Status of Test Facility to Confirm the IVMR Strategy for VVER 1000/320

Zdarek Jiri, David Batek, Jan Wandrol , Vladislav Krhounek
UJV REZ a.s. Husinec, Czech Republic

Introduction

After the Fukushima Daichi severe accident very intensive work started to prevent severe accident on all existing NPPs, as well as on new built units. The most critical scenario is possible melt through of the RPV wall and corium release outside containment. For small power NPPs up to 600 MW the In Vessel Melt Retention (IVMR) strategy was first studied and applied on the VVER 440 units. For larger units first experiments started for WEC AP 1000, than follow experiments in France, Korea and China. Recently the CEA published paper where is stated that all above built and performed large scale experiments to justify the IVMR are not fully representing the RPV and cavity configuration as well as other key design configurations.
In our Institute UJV Rez a.s. we are extensively working to build the large scale facility THS-15 with exact configuration of the VVER 1000/320 to test the IVMR strategy with external RPV surface cooling. This project is part of the EC HORIZON 2020 IVMR project.
Presented paper will summarize present work and results on small scale facility BESTH and large scale facility THS-15.

1. Small scale test facility BESTH

Before starting our large scale experimental facility design we have built small scale facility BESTH. Test specimen was prepared with use of Cu bloc and explosively welded steel plate. Drilled holes were provided to install heating patrons. View on the test specimen is on Fig.1.

Fig. 1. Test sample Cu bloc with explosively welded steel

Important item in performance of the small scale as well as large scale experiments is temperature measurement. On the next Fig.2 we are providing positions of installed TC very near the welded steel surface.

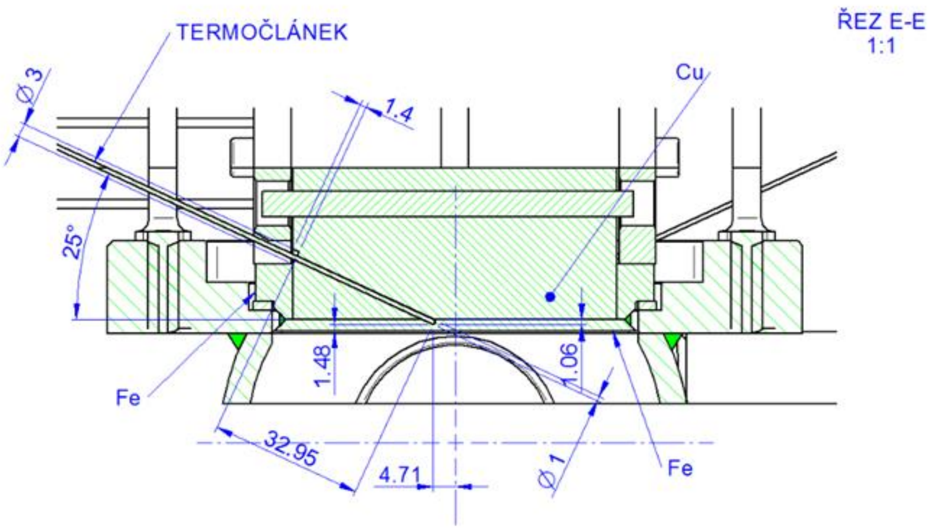

Fig. 2. Test sample with TC position

Tests are performed in ten degrees inclination from zero degree to 90 degree.

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On the BESTH facility over 100 experiments were performed. First experiments were performed with clean surface, than two types of surface modifications were performed and tested. Results with latest surface modification are shown on Fig.3. The results are providing clear indications that with surface modification we can increase the safety margin to the CHF with respect to the margin with clean surface. The surface modification is under development with respect to application on the large-scale test facility. On the small-scale facility, the position with low inclination is also not fully representing actual situation at the lower head RPV. The large-scale facility should provide more precise data, also in this position.

