Centrum výzkumu Řež
Research Centre Řež

FHR neutronics benchmark study and MSR technology development in the Czech Republic

presented by

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Remark to the historical background of R&D on MSR technology in the Czech Republic

Czech MSR program was launched in 2000 under the grant of the Ministry of Industry and Trade (MoIT).

Two most important domestic project in the period of 2000 - 2012 were:

Nuclear system SPHINX with molten fluoride salts based liquid nuclear fuel

- R&D project devoted to MSR technology covering theoretical and experimental activities in MSR physics, fuel cycle chemistry, molten salt thermohydraulics, structural material development and testing of apparatuses for molten fluoride salt media

Fluoride reprocessing of spent fuel of GEN-IV reactors

- R&D project devoted to pyrochemical fuel cycle technologies focused mainly to fluoride separation processes suitable for MSR technology including thorium - uranium fuel cycle and separation of transuranics

Present activities – collaborative project with ORNL on FHR/MSR neutronics benchmark study

Main current and future activities come from the bilateral agreement (Memorandum of Understanding) concluded between MoIT and US-DOE in 2012 regarding the FHR and MSR technology.

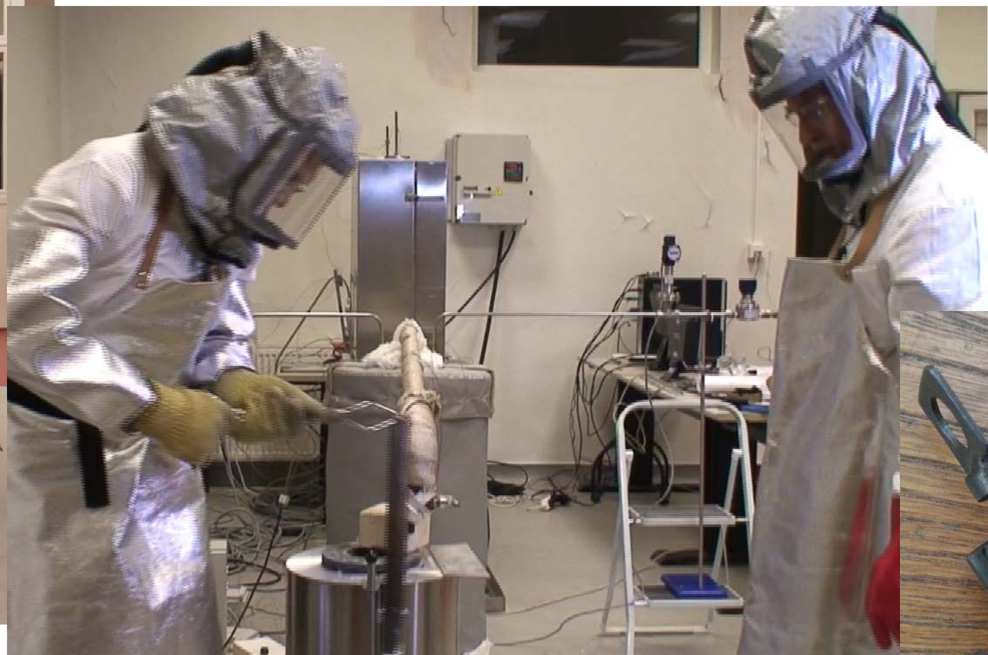
Based on this agreement, in 2013 ORNL shipped about 75 kg of coolant salt FLIBE (^7LiF-BeF_2) to Řež for experimental in-core neutronic studies (Evaluation of reactivity coefficients of FHR/MSR fluoride salt).

Collaborative R&D on FHR and MSR technology

Collaborative project is focused on the study of FHR/MSR neutronics:

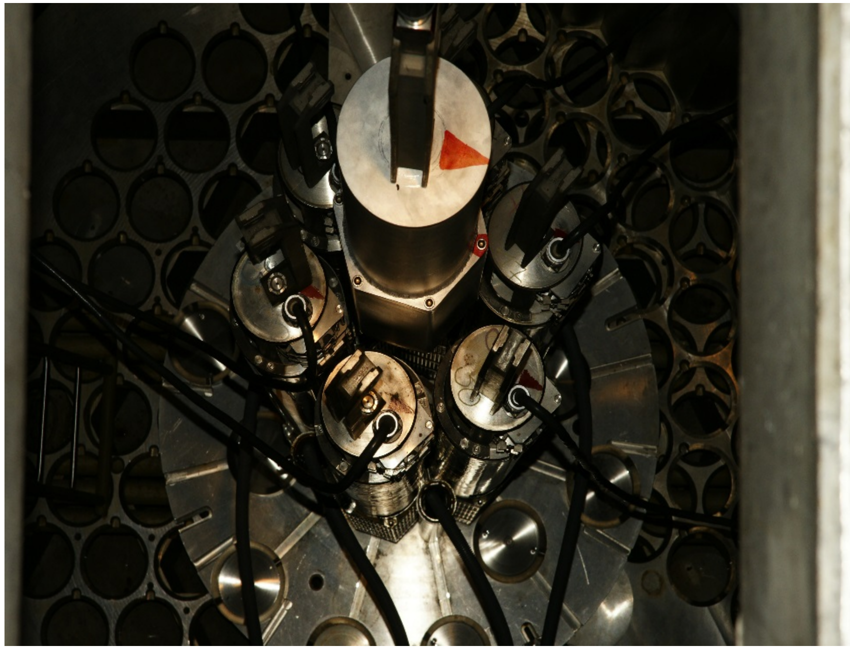
“Evaluation of reactivity coefficients of FHR/MSR fluoride salt”

