ÚJV Řež, a. s.

Experimental Support for the IVMR Strategy

J.Zdarek, D.Batek, V. Krhounek, S.Vlcek

International Conference VVER 2016

ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Presentation summary

Summary of present results on small scale tests with „ cold spray“ at UJV Rez.a.s.

Increase the efficiency of external cooling with „ cold spray“ application.

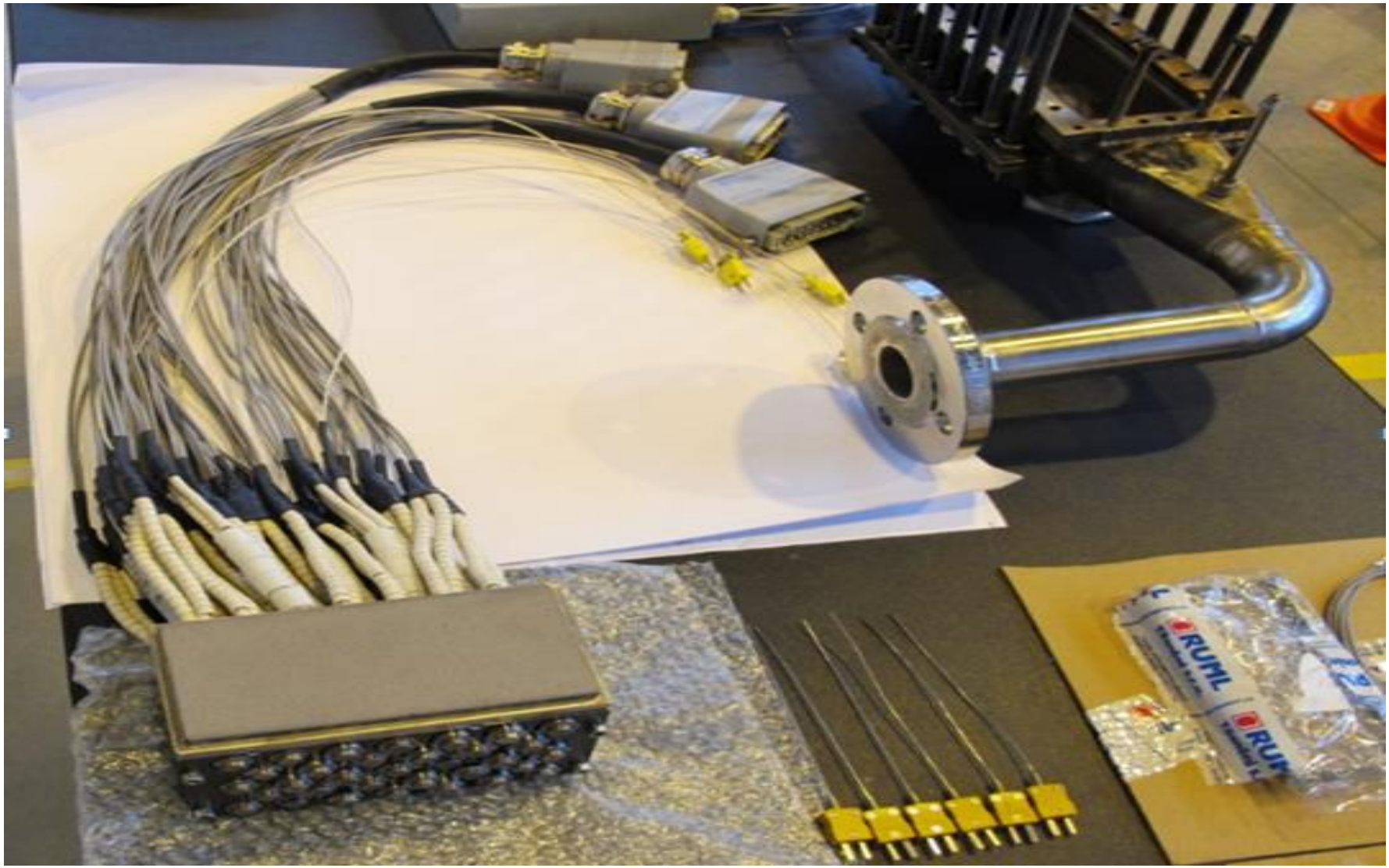
Status of work with large scale experiment

General comment

As boiling of water takes place on the vessel outer surface under severe accident conditions, the vapor masses generated on the vessel outer surface would flow upward through the annular channel under the influence of gravity

