EASI SMR

EASI-SMR Workshop on scaling issues

Evaluation of applicability and limitations of existing scaling techniques

IVR LOOP

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Agenda

- ❑IVR LOOP (THS-15) construction background
- ❑Scaling (issues) approach
- ❑IVR LOOP within EASI SMR project

IVR LOOP – motivation to built (1)

- Following the Fukushima accident, it became necessary to identify knowledge gaps in nuclear safety and ensure that appropriate research was performed to address these gaps.
- One of the gaps was to define a strategy for dealing with a severe accident that would result in the melting of fuel and internal reactor components, with the aim of stabilizing the corium in the NPP containment area.
- Gen III+ reactors already have solution integrated into their design (ExVC – core catcher / IVR - ERVC).
- What about NPPs that are Gen II and have been in operation for years?

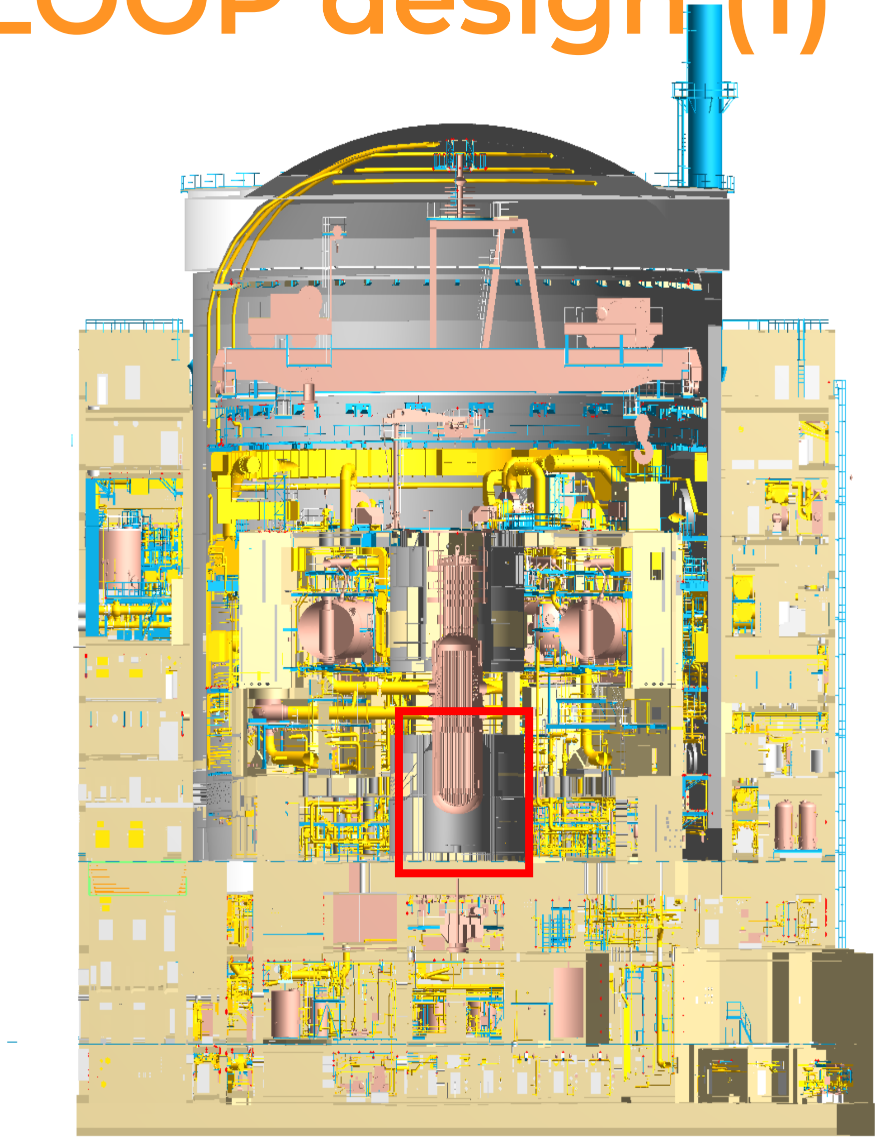
IVR LOOP – motivation to built (2)

- For Temelín NPP (VVER 1000, in operation since 2000), both strategies (ExVC/IVR) were investigated.
- IVR were accepted for VVER 440 before, but what about 1000 MWe reactor in operation?
- The success of the IVR strategy (from a physical point of view) and how to demonstrate?
  - 1) Heat flux (HF) < CHF.
  - 2) The integrity of the RPV is maintained at the same time.

- → experimental data (+ analysis) needed.
- → RPV material data (+analysis) needed.

