CZECH EXPERIMENTAL PROGRAM IN MOLTEN SALT REACTOR PHYSICS

presented by

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Outline:

- History of MSR technology development in the Czech Republic, influence of MSRE on present Czech R&D activities
- Main results of existing Czech MSR projects
- MSR/FHR collaborative program with US-DOE
- Current status of experimental program in MSR physics and future directions

Influence of MSRE on existing Czech R&D activities

Prominent Czech activities in the area of R&D on GEN IV reactor systems have been devoted to MSR technology and pyrochemical partitioning.

- Decision to develop selected technologies of MSR system and to resume on the ORNL effort from 1960s was made in 1999
- Ministry of Industry and Trade has been supporting the R&D program since 2000

We gradually identified ourselves with the idea of Eugene Wigner, Alvin Weinberg and Raymond Clare Briant that nuclear reactors should be understood as physical-chemical systems – nuclear reactor is a chemical plant – "*the ultimate rationalization is to be sought in simplifying the handling and reprocessing of fuel.*"

- ***This opinion was significantly influenced by our personal discussions in 1998 - 2002 with A. Weinberg, L. Mac Toth, J.R. Engel and D.F. Williams from ORNL, Ch. Bowman from LANL, with K. Furukawa from Japan and with A. Lecoque and H. Mouney from France.***

History of R&D of MSR technology in the Czech Republic

R&D on MSR technologies was realized under the project “SPHINX” by the consortium of Czech R&D institutions and industrial companies leaded by the Nuclear Research Institute Řež (today ÚJV Řež, a.s.). Other members of the consortium were Research Centre Řež, ŠKODA Nuclear Machinery, COMTES FHT, Enregovýzkum Brno, Czech Technical University Prague and Institute of Nuclear Physics

Main sense of the program:

- **To appropriately contribute to the knowledge of MSR reactor physics, core design and safety, structural material development and Th – U fuel cycle**
- **To focus on R&D of technologies applicable within the MSR on-line reprocessing of liquid fuel**
- **To verify experimentally selected important areas of MSR technology and to solve existing bottlenecks**

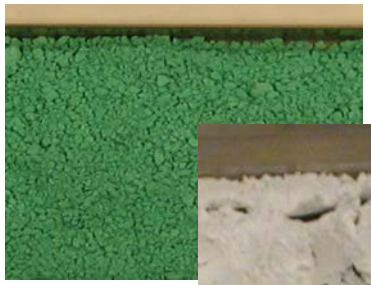
Czech scientists and researchers also actively participated in several MSR projects of EC-EURATOM, IAEA and Gen-IV.

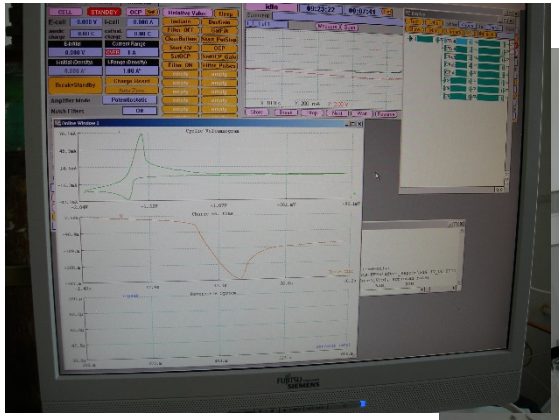
Main results achieved in the R&D on MSR technology - 1

- Development of the Thorium – Uranium Fuel Cycle covered both the verification of MSR liquid fuel processing ($LiF-BeF_2-UF_4$ and $LiF-BeF_2-ThF_4$) and the laboratory investigation of on-line reprocessing technology

Processing of pure UF_4 and ThF_4

Preparation of liquid fuels and preparation of pieces of $LiF-BeF_2-UF_4$ salt disposable for LR-0 reactor inserted probes





Investigation of electrochemical separation processes from molten fluoride salts applicable for MSR on-line reprocessing technology

Main results achieved in the R&D on MSR technology - 2

- Development of structural material for MSR technology, which was realized by ŠKODA JS - Nuclear Machinery in collaboration with COMTES FHT company, was in 2011 crowned by experimental production of tubes and sheets from new nickel-alloy called MONICR (Ni-Mo-Cr type super-alloy)

Present development of MONICR alloys is under way in the COMTES FHT company in the collaboration with other companies including the Research Centre Řež.