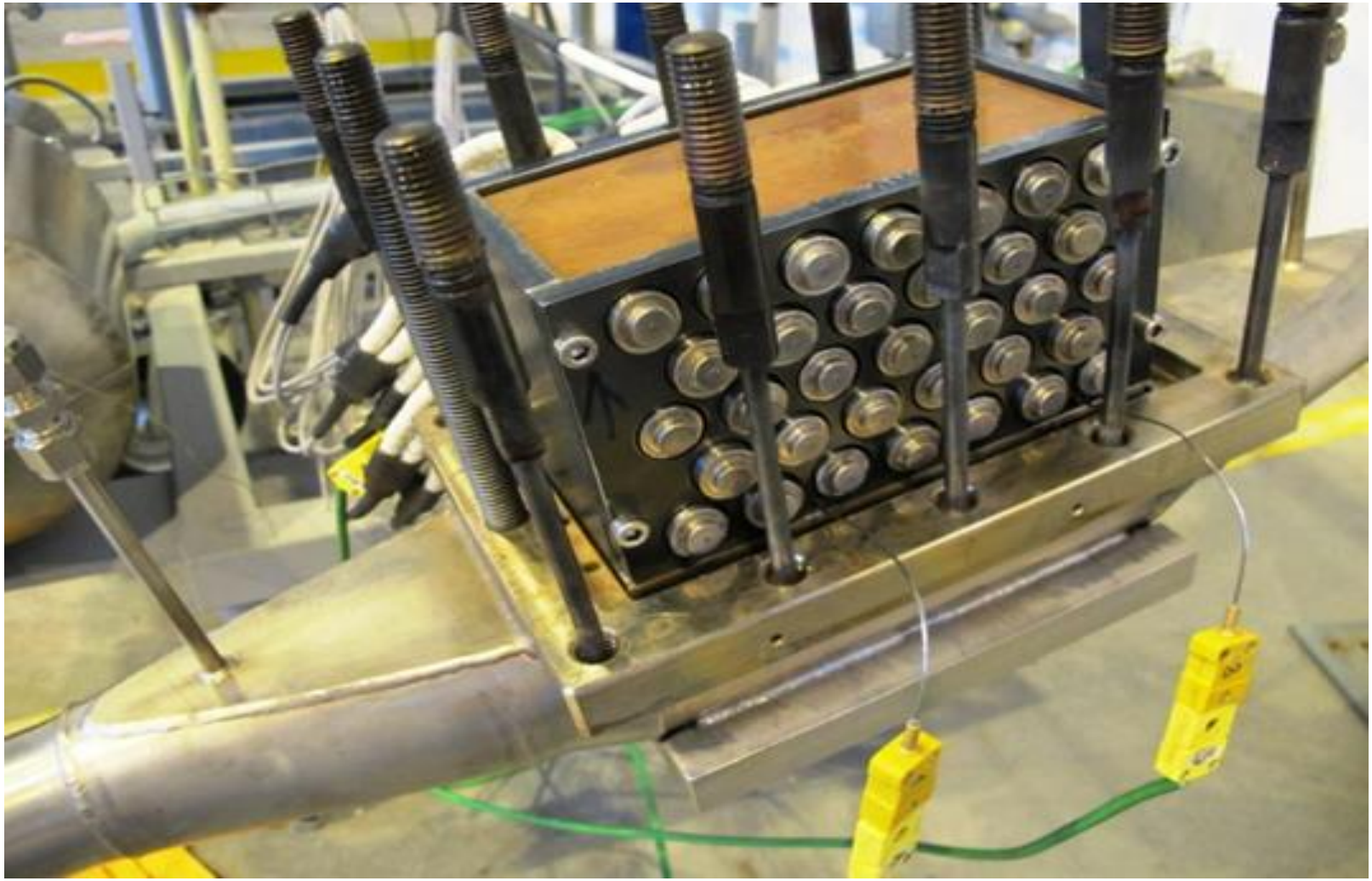
Small scale tests at UJV Rez a.s. on test samples with porous cold-spray coating prepared at ARL/PSU

Test sample with cold spray. Steel plate explosively welded on Cu heater bloc.



ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Test sample with heating patrons ready to be installed in the cooling channel