The experiments are realized at LR-0 experimental reactor in RC Řež. The salt for the experiments is highly enriched $^{7}LiF\text{-}BeF_2$ (FLIBE) originally used as a coolant of MSRE.



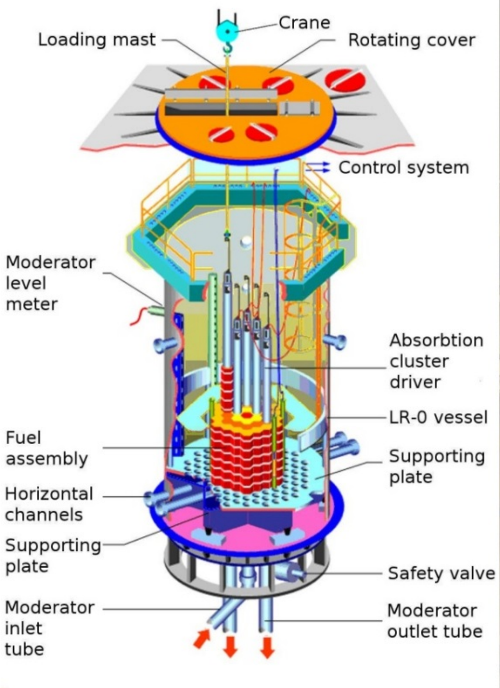
FHR and MSR inserted experimental cores

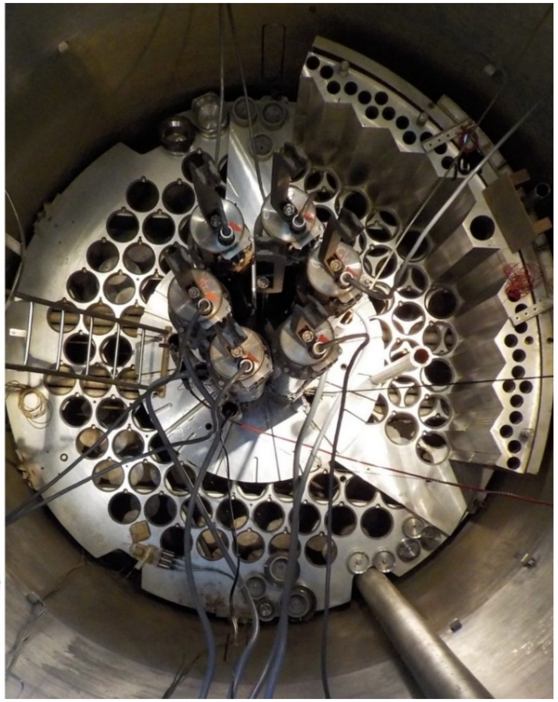
- The experiments are intended to the validation of calculation codes used for the FHR design. LR-0 reactor offers enough space and possibilities for such experiments, effectively limited only by its maximum thermal power, which is 5kW.
- The experiments are configured as an “inserted zone”, i.e. the experimental device is inserted to the center of conventional reactor core replacing one or more fuel assemblies. The materials inserted and their geometry is as similar as achievable to the intended FHR design.
- The whole project is divided to several stages regarding the problem complexity. The measurement was preceded by a “stage zero tests” using LiF-NaF and LiF-BeF_2 mixtures in three different geometries. *(Natural Lithium)*