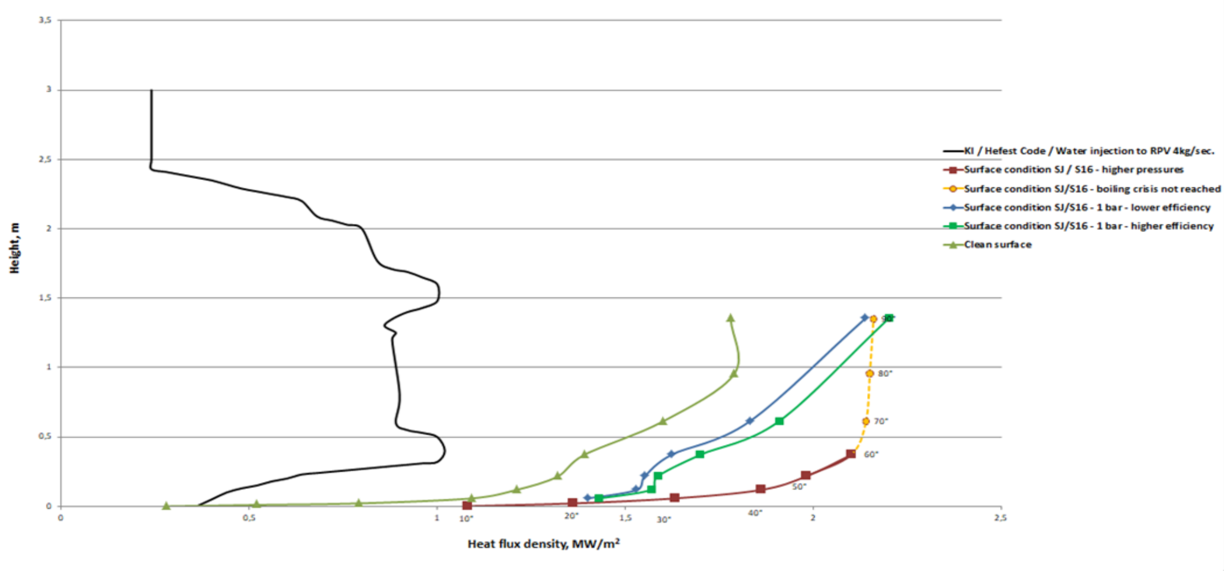
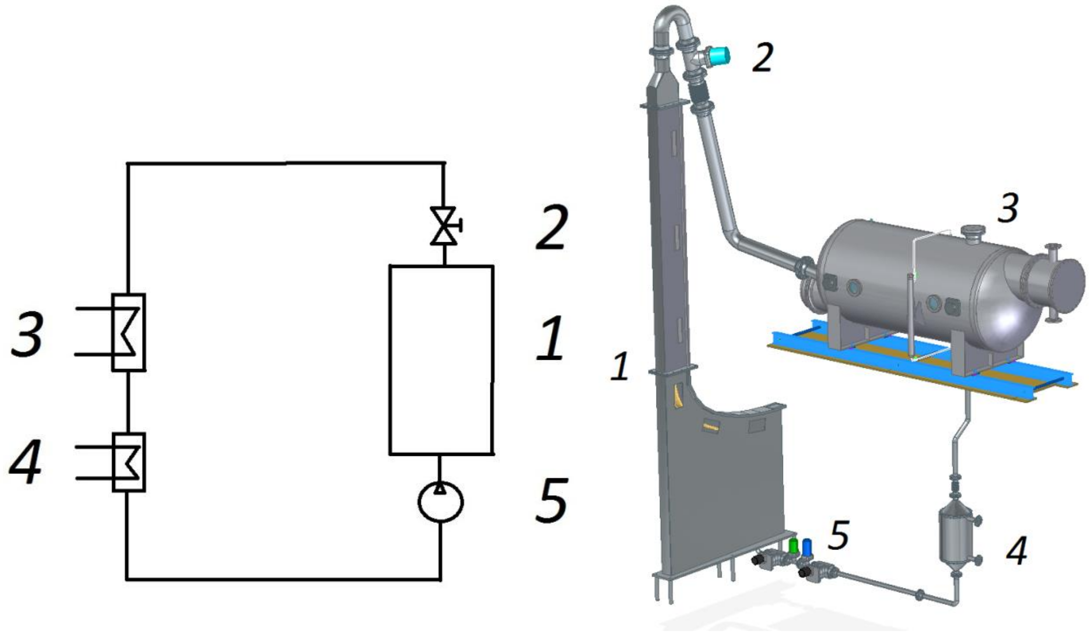


Fig. 3. Results with comparison of clean surface(light green) with modified surface

The tests on BESTH facility will continue. At present time tests will be carried out to receive data for calibration of new opto sond which will be able to measure steam volume in the cooling channel also in the large-scale facility THS-15.

2. Large scale test facility THS-15

The large scale facility THS-15 is built with exact configuration of VVER 1000 RPV and cavity. The cooling water input through the air cooling channel in the cavity floor and possibility to simulate available space for the steam release around the RPV support ring even considering heat expansion of the RPV wall during the SA are one of most crucial requirements on exact configuration management. On Fig.4 is design configuration of the cooling channel with condenser and piping system.