UJV approach to IVR LOOP design (1)

- Inspiration from previous experience with large-scale IVR experiments (ULPU, CERES, REPEC/3D-IVR,..).
- Analytical data research.
- Situation and specific needs for VVER 1000.
  - Containment, RPV geometry.
  - Coolant parameters.
  - Heat flux distribution profiles, etc.



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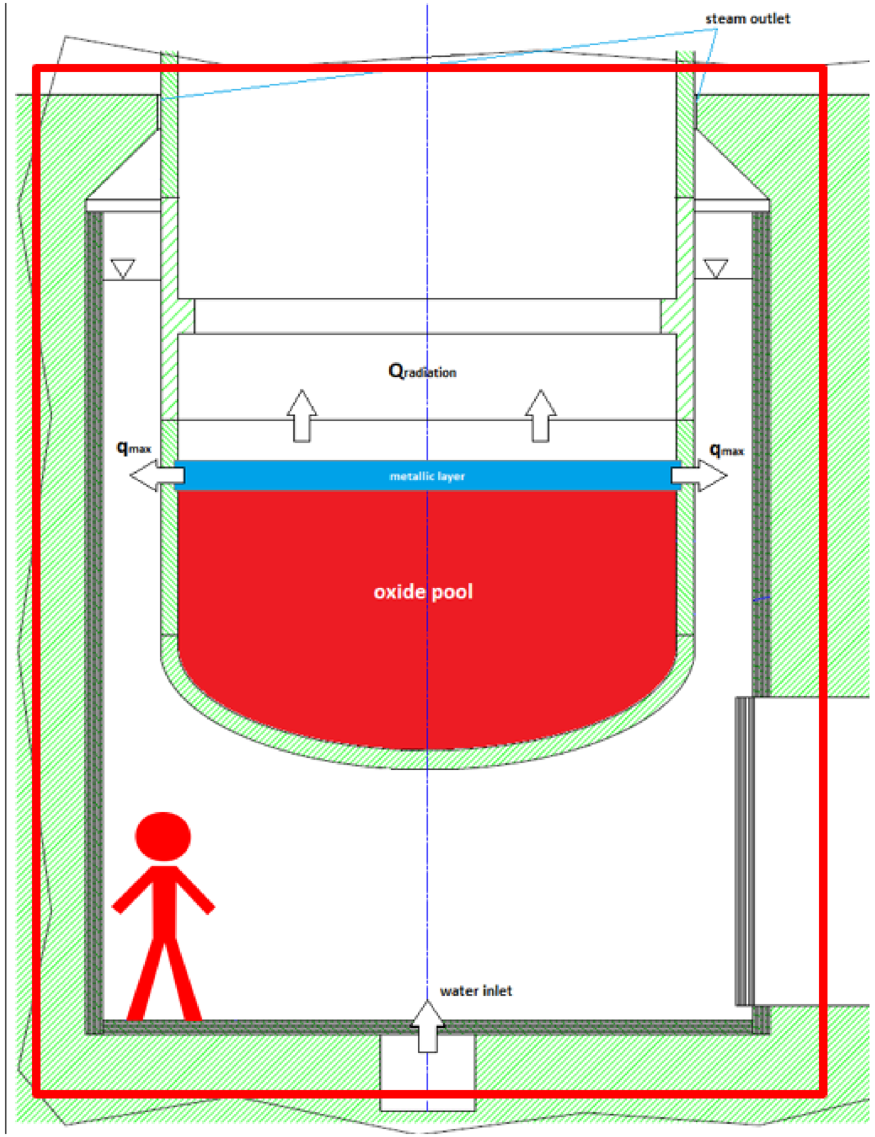
UJV approach to IVR LOOP design (2)

- Goals to simulate (as real as possible):
  - Real RPV material,
  - Real environmental conditions (pressure, Water level etc.),
  - Positions of coolant inlet/release,
  - Equivalent heat flux distribution and coolant parameters (by volume).
- → Power to volume scaling.
- Goals to investigate (3 phases):
  1. Coolability/stability of the loop according the conditions within pool boiling. (2018/19)
  2. CHF phenomena. (2020/25)
  3. Safety margin to the CHF. (2020/25)