The composition of original MONICR alloy is:

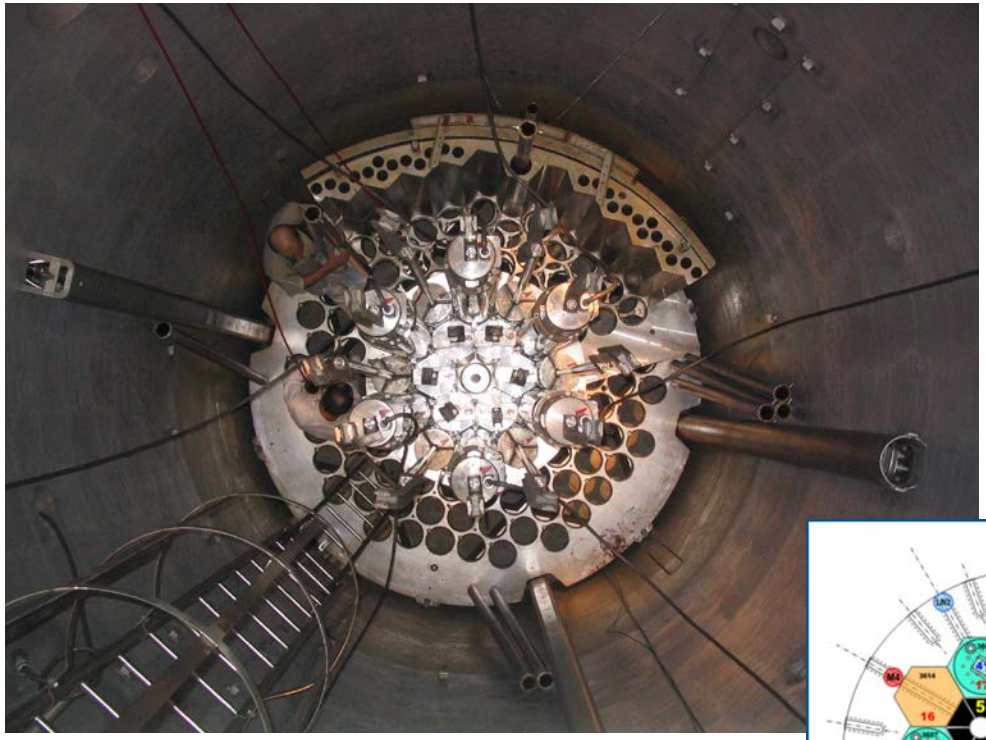
Ni	Mo	Cr	Fe	W	Al	Ti	C	Co, Nb, Zr
bulk	13.2 %	6.85 %	2.27 %	< 0.1 %	< 0.1 %	< 0.1 %	< 0.1 %	< 0.1 %

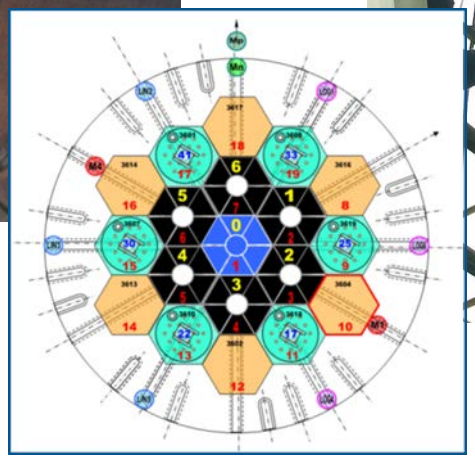
COMTES FHT company reached the experimental pilot production of MONICR alloy (ingots, sheets, wires, tubes).

Further development of MONICR alloys is in progress.