__1__ – RPV Cavity Model, __2__ – Valve to simulate the steam release, __3__ – Condenser, __4__ – Additional Cooler, __5__ – Pump

Fig. 4. Design configuration of THS-15

Key design parameters of the facility are summarized in Table 1.

Parameter	**Value**
Conditions inside the RPV	No pressure inside the RPV, corium melt
Time for Corium pool in LH formation	5000 sec
Remaining power in time 5000 s	22506,0 kW
Input Power for the THS-15	750 kW
Losses (max. 20%)	150 kW
Remaining resource to increase power	20%
ID for steam release pipe	200 mm
ID for piping with water supply	50 mm

Calculated pressure	0,7 MPa
Width of the cooling channel	0,15 m

Table 1. Design parameters of THS-15

On the following Table 2 is provided comparison between THS-15 and real VVER 1000/320 design parameters.

Parameter	VVER-1000	THS-15
Scale (volumetric)	1:1	1:95
Size of cooling channel by deflector [mm]	120 (100 – 250)	120 (100 – 250)
Angular sector	360°	3.8°
Flow area of channel in cylindrical part of RPV [m^2]	1.755	0.0184
Hydraulic diameter of channel [m]	0.24 (annulus)	0.135 (trapezium)
Height of cylindrical part of deflector up to [m]	2.9	2.9
Heat flux to wall	25 MW	263 kW

Table 2. Design parameters of THS-15 and VVER-1000/320

Facility THS-15 is now completely installed in the experimental hall. On Fig.5 is view on the design of theTHS-15. Here is clearly shown the primary water cooling input through the cavity floor.

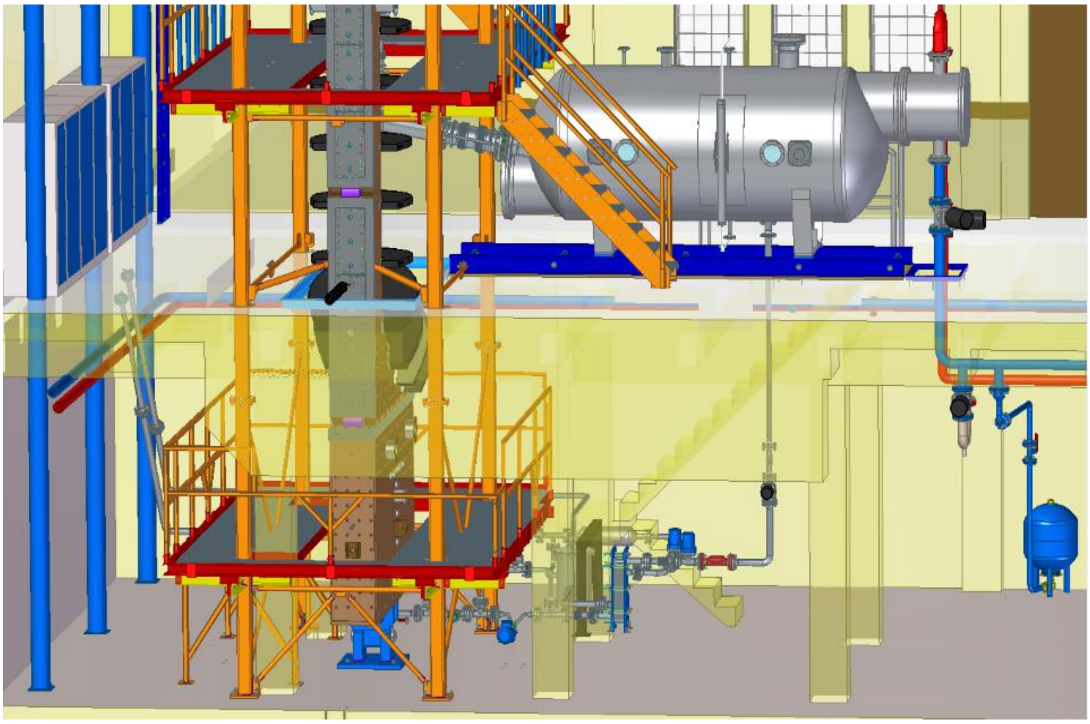


Fig. 5 Design configuration of THS-15 with position of the primary cooling water input and position of the Condenser.

First test was finished in March 2018. On Fig.6 is provided HF profile fully simulated in the facility. Heat flux profile was calculated by the MELCOR Code at UJV.