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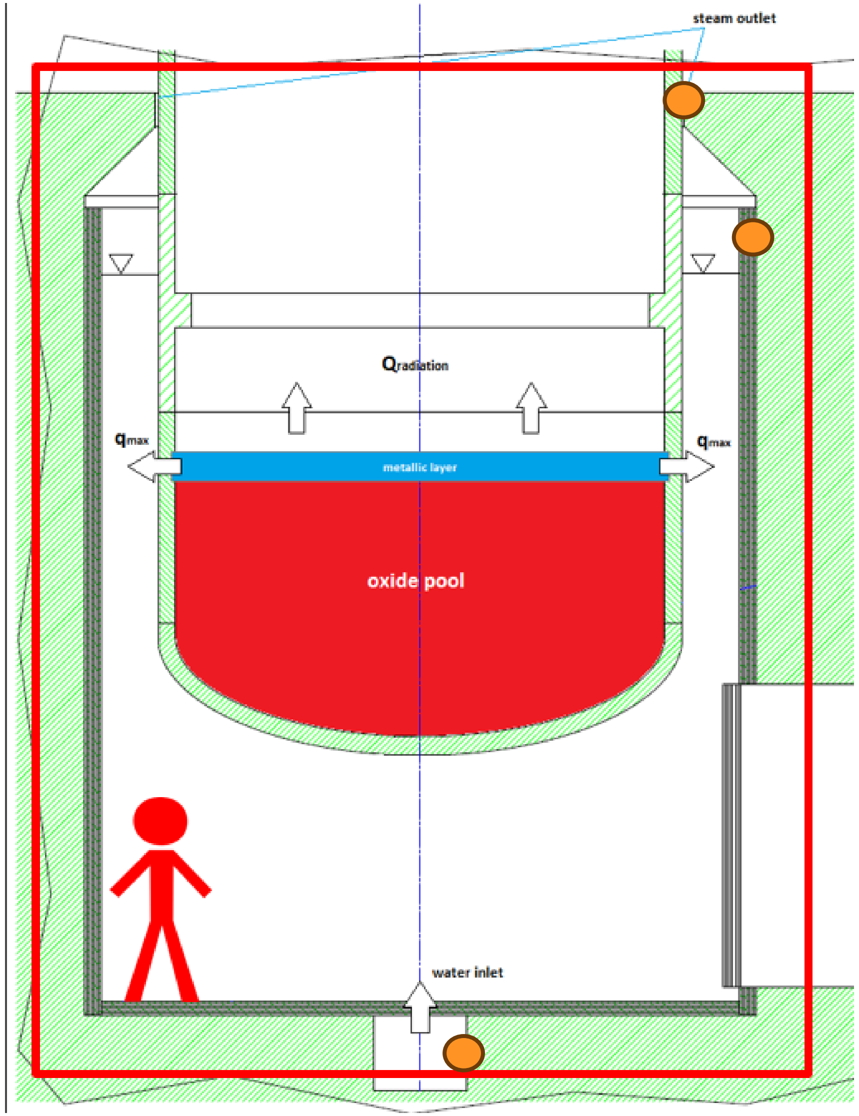
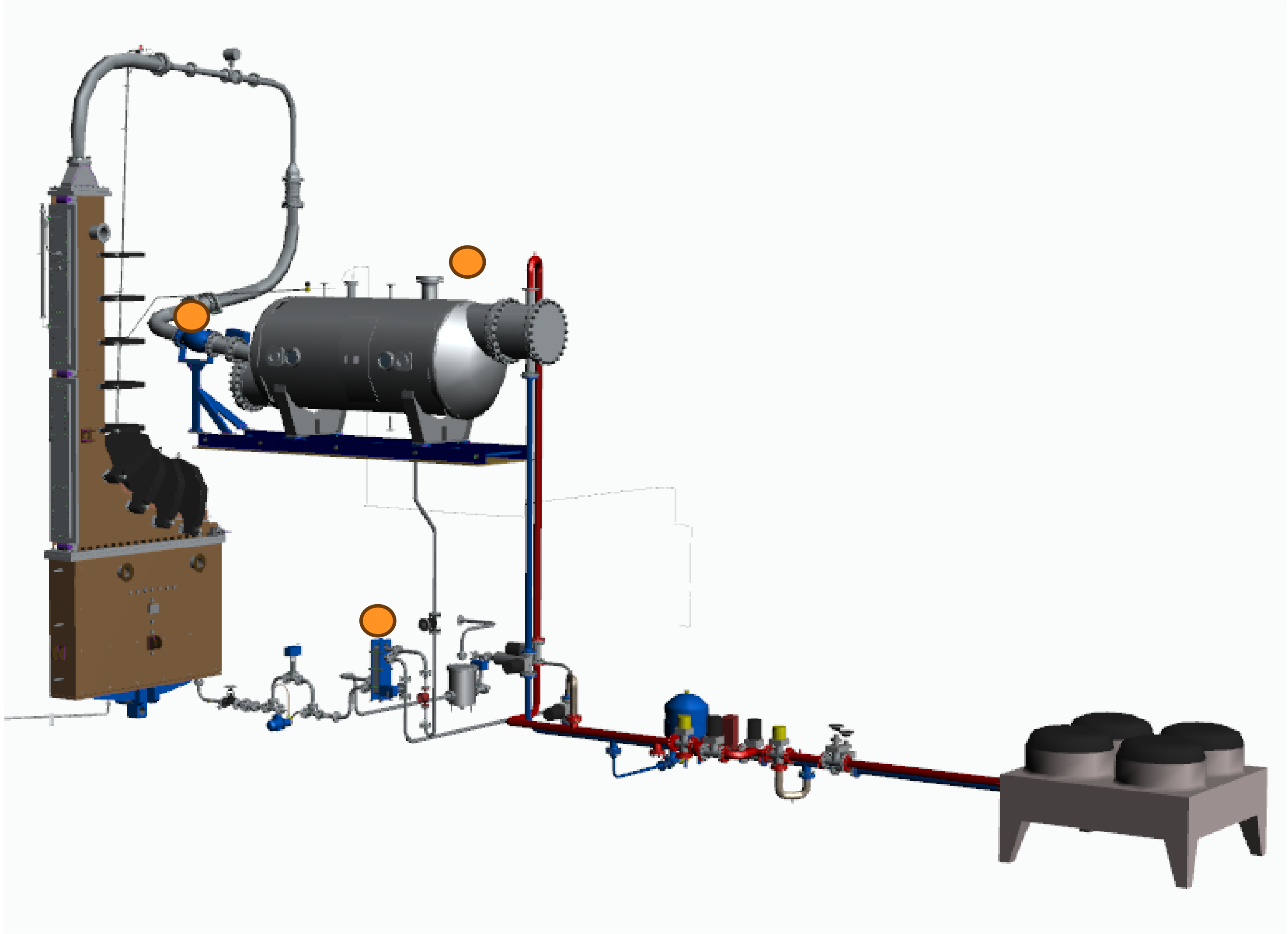
Real Prototype vs. Experimental Loop