Main results achieved in the R&D on MSR technology - 3

- Investigation of MSR physics was focused on the experimental measurement of fluoride salt neutronics in the LR-0 and LVR-15 reactors of the Research Centre Řež. Basic principles of the method of measurement were successfully verified and selected neutronic data of several fluoride salt mixtures containing U and Th were obtained by irradiation of instrumented probes inserted into central part of LR-0 reactor core where the standard VVER fuel assemblies served as neutron driver





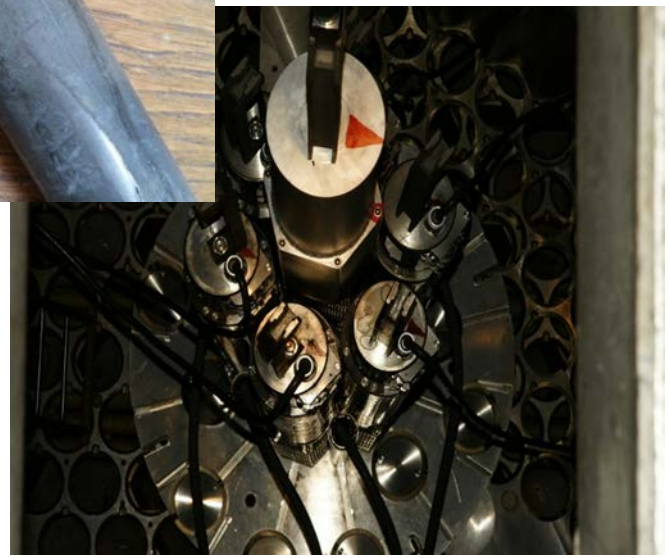
Inserted zone with fluoride salt in LR-0 reactor

Present activities:
MSR/FHR collaborative program with US - DOE

Main current and future activities come from the bilateral agreement concluded in 2012 between the Ministry of Industry and Trade of the Czech Republic and the US – Department of Energy regarding the collaborative R&D on FHR and MSR technology.

Based on this agreement, in 2013 ORNL transferred about 75 kg of original MSRE coolant salt (^{7}LiF-BeF_2) to Řež for experimental in-core neutronic studies (Evaluation of reactivity coefficients of MSR/FHR fluoride salt).

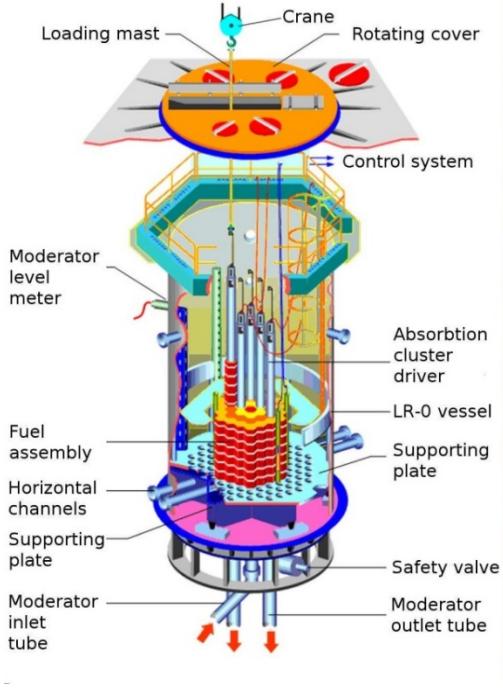
Present activities in the Research Centre Řež directed to the FHR / MSR reactor physics