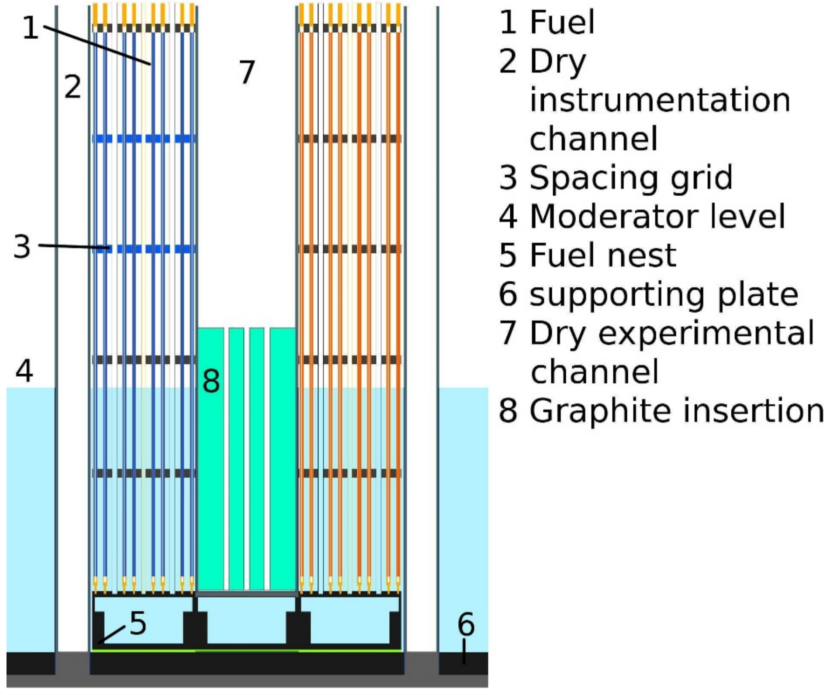


Measurement of neutronics in LR-0 reactor

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.







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.

Ongoing U.S. – Czech FLIBE experiments at LR-0 reactor in 2016

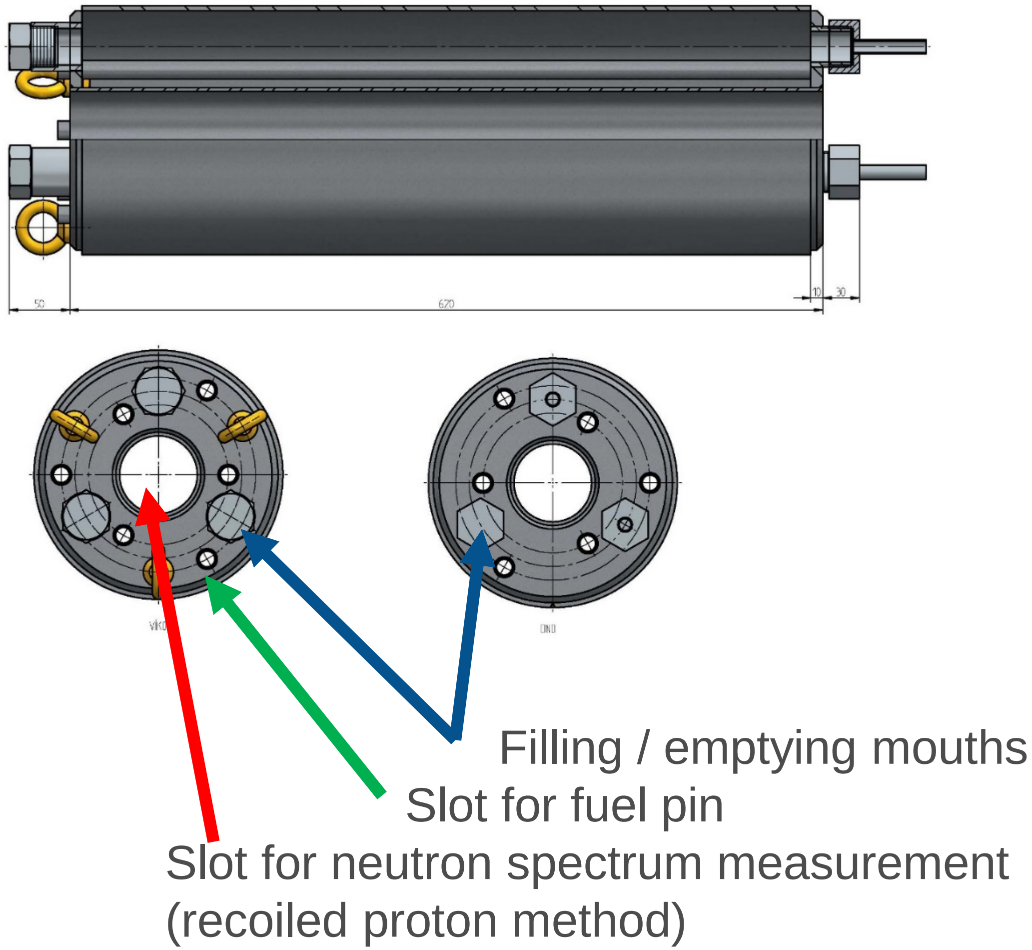
These experiments are the continuation of previous experiments realized in 2014 and 2015.