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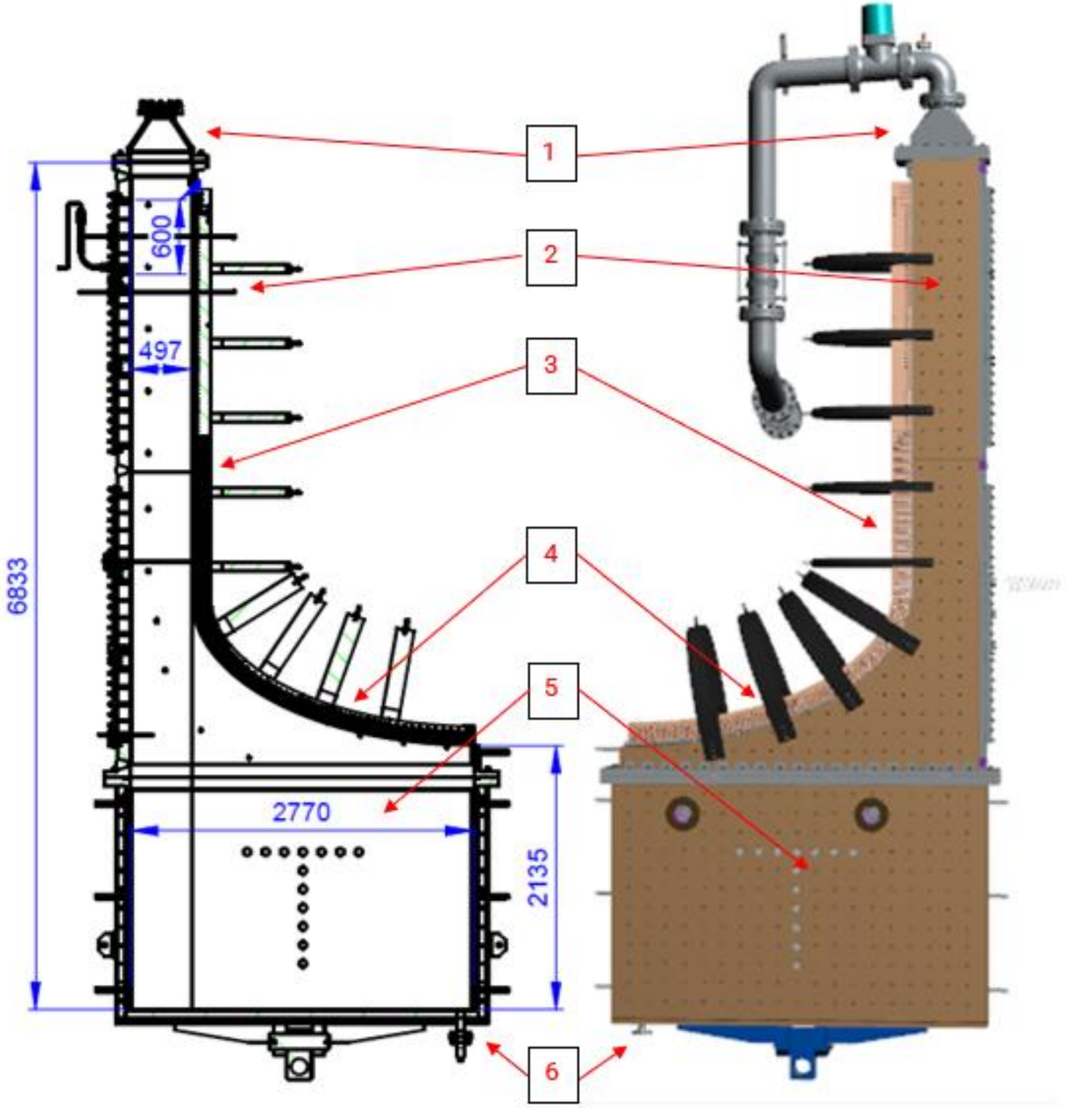
IVR LOOP – Experimental channel