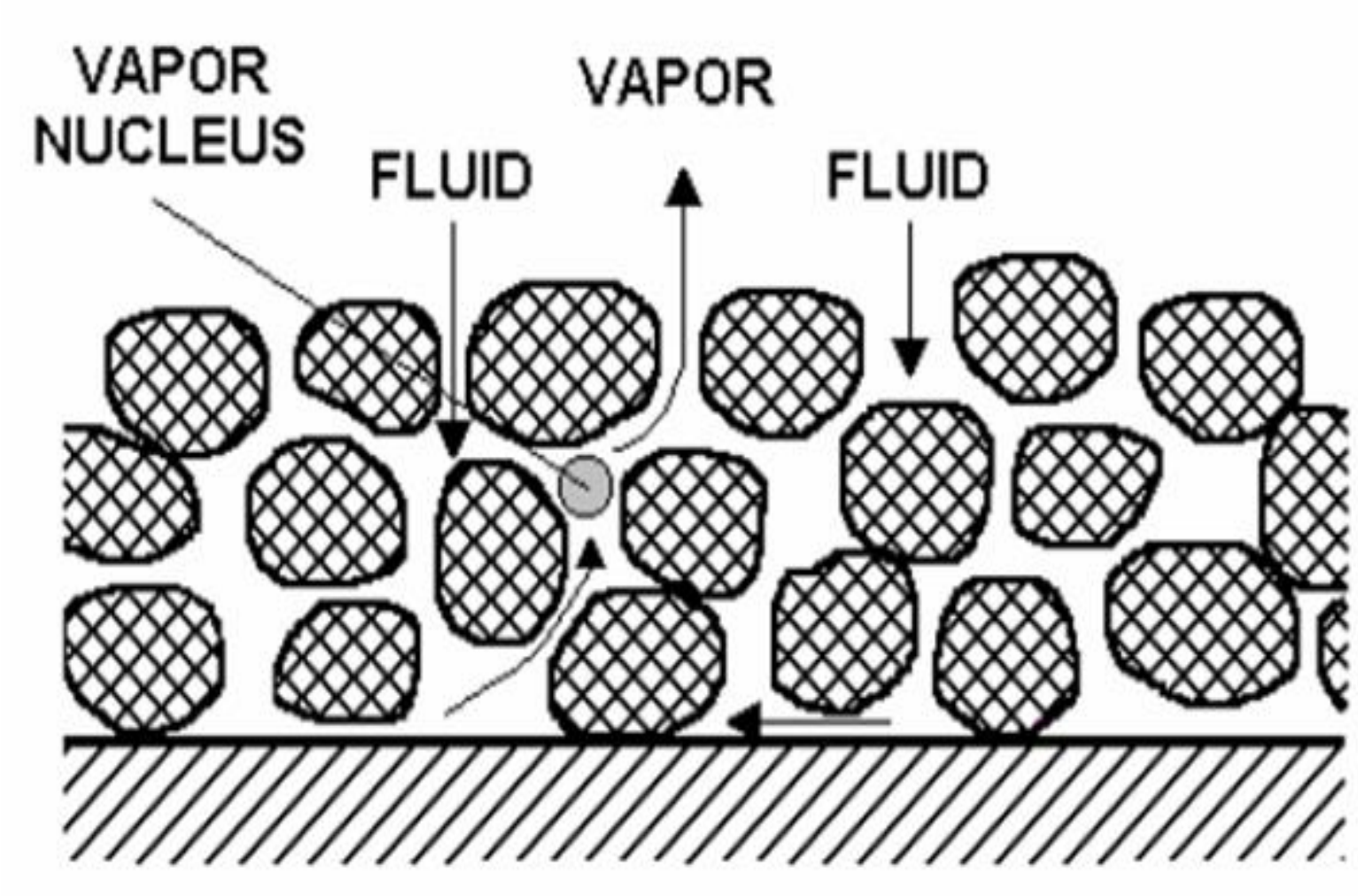
Side view on the test facilty with inclination (available inclination from zero to 90 degrees)

Overall view on the test facility.

Vessel Coating to enhance downward facing boiling

- **Vessel coating could represent a simple, economical way to enhance boiling heat transfer and increase the CHF limit for ERVC under severe accident conditions. The goal is to enhance the local CHF limits so as to improve the margin for IVR.**
- **For the VVER situation the cold spray cannot influence the quality of the NDE results which are also performed through the outside surface of the RPV.**

