total and axial), and its evolution during the whole reactor cycle.
- Confirmation of mechanical and operational integrity of positioning systems.
- Identification of optimal motor specifications for automated movement.
- Validation of system readiness for reactor installation.

Timeline and project Deliverables

Timeline

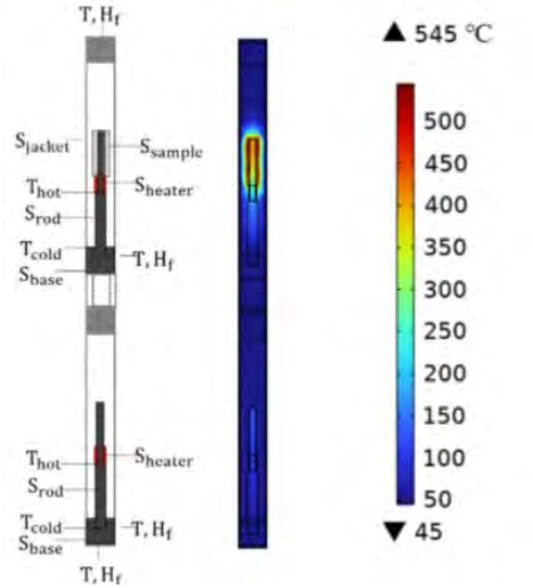
- 06/2026 – 04/2027
- Already ongoing regular meetings with CEA to discuss the interfaces between moving system and calorimeter/ionization chamber

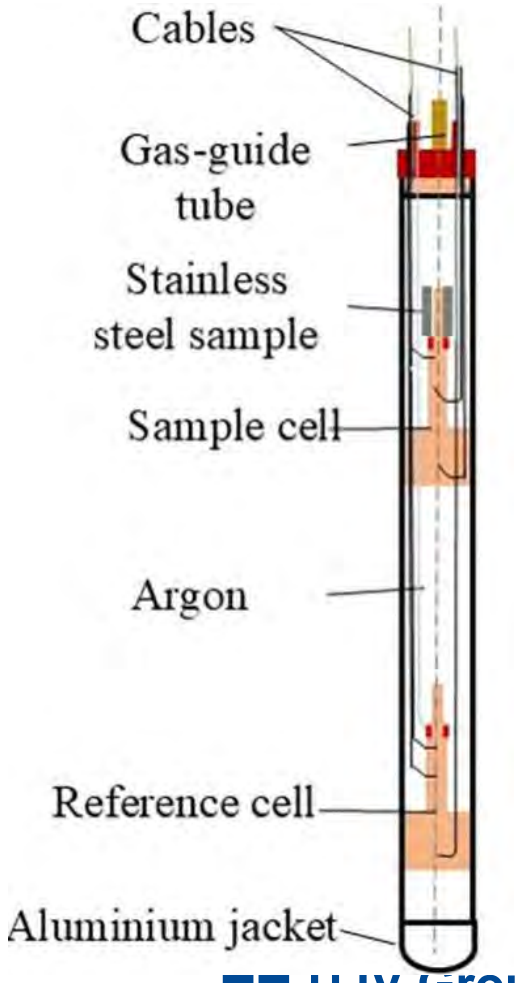
Deliverables

- Detail design of the moving system and brief description of calorimetry and ionization system
- Report from the measurement
- Scientific publications: RRFM, IGORR, FIDES-II

Calorimeter design and development

- Technology of differential calorimeter was selected by CEA
- Measurement of temperature in sample and reference cell, calibration using implemented electrical heater, comparison with thermal model
- Possibility to measure gamma heating in various materials
- The design exists, but must be adapted to LVR-15 conditions (gamma heating values 0 – 3 W/g, geometric parameters)

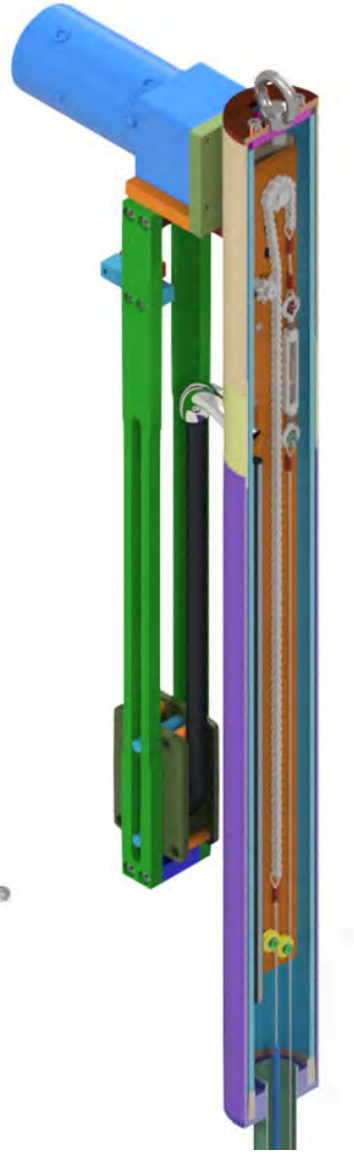




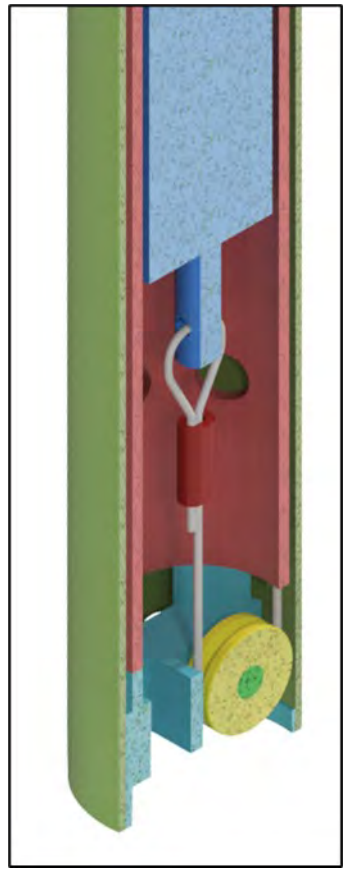
Calorimeter design and development

- Axial positioning of calorimeter must be ensured for two reasons:
  - To measure at both sample cell and reference cell at the same position
  - To enable measurement along the entire height of the core
- CVR develops axial moving mechanism to ensure movement 0 – 70 cm
- The proposed system is based on the principle of pulleys and chain wheels
- The system will be assembled, tested and calibrated out-of-pile, then optimized and used in the LVR-15 reactor

UPPER PART OF THE MOVING SYSTEM



BOTTOM PART OF THE MOVING SYSTEM



Conclusions

Preparation works in progress

First demonstrator unit of the movable system fabricated

First tests and optimization works ongoing

Larger progress expected in the second half of 2026 when the calorimeter is integrated with the movable system

Thank you