- Large scale (comparing VVER-1000):
  - 1:1 in height (approx. 7 m)
  - 1:2 in diameter – length (approx. 2,8 m)
  - 1:95 in depth (15 cm slice)

- Range of parameters:
  - 1-6 bar (abs.)
  - 1,5 – 2,3 MW/m^2 reachable heat flux
  - 950 °C - Max. heating temperature
  - 150 (200) °C – max. Water temperature
  - 1,5 – 2 m^3 volume



- Description of the experimental channel parts on Figure: /1/ - Upper end for steam outlet, /2/ - Approximate level of water, /3/ - Vertical part of vessel, /4/ Ellipse shaped heating system, /5/ - Space for water below RPV (according to VVER 1000 cavity dimensions), /6/ - Flange for water inlet

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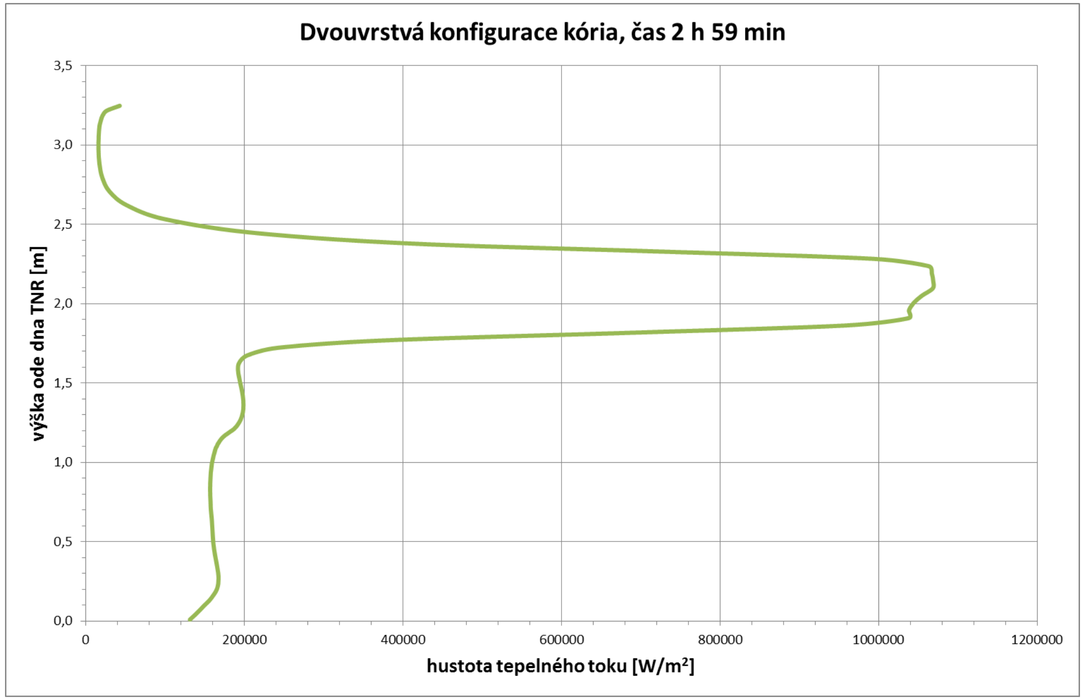
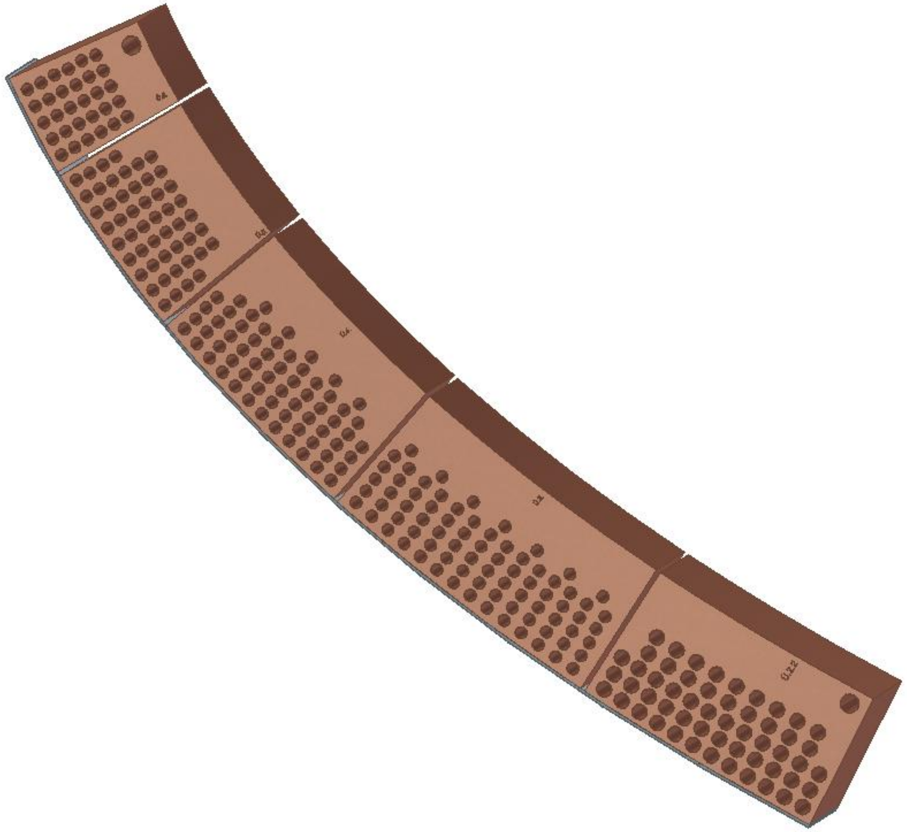
IVR LOOP – P/V scaling?