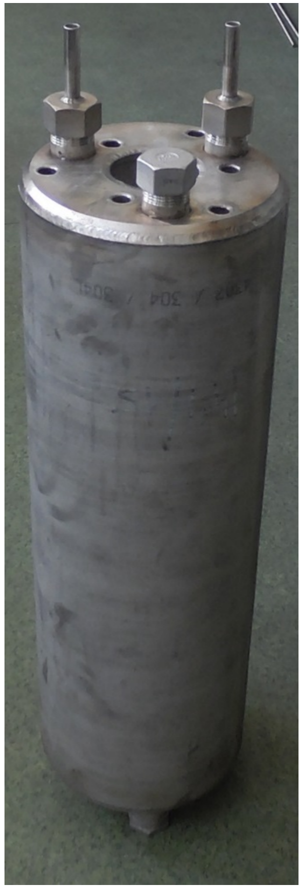
- **New instrumented inserted zone was designed, produced and filled by FLIBE salt and loaded into LR-0 reactor core**

Present program with new FLIBE inserted zone:

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

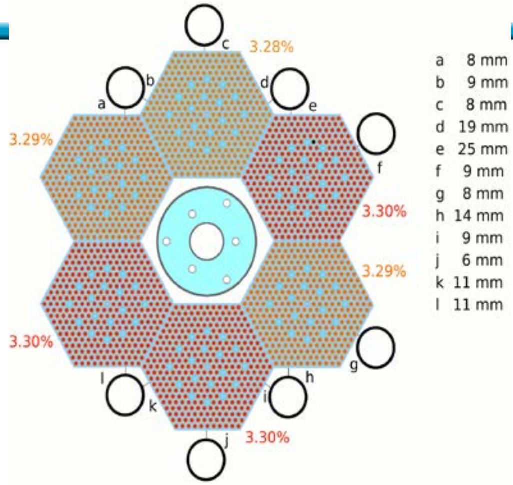
New inserted zone for FLIBE salt



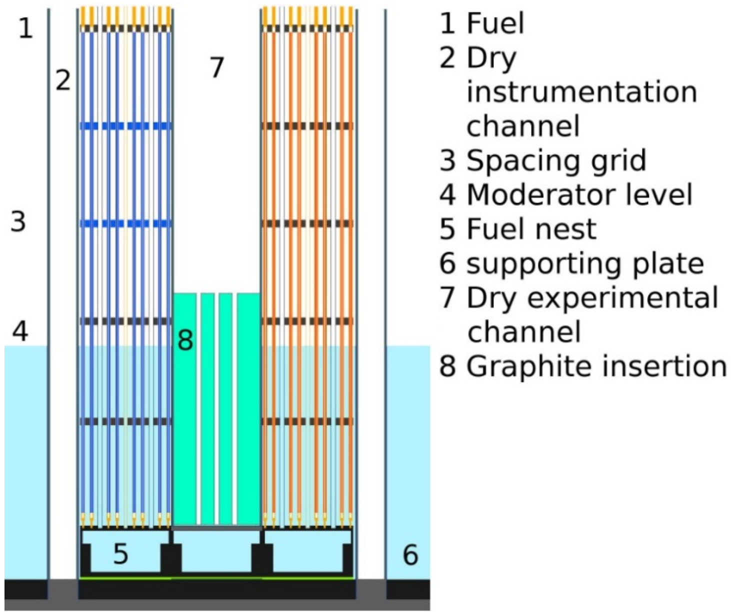


Manufactured new inserted zone
(bottom-up)

How do we do the experiments at LR-0



- Integral experiments concerning MSR research with insertion cores have been carried out in since 2013 at LR-0 (improvement and continuation of old experiments from 2006)
- LR-0 has 2 zones: driver fuel and subcritical zone, enabling insertion of significant amount of material being investigated
- Precise determination of criticality gives possibility to do precise integral experiments



Work done in 2016

- **Based on previous results and standardized (benchmark – reviewed by OECD subgroup) methodology:**
- **Investigation of fluorine in terms of criticality and neutron spectrum**
  - Via most common fluorinated compound CF_2=CF_2 (TEFLON®)
- **Investigation of FLIBE salt in terms of criticality and neutron spectrum**
  - Highly enriched by Li-7 supplied by ORNL

K_{eff} results

- Critical experiment always gives keff=1 at determined critical parameter (moderator level). Using our benchmark MCNP model for modelling of FLIBE and TEFLON, we obtained following values for different nuclear data libraries: … there is something wrong with fluorine