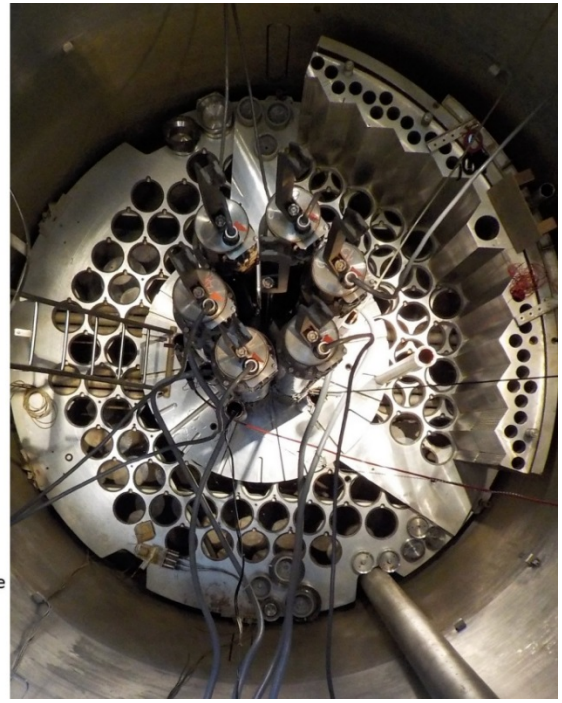


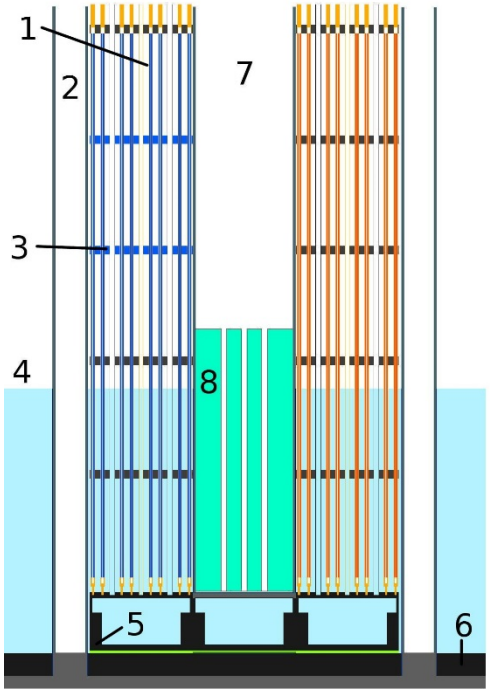
- Transport of the container with FLIBE salt
- Siphoning of the melted salt from the transport container into the probes (inserted zones)
- Inserted zone with FLIBE Li-7 in LR-0

Measurement of neutronics in LR-0 reactor

The experiments are intended as benchmarking data source to validate calculation codes intended for the MSR / FHR design. LR-0 reactor offers enough space and possibilities for such experiments, effectively limited only by its maximum thermal power, which is 5kW.







1 Fuel
2 Dry instrumentation channel
3 Spacing grid
4 Moderator level
5 Fuel nest
6 supporting plate
7 Dry experimental channel
8 Graphite insertion

The experiments are configured as an “inserted zone”, i.e. the experimental device will be inserted to the center of conventional reactor core replacing one or more fuel assemblies. The materials inserted and their geometry are as similar as achievable to the intended MSR / FHR design.

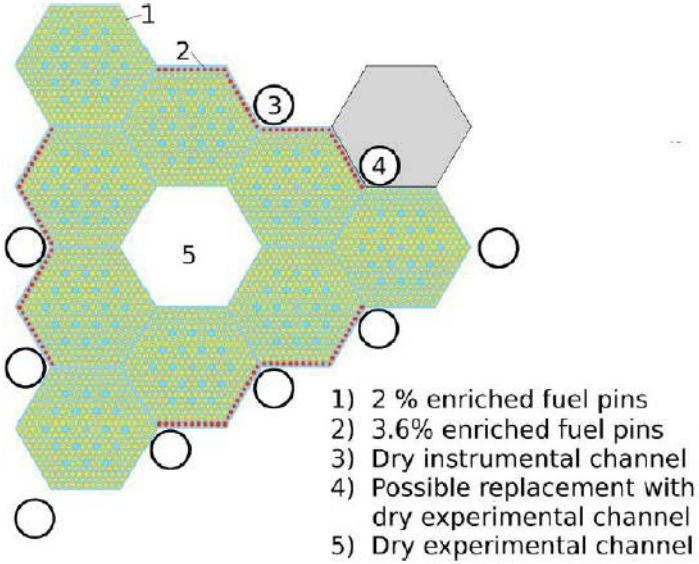
The whole project is divided into several stages regarding the problem complexity. The measurement was preceded by a “stage zero tests” using LiF-NaF and LiF-BeF_2 *(nat. Lithium)* mixtures in different geometries.