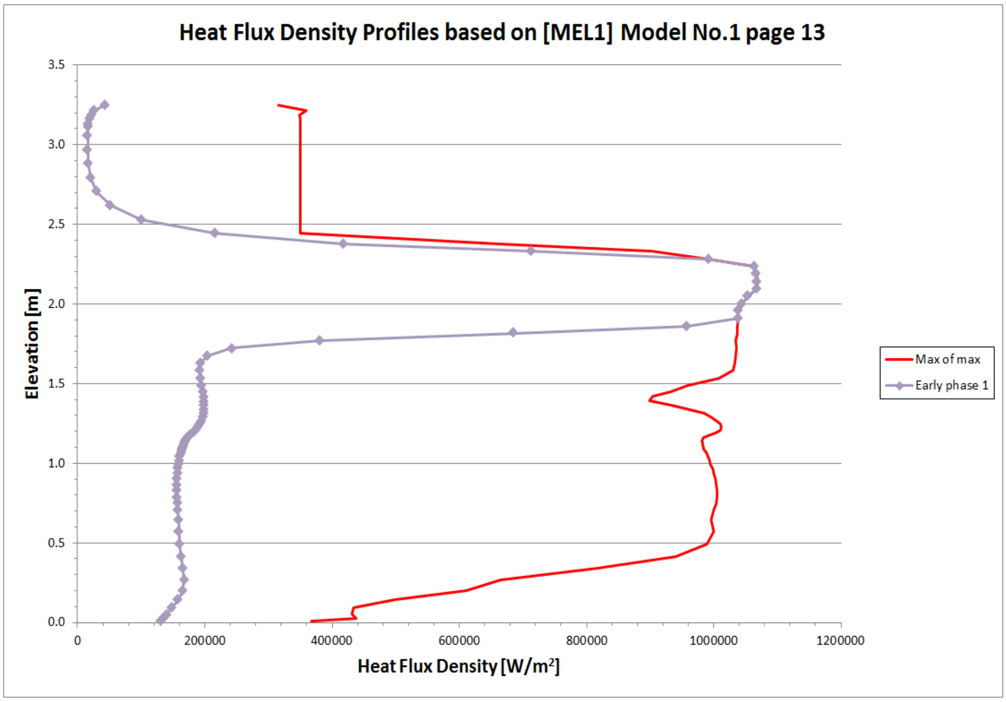


Fig. 6 Tested HF profile is shown in blue

Maximum HF simulated was 1.15 MW/m2. The boiling crisis was not reached. Clear target on the HF to be reached is more than 2 MW/m2. Based on the first test performance several hardware and software improvements were proposed and realized. All those measures were targeted to increase safety and also much easier operator actions. Facility with new improvements was completed early May 2018 and tests with selected HF profiles started. On Fig.7 and 8 are just two examples of heat flux profiles prepared for next series of tests. All tests until the date of the Conference on the THS-15 will be performed without surface modifications and without deflector. Also, other effects such as cooling water pressure and temperature will be studied during the year 2019. All above factors have potential to increase the margin to the CHF. Today is possible to declare that we have already significant safety margin to the CHF. Results of all performed tests which will be performed till February 2019 will be presented during the Conference.