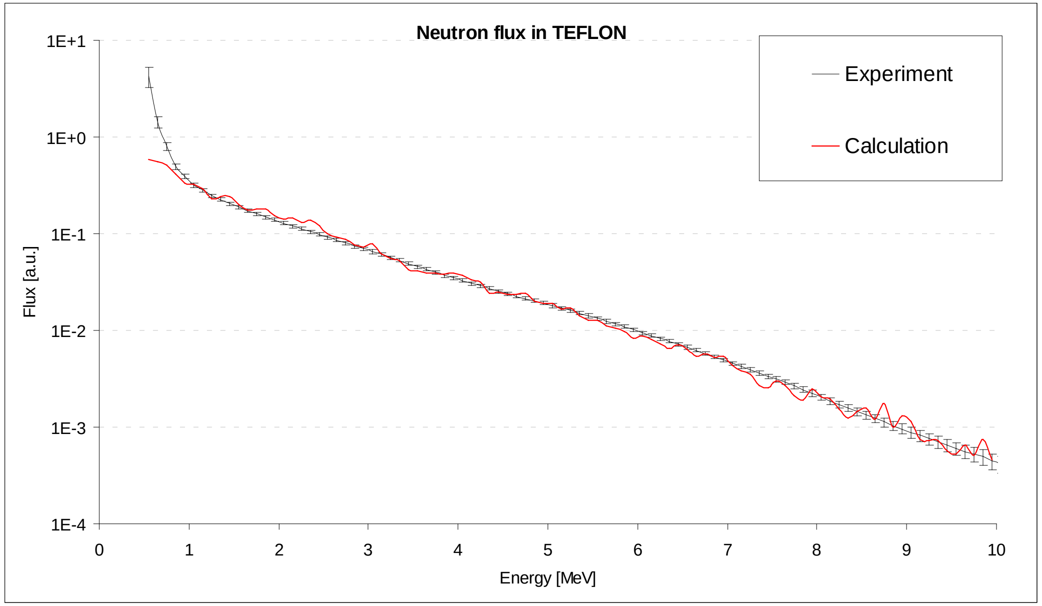
	FLIBE	TEFLON
ENDF/B-VII.1	1.0031	1.00064
JEFF-3.1	1.00313	1.00057
JEFF-3.2	1.00316	1.00063
JENDL-3.3	1.00349	1.00098
JENDL-4	1.00338	1.00103
CENDL-3.1	1.00235	1.00055
ROSFOND-2010	1.00334	1.00114

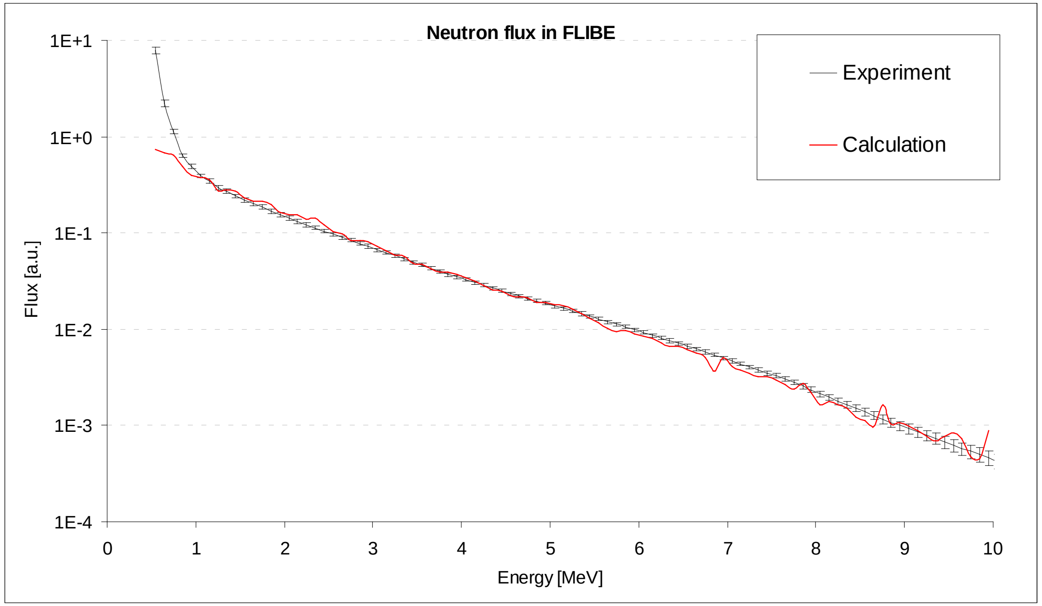
	FLIBE	TEFLON
ENDF/B-VII.1	0	0
JEFF-3.1	3	-7
JEFF-3.2	6	-1
JENDL-3.3	39	34
JENDL-4	28	39
CENDL-3.1	-75	-9
ROSFOND-2010	24	50