Flow Paths within a Micro-Porous Layer Coating

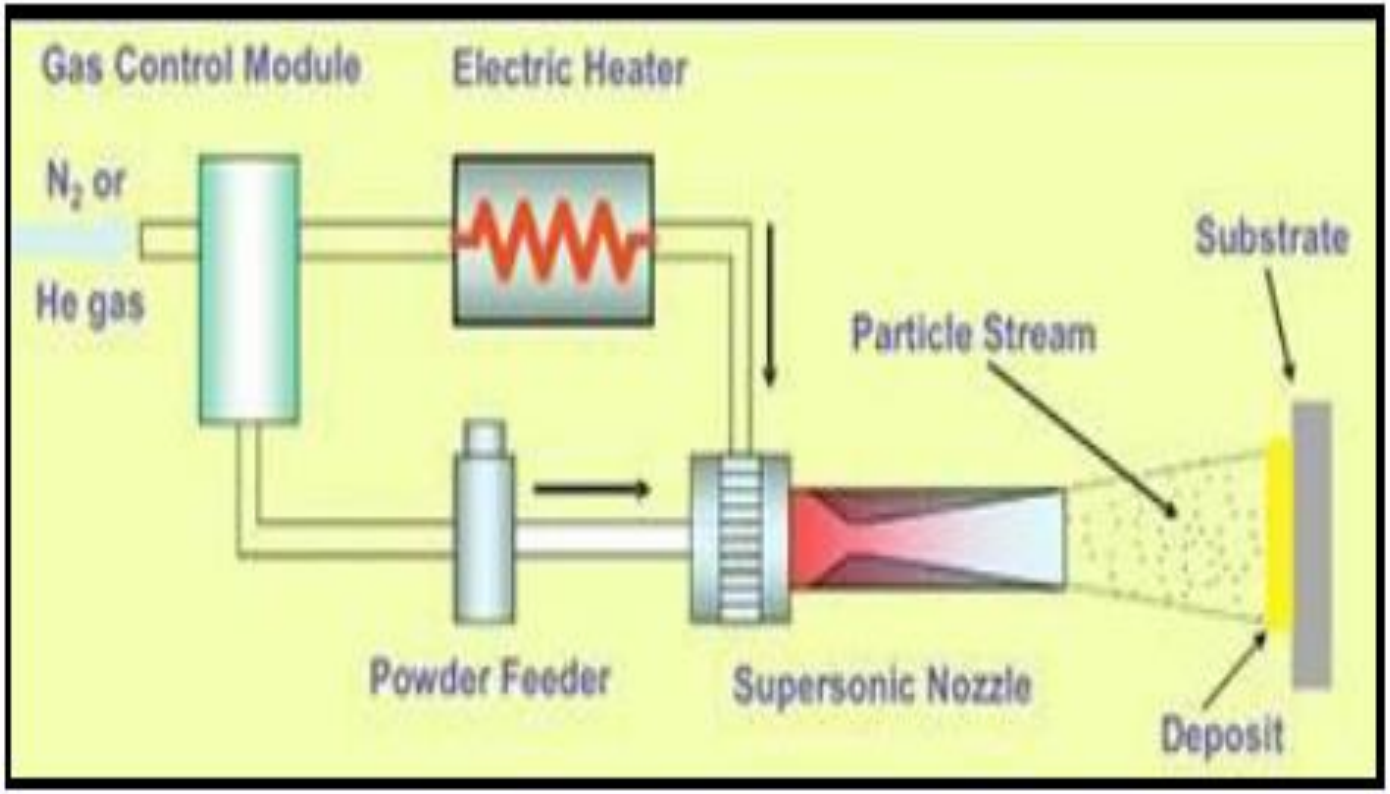


ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Technical Approach and Cold Spray Kinetic Process

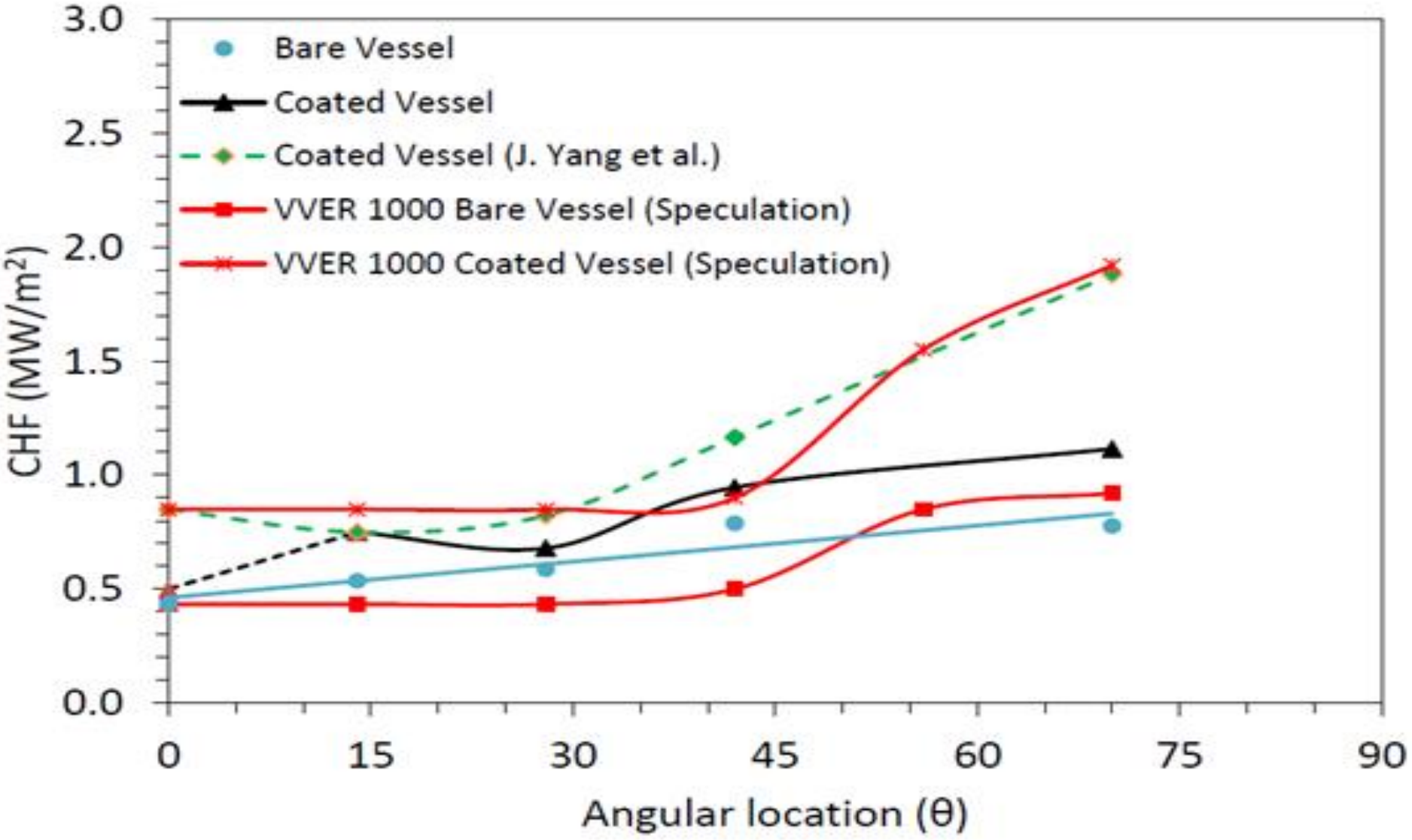
- **Develop composite powder/coatings systems with one sacrificial constituent using Cold- Spray.**
- **Deposit and than etch coatings to remove sacrificial material.**
- **Evaluate and analyze coatings for Porosity, Bond, Wear, Fatigue, Critical Heat Flux (CHF) etc.**
- **Particles deposited in a solid state**
- **Minimal heat transfer to substrate**
- **Critical velocity must be met to allow plastic deformation for bonding**