- Advantages (relative to prototype)
  - Energy distribution acc. RPV area
  - Full pressure
  - RPV shaped geometry





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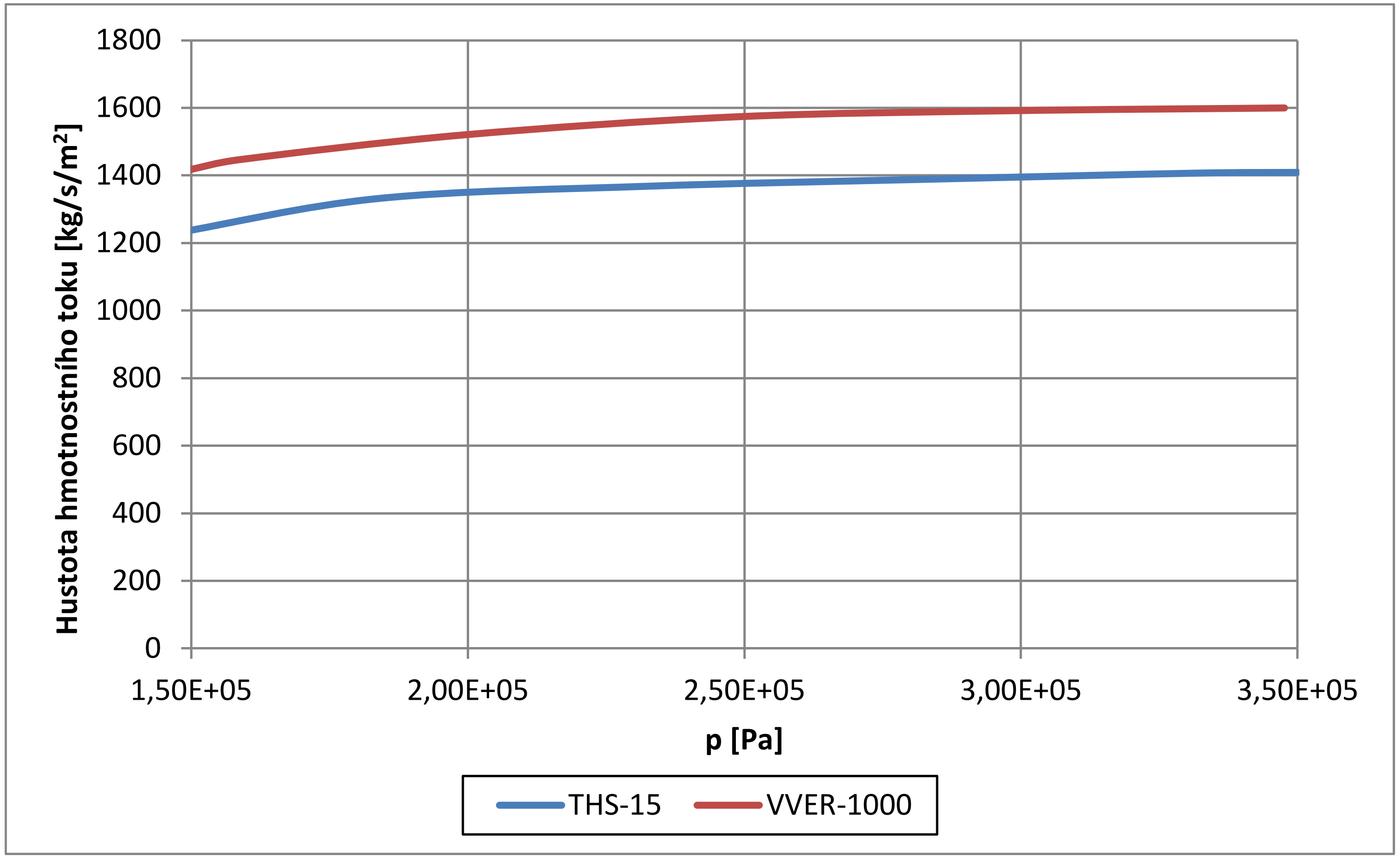
IVR LOOP – P/V scaling?