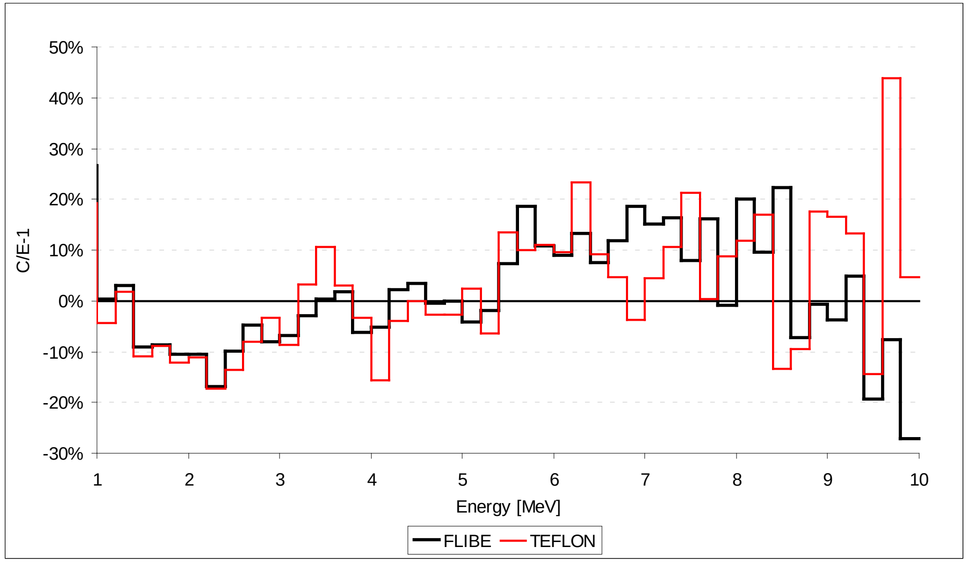
Results of neutron spectrum measurement

- **Neutron spectrum was measured by organic scintillator**
- **Signals were digitally processed**
- **Very good agreement with MCNP calculation was found (see following slide)**
  - The discrepancies in wide groups are less than 20 % in energy region < 6 MeV

Results for TEFLON® and for FLIBE







Partial conclusions

- **Current results from CV Řež were obtained with partners from MIT/ORNL and reviewed by highly credible international subgroups**
- **Results from 2016 are showing very good agreement of criticality and neutron spectrum measurements with benchmark models for TEFLON ®**
- **Measurements with FLIBE are showing perfect agreement in neutron spectrum, the results of k_{eff} are influenced by content of ^{6}Li in supplied salt, which is not precisely known yet.** *(It will be analyzed soon.)*

These results were jointly evaluated by ORNL and CV Řež experts in September 2016.

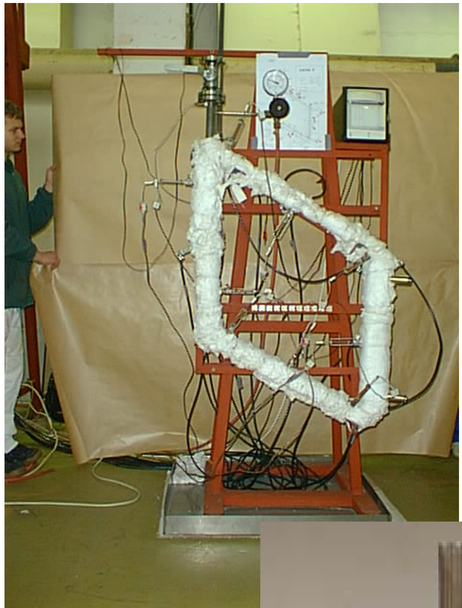
Other Czech activities in MSR / FHR technology

Today, existing U.S. – Czech collaborative project represents only a part of the Czech development program on MSR/FHR technology.

Other parts include:

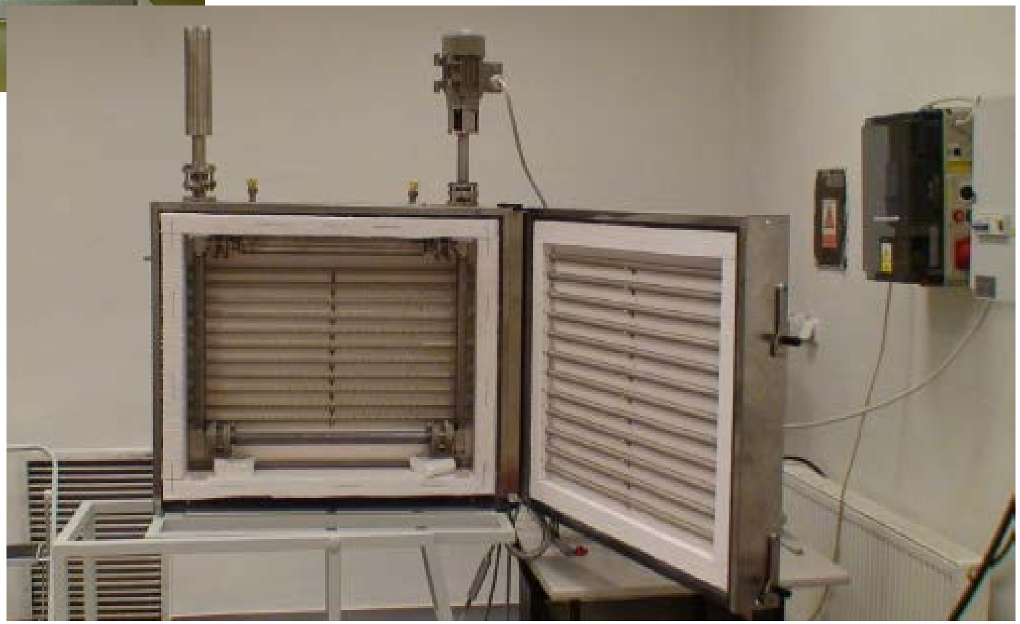
- MSR fuel cycle technology - *solved by ÚJV Řež and CV Řež)*
- Development of structural material (nickel alloys "MONICR") for MSR and FHR – *solved by COMTES FHT*
- MSR/FHR material studies (molten salt loop program) – *solved by CV Řež, EXPS and TARPO companies*
- Development of MSR / FHR components – *solved by MICo and SKODA JS*
- Basic FHR design studies – *solved by ÚJV Řež*