Key components of cold spray



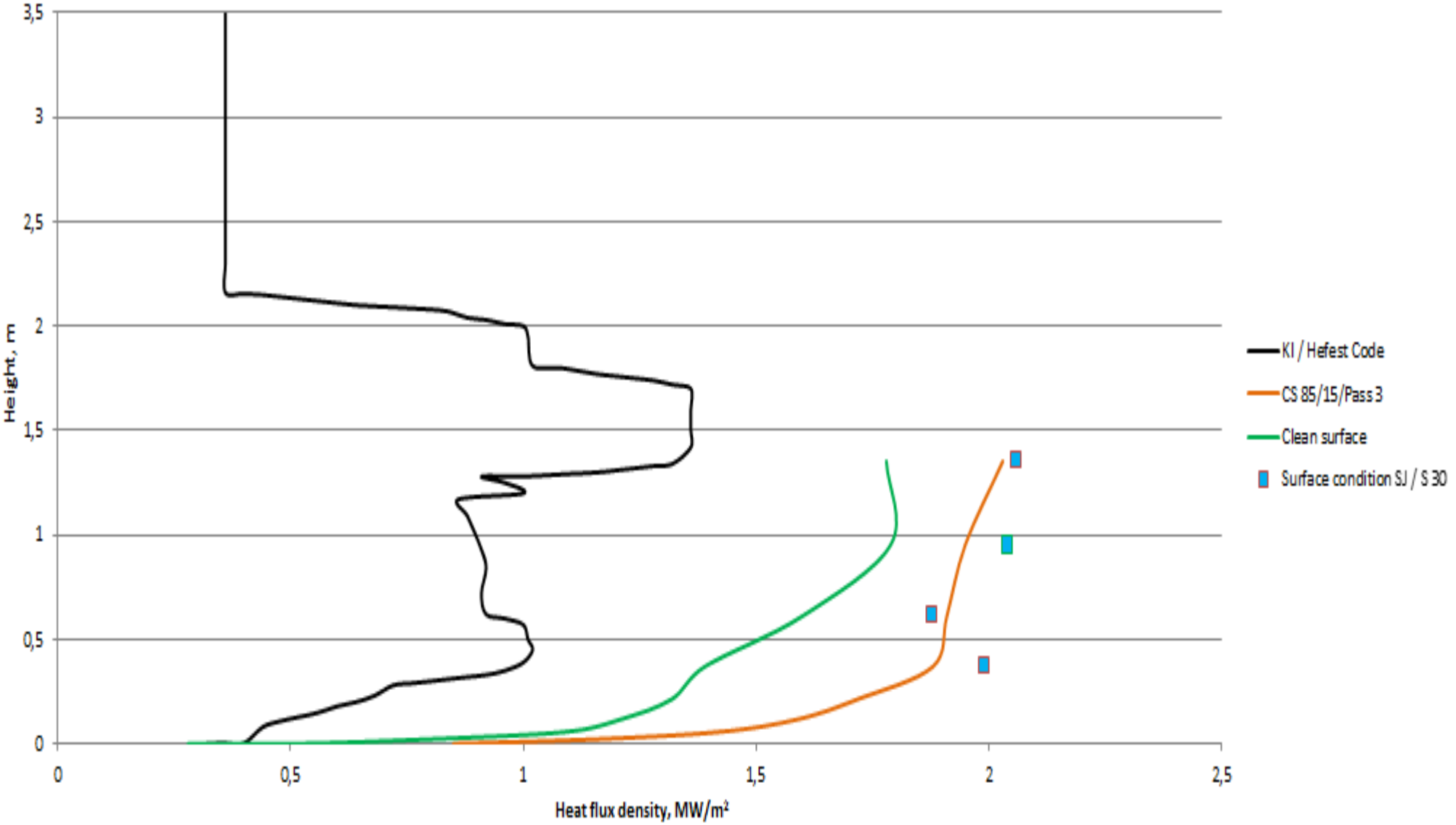
ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Anticipated Local CHF Limits for Bare and Coated VVER Vessel



ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Cold spray test results comparison with KI CHF profile, provides very positive results



ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Distinct Advantages of Cold-Spray

- Minimal microstructural changes and/or oxidation
- Low temperature, solid-state proces allows deposition on plastics and composites, as well as ceramics
- Easily functionally graded or composited in situ
- Field deposition and/or repairs possible and economical
- No-macro or mikro-segragations of the alloying elements
- Nano-phase, intermetallic, and amorphous materials possible and/or used

Large scale test facility THS-15 built at UJV Rez

- UJV Rez a.s. is participating within the EU project HORIZON 2020 “IVMR for Existing and Future NPPs” and is a leader of TASK 4 “External Cooling”of the RPV. It was agreed, that key goal of this TASK 4 is to build Large Scale Experimental facility with full configuration of the VVER 1000/320.
- However the Thermo-hydraulic loop is designed as universal facility for thermo-hydraulic tests with possibility to change the cooling test channel.

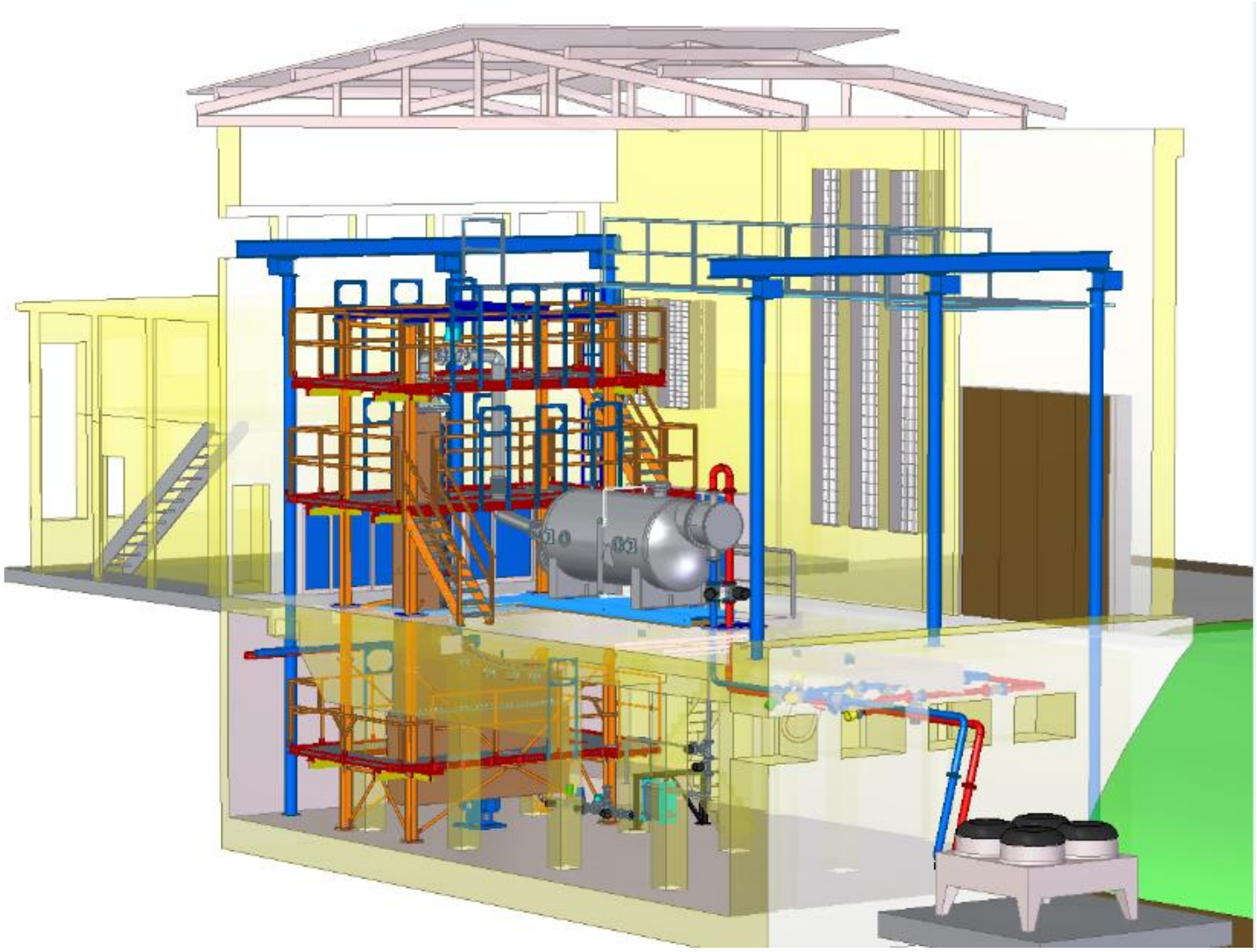
Large scale test facility THS-15 built at UJV Rez