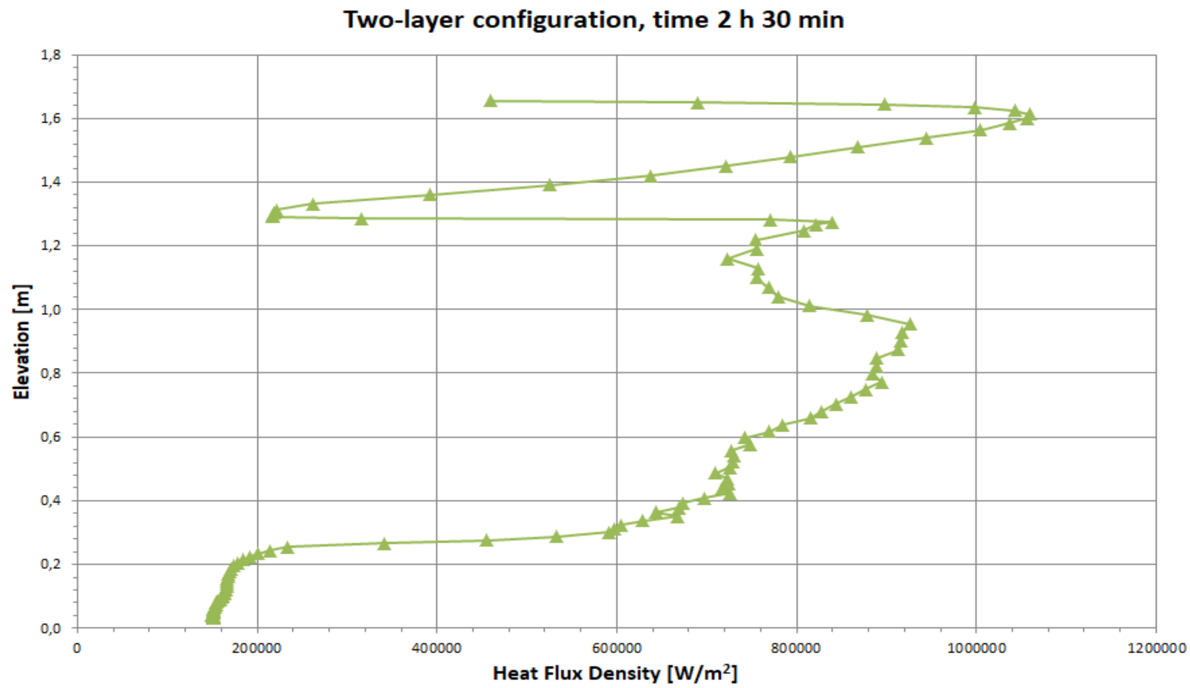


Fig. 7 Two layer HF profile

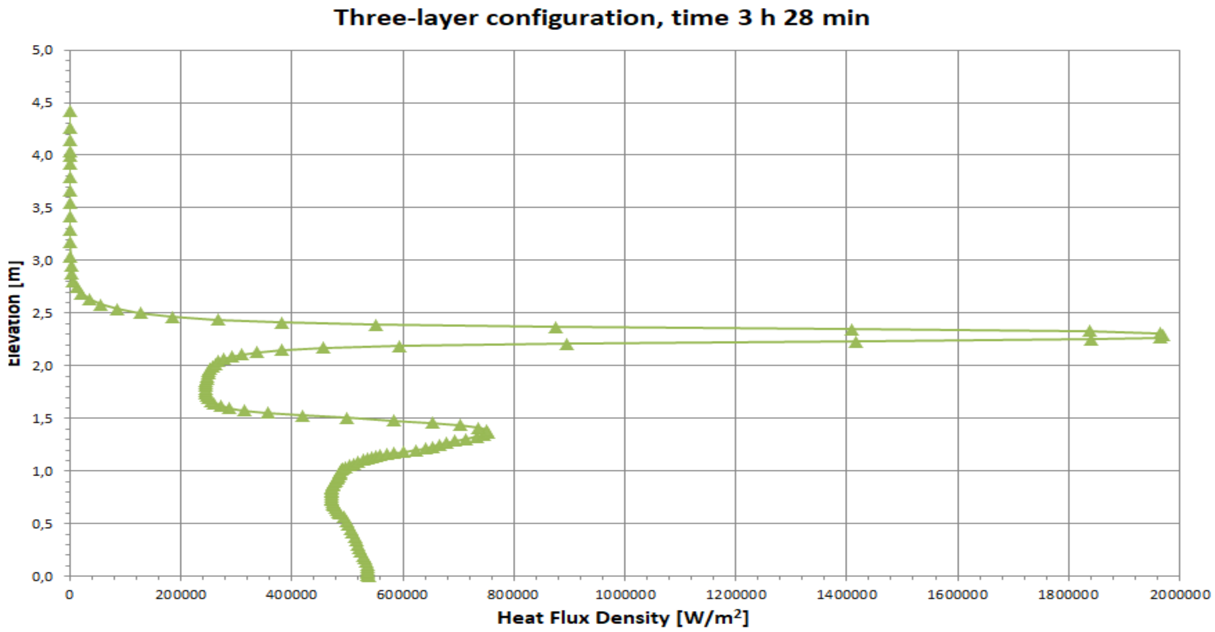


Fig.8 Three layer HF profile

3. Conclusions

After the Fukushima Daichi severe accident, lot of new safety measures we prepared and performed. Our research work is targeted on Severe Accident mitigation with the In Vessel Melt Retention (IVMR) strategy on existing VVER 1000/320 units in operation. We started our project with small scale facility and test blocs, with key target to learn and justify design and some manufacturing technology e.g. explosive welding of the steel plate with Cu bloc, to be introduced on our large scale facility THS-15, again with exact configuration of the VVER

1000/320, but not only as a cooling channel, but whole configuration of the RPV, surrounding cavity, input of the cooling water and steam release. Our Institute UJV Rez is TASK 4 leader of the EC HORIZON 2020 project with responsibility to build this facility and perform representative tests. As described in our paper, facility is build, first test performed and getting ready with some hardware and software upgrade for further tests. During the Conference latest results of our project will be presented.

4. References

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