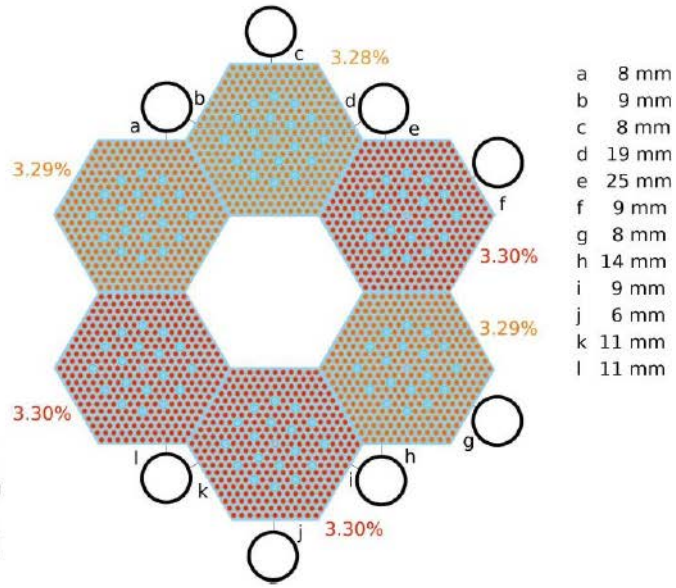
Goals of MSR / FHR experiments at LR-0

- Design of highly sensitive cores
- Methodological measurements
- Critical experiments
- Neutron spectrum measurements
- Temperature feedback investigation

Design of highly sensitive cores

- **High water level response on small reactivity change**
- **Cores designed and experiments performed in 2013-2015**
- **Investigated materials: MSR construction parts - FLINA salt and graphite**



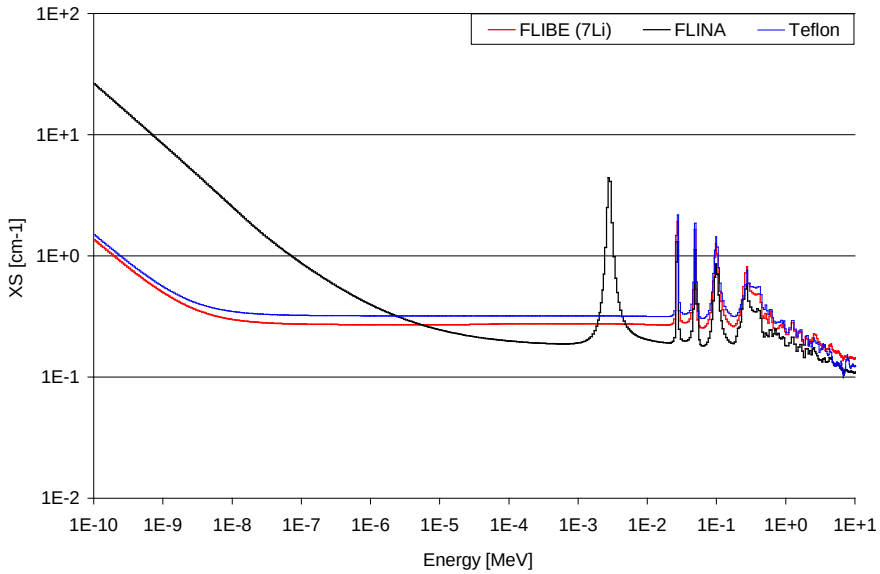


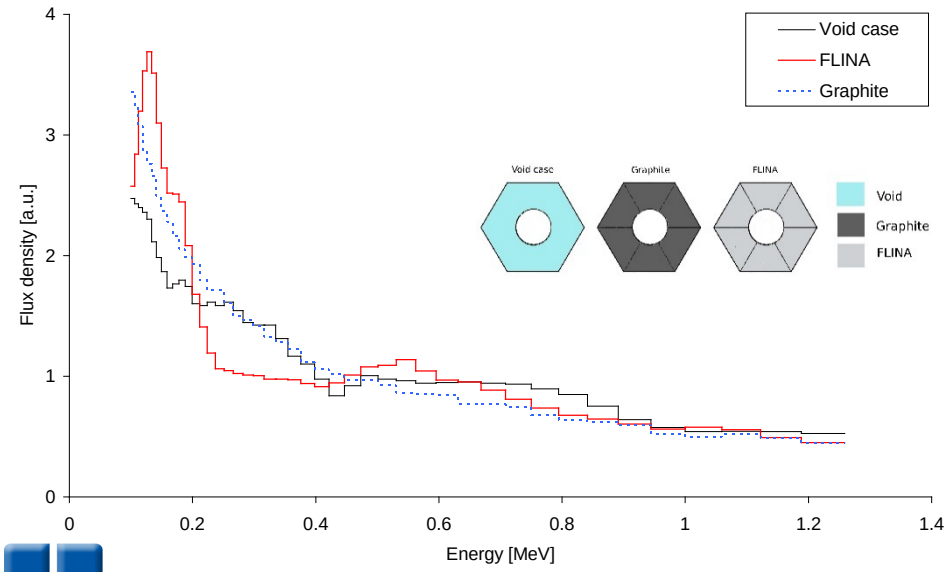
Neutronic parameters of a low enrichment core in reactor LR-0 for MSR research,
Kostal et al, Annals of Nuclear Energy, 75, (2015), pp 316-322