Material research for MSR – loop program



1999 - 2001

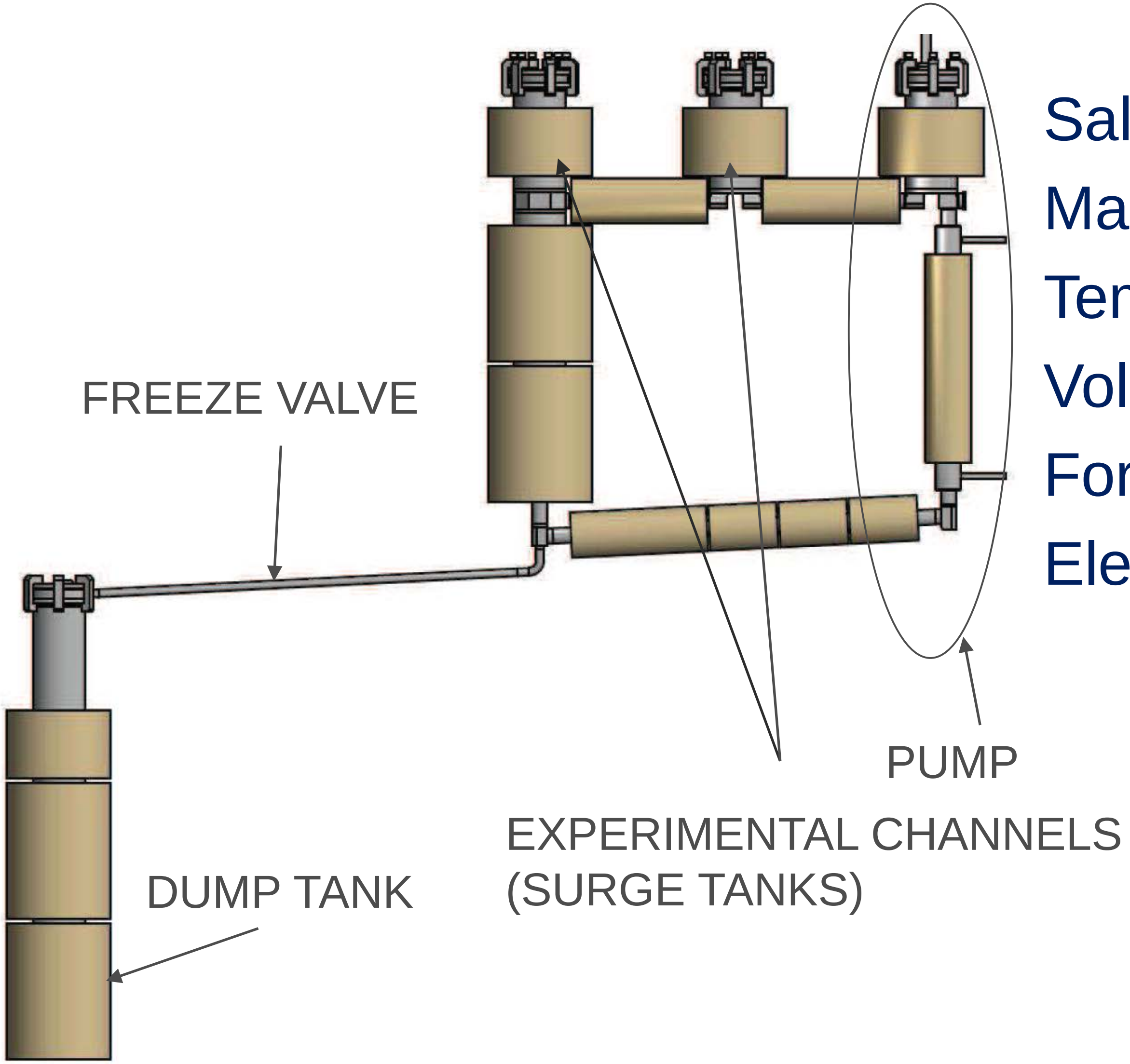
Since 2012



UJV & CV Řež Loops:
Program BLANKA

Salts:	LiF-NaF
Materials:	Inconel 686
(nickel-based alloy)	
Temperature:	< 900°C
Volume:	about 2.5 liters
Forced circulation	
(axial pump)	