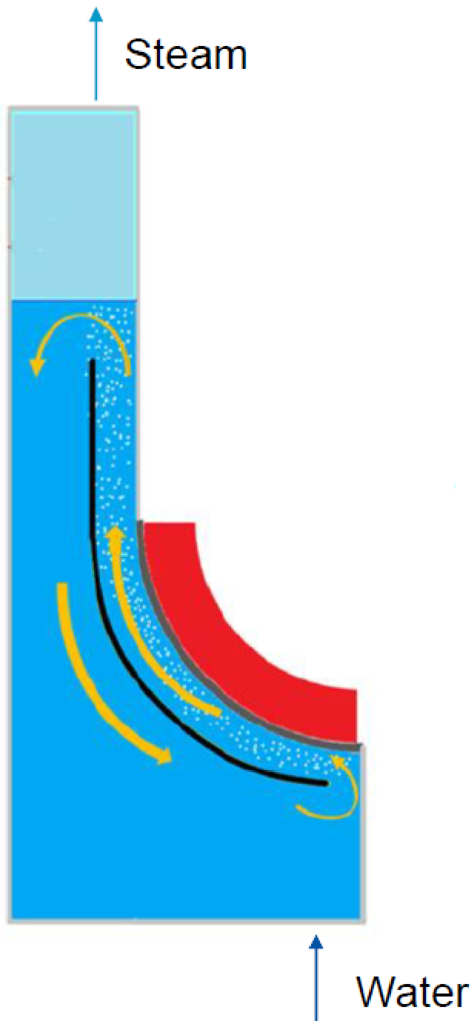
- Distortions → accompanying analyses and measures
  - Heat losses
  - Pressure drops/flow regimes*

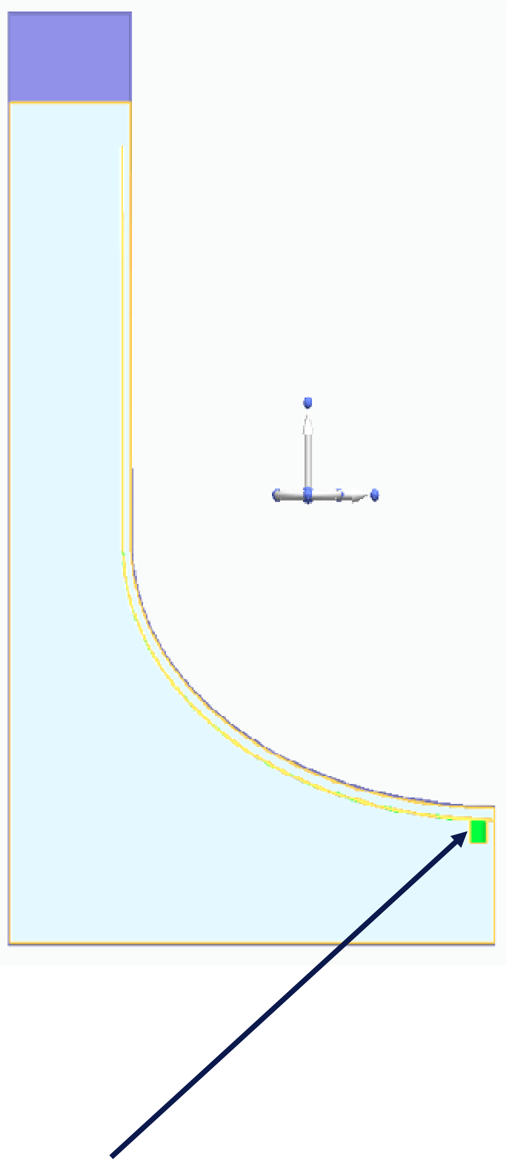
→ but taking acount to our goal (CHF phenomena), distortions lead to conservative CHF values in this SET facility