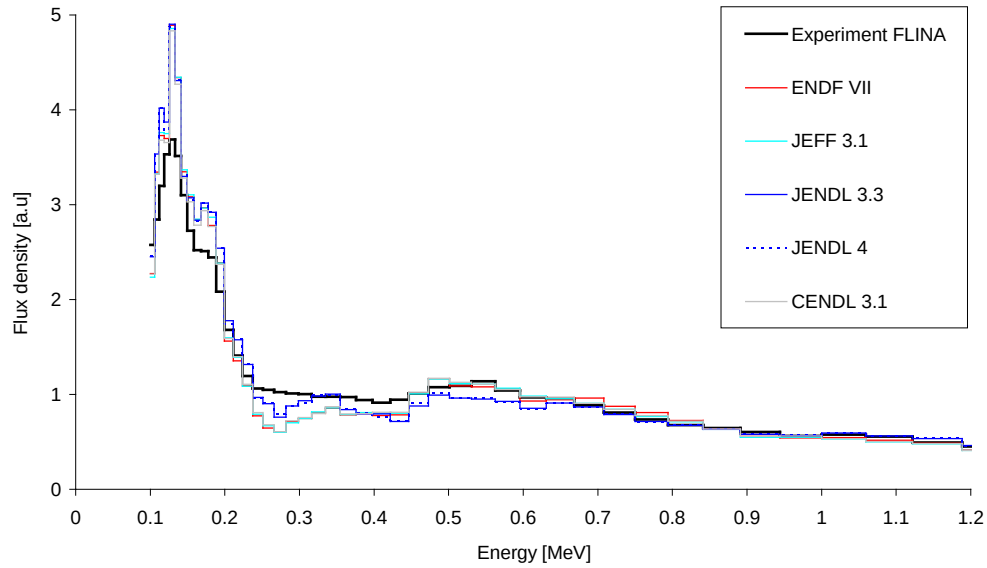
Comparison of fast neutron spectra in graphite and FLINA salt inserted in well-defined core assembled in LR-0 reactor
Kostal et al, Annals of Nuclear Energy, 83, (2015), pp 216-225

Effect of inserted fluoride salts on criticality in the LR-0 reactor
Losa et al, Annals of Nuclear Energy, 81, (2015), pp 18-25