- **Experimental work to verify the IVR strategy were started at UJV Rez a.s. in the year 2012 with UJV internal financial support, also with support from Government (TACR Beta- Regulatory Body) and Czech Utility CEZ a.s.**
- **The EC Project HORIZON 2020 IVMR will last till 2019, however UJV Rez a.s. promised to our Czech Utility CEZ, provide first large scale experiment data ASAP**

Large scale test facility THS-15 built at UJV Rez

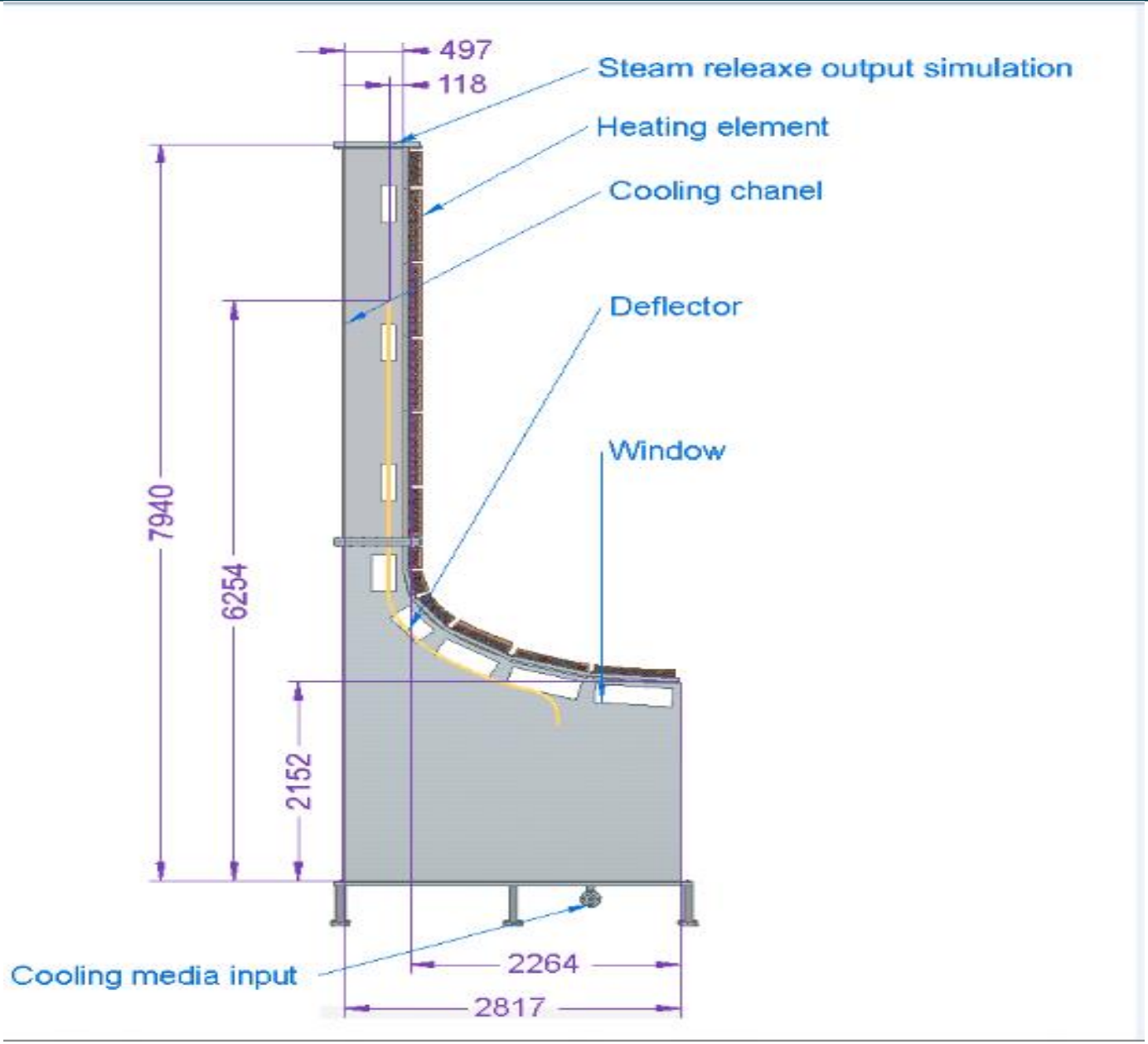
- **Experimental work to verify the IVR strategy were started at UJV Rez a.s. in the year 2012 with UJV internal financial support, also with support from Government (TACR Beta- Regulatory Body) and Czech Utility CEZ a.s.**
- **The EC Project HORIZON 2020 IVMR will last till 2019, however UJV Rez a.s. promised to our Czech Utility CEZ, provide first large scale experiment data ASAP**