IVR LOOP in EASI SMR project

- 1) Pool boiling tests (not a part of BENCH_5). → CHF phenomena
- 2) Thermo – siphon tests (BENCH_5)
  - The goal is to investigate the ERVC endurance and efficiency in liquid thermo-siphon mode.
  - Conditions:
    - HF distribution
    - Pressure range
    - Gap geometry (50 mm / 100 mm)
    - Improved measurement (flow/velocity meter inside the ECH)





- **Thermo – siphon tests → Water level is ALWAYS ABOVE the level of the upper end of deflector (left figure)**
- **Design of deflector defining 50 mm gap (on the right figure in yellow) (CEA)**

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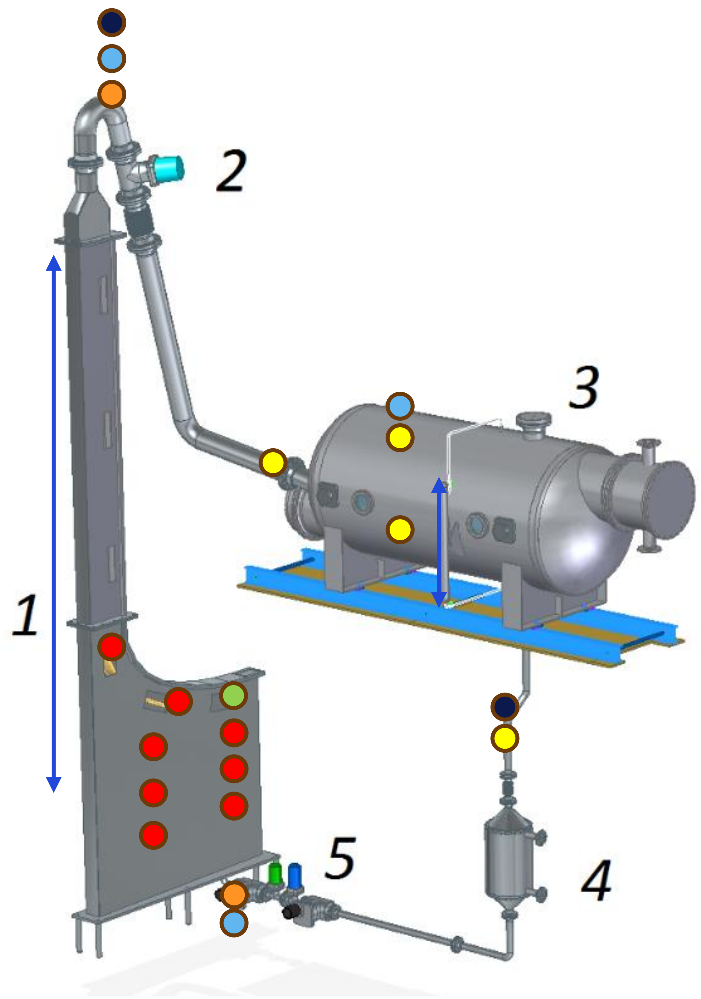
IVR LOOP in EASI SMR project - instrumentation

Measured parameter (unit)	Location of sensors (measured substance)	Number of sensors (event. Type)
Temperature (°C)	Heating sections (copper - on the upper surface, inside heating cartridges)	64 (K-type thermocouples - TC)
	"Surface" of the RPV sample (copper/RPV steel)	83 (K-type TC)
	Inlet/exit into(from the experimental channel (water/steam)	2 (Pt-100)
	Experimental channel (water)	8 (6xPt-100/ 2x K-type TC)
	Circuit piping - behind the condenser, under the sub-cooler, inside a condenser (water/steam)	4 (K-type TC)
Pressure (MPa)	Inlet into the experimental channel	1
	Exit from the experimental channel (before the regulation valve)	1
	Condenser	1
Mass flow rate (Kg/hour)	Circuit piping (hot leg for steam, cold leg for water)	2
Flow rate/fluid velocity (m^3/s) *	Inlet of thermo-siphon deflector	1
Measuring water level (mm)	Experimental channel, condenser	2



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References

- Bencik M.: VVER-1000 and THS-15 comparison analysis in RELAP5-3D, M., UJV Rez, 2015
- Batek D., Zdarek J. et.al.: D4.4 Final report on full scale tests, IVMR project, ref. No. 662157, Horizon Euratom 2020

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