Methodological measurements with FLINA



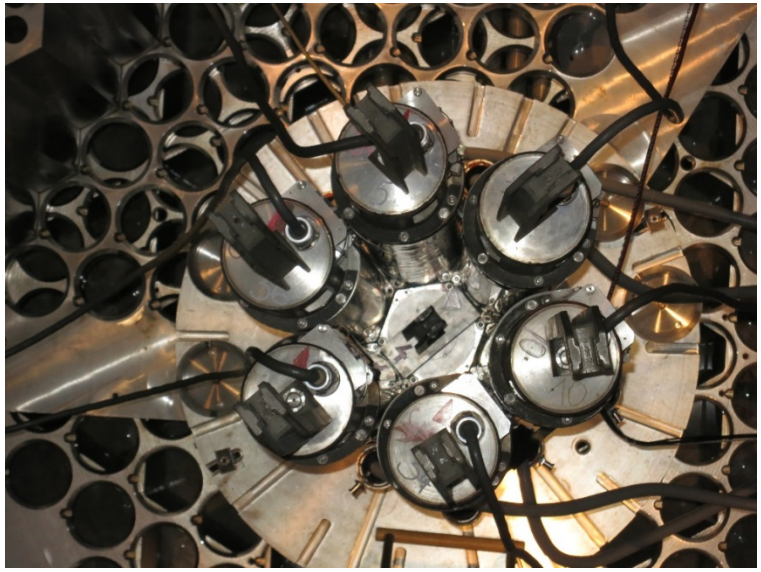




Critical experiments with FLIBE salts at LR-0

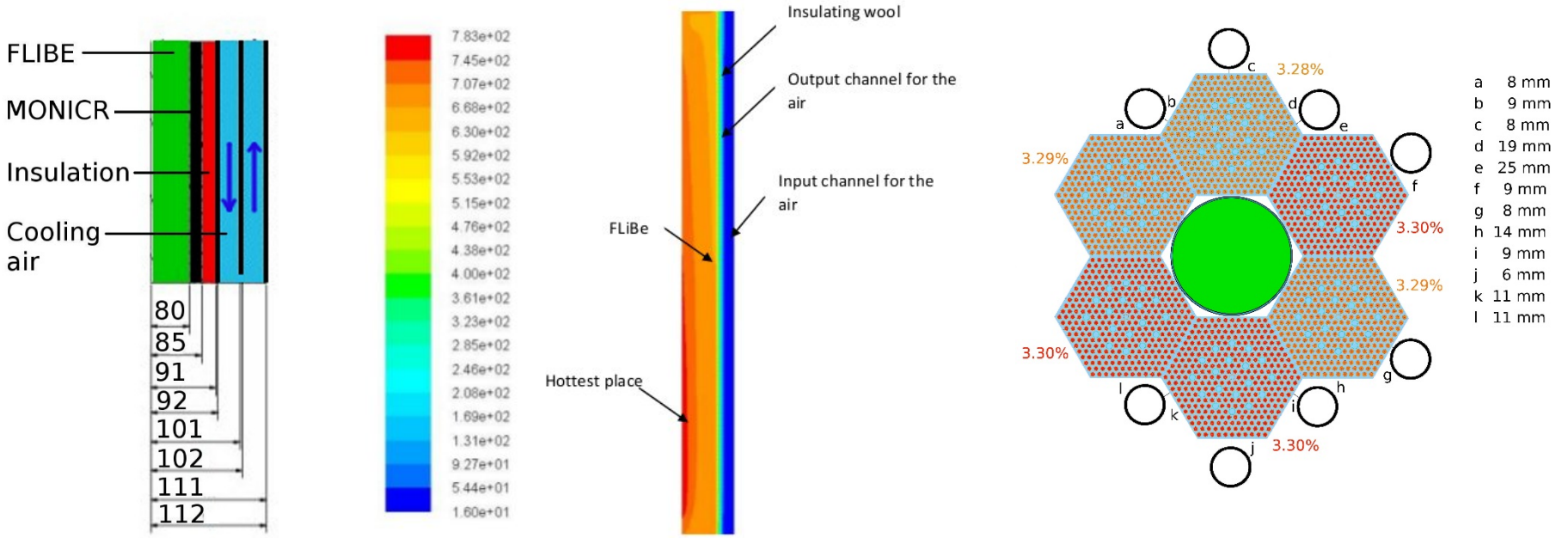
Tests with new sample and comparison of inserted reactivity

Case	Critical height
Empty dry channel	486.6 mm
Cask insertion	489.2 mm
$^{nat}LiF\text{-}BeF_2$ sample	507.9 mm
$^{7}LiF\text{-}BeF_2$ sample	488.9 mm



Temperature feedback investigation

- **Predesign based on accessible materials**
- **Criticality and CFD simulations of temperature field in capsule**



- **Reactivity change between hot state with calculated temperature distribution and cold state differs by few tens of pcm**

Conclusions

- Ability of small reactivity measurements at LR-0 was proved
- Discrepancy in nuclear properties of fluorine discovered (further investigation planned in 2016)
- Preliminary design of heated capsule done
- Amount of FLIBE salt available in Řež would cause reactivity change in order of 30 pcm, which is measurable at LR-0 in investigated core configurations

Future activities should continue in the investigation of selected areas of MSR and FHR technology – mainly of salt cooled reactor physics, molten salt chemistry and technology, further development of structural materials and the molten salt loop program.

Thank you for your attention

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