Overall view on the facility



ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Cooling channel details



ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Segments No. 2 and 3 after shaping

Time schedule for civil construction

	Tasks	Year	2016																									
		Month	4	5					6				7				8					9						
		Week	25.4	2.5	9.5	16.5	23.5	30.5	6.6	13.6	20.6	27.6	4.7	11.7	18.7	25.7	1.8	8.8	15.8	22.8	29.8	5.9	12.9	19.9	26.9	3.10
		Continuity																										
1	Distribution of design documentation to public authorities																											
2	Tender documentation																											
3	Electricity & Sewerage connections (E&S) - Tender for contactor	2																										
4	Construction works (CW) - Tender for contractor	2																										
5	E&S - Comments by public authorities	1																										
6	CW - Comments by public authorities	1																										
7	E&S - Building permission proceedings	5																										
8	CW - Building permission proceedings	6																										
9	Electricity & Sewerage connections - works	7																										
10	Construction works	8																										
11	Milestone: Finish of CW and E&S																											

ÚJV Group
TECHNOLOGY | INNOVATION | PEOPLE

Conclusions

- **Lessons learned from all performed LSE were studied and fully respected during the design of the THS-15 with full configuration of the VVER 1000**
- **Also analytical results first performed by KI Moscow and than extended wihin the JRC Benchmark are acknowledged .The heating and regulation capabilites to be available on THS-15 will allow to simulate the heat flux profiles which will be approved as most verified.**
- **Explosively welded Cu heater bloc with steel is verified as durable and most effective. As seen from previous slide, all needed segments are already shaped and further manufacturing process is under way.**

Conclusions

- **Tests will first start with steel surface clean and water cooling. Than the tests will be performed with installed deflector inside the cooling channel again fully representing actual cavity dimensions, cooling media input from the RPV cavity floor and steam release at the top of the cooling channel again representing available release space in the actual design and operation.**
- **Test steel surface will be cleaned before the tests starts , but also after each set of experiments which will change the steel surface quality.**
- **The same sequence of tests will be performed with steel surface with applied cold spray, again without deflector, with the deflector and also with defferent types of cooling media**

Conclusions

- Total number of heating patrons is over 1200 along the whole length of the cooling channel
- Total 17 heating zones are planned for possibility to generate diffrent heat flux values
- Maximum heat flux to be available for simulation is 2.4 MW/m2
- At present 16 exactly defined manufacturing operations for the cooling channel are under final contract negotiations
- We expect to receive final building permit for civil construction within 6 weeks

Conclusions

- **At present all design and manufacturing work is running according to agreed time schedule.**
- **Start of the first tests is planned on March 2017, with first set of results to be presented to our Czech Utility and also to the regular meeting of the HORIZON 2020 IVMR project during November 2017**
- **We will welcome any suggestions and support for our THS-15 experiments, we will also welcome visits to our facility.**
- **We would like to express our thanks to the EC for supporting this project, to the IRSN for overall managament and all participants for their interest and support.**

Conclusions

- More than 100 small scale tests finished . They proved that explosive welding is perfect technology for heat transfer and absolutely durable.
- Large scale tests with test segment manufactured from Cu heater bloc and steel plate with EXW has very strong chance to be again heat transfer effective and durable.
- Cold spray with selected compositions of porous coating after more than 100 tests again proved to be durable and effective
- Small scale test cannot fully simulate the cooling on the semieliptical lower head, even though reached CHF results with cold spray application are positive as seen from last slide.
- Cooling with „cold spray“ is much faster than on bare surface and in most critical locations.

Many thanks for your attention

- **Questions are welcome**