New FLIBE loop (since the end of 2016)



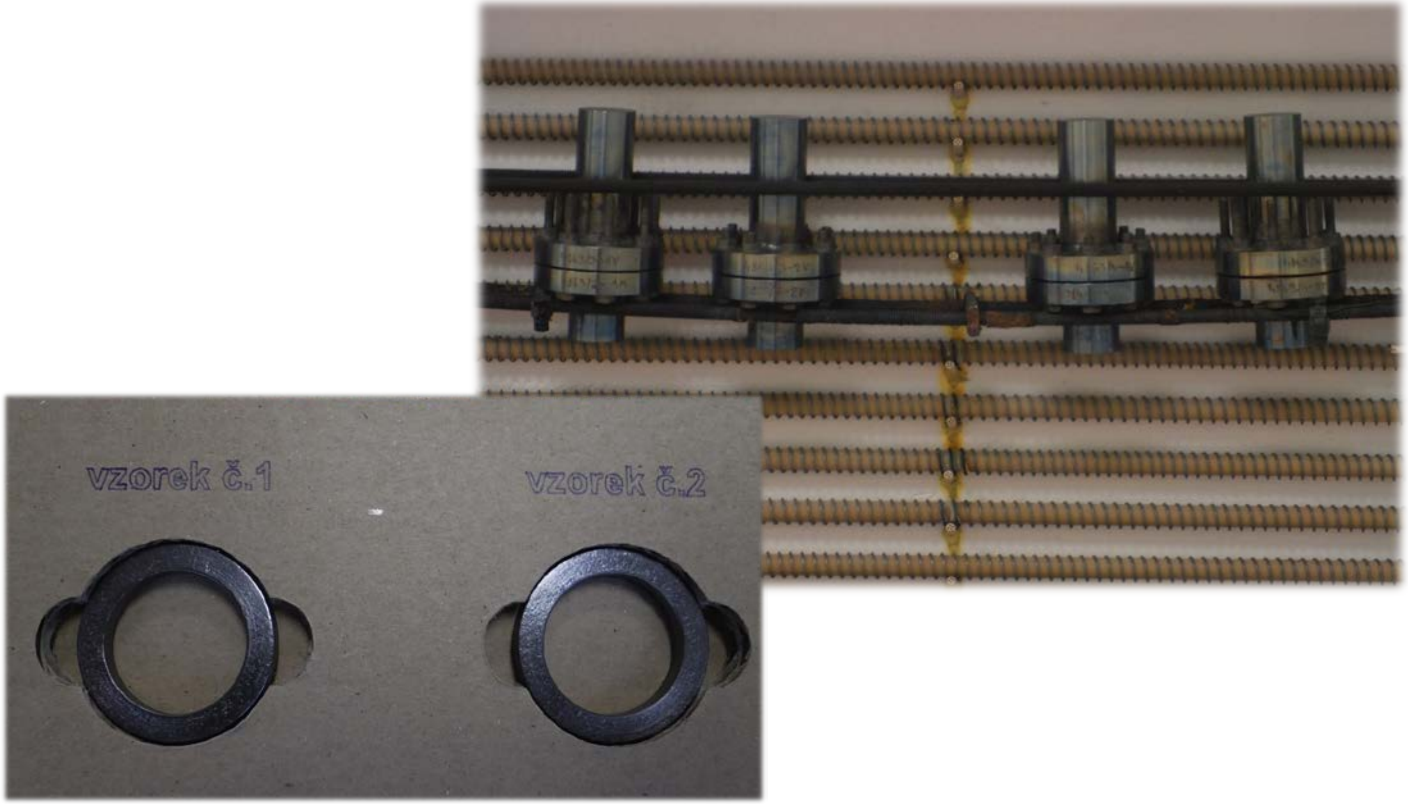
Salt:	LiF-BeF_2
Materials:	nickel-based alloy
Temperature:	< 760°C
Volume loop:	9 liters
Forced circulation	
Electric power:	< 25 kW

Schematic picture of the loop [A. Půtová 2013]

Development of special graphite gaskets for fluoride salt media in cooperation with MICo

Special graphite based gaskets for molten salt media are under development by MICo company and tested in Research Centre Řež in fluoride molten salts.

The gaskets were successfully tested for several disassembling flange types in FLiBe media in temperature range around 600 °C.



Conclusions

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