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SNETP Forum

MODELLING OF NATURAL CIRCULATION IN PMK-2 EXPERIMENTS USING RELAP5 CODE

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1. Introduction:

Systems utilizing natural coolant circulation are valued for not needing human intervention and being able to operate without external power supply systems. Such systems are widely used in different passive safety systems of current nuclear reactors and is the main distinctive feature of Small Modular Reactors (SMR). SMRs introduction is planned in several EU countries – Lithuania and Hungary included.

The Lithuanian Energy Institute (LEI) and the Hungarian Centre for Energy Research (HUN-REN EK) are working together in the bilateral project issued by Lithuanian and Hungarian Academies of Science in 2022. The joint project titled "Contribution to the Development of Small Modular Reactor Concepts for the European Union“. The most promising SMR concepts, the main safety challenges related to employing passive safety systems for nuclear reactor cooling during accidents, investigation of critical heat transfer, and other issues are analysed.

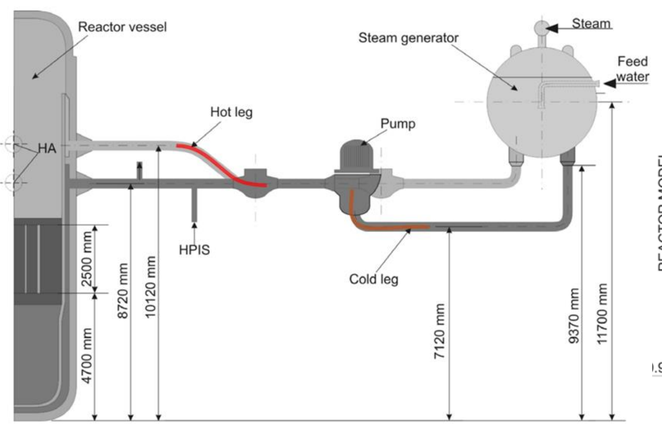
In this work the investigation of natural circulation of coolant were performed in both institutions – HUN-REN EK and LEI. HUN-REN EK has the PMK-2 experimental facility where several experiments were conducted related to natural circulation. LEI colleagues using the thermal hydraulic code RELAP5 were modeled the natural circulation phenomena observed in these PMK-2 experiments. RELAP5 code calculation results against experimental data is presented and discussed.

2. PMK-2 facility

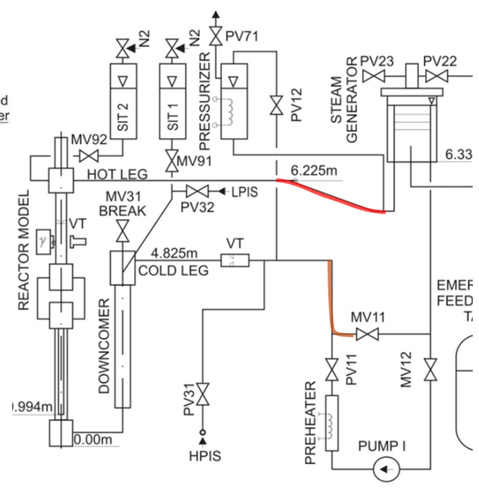
- Integral Test Facility
- Power and volume scaling is 1:2070
- Primary circuit
- Steam generator model
- Feedwater, Emergency feedwater
- Isolation valves
- Relief & Safety valves
- Full pressure model (16 MPa)
- Full height model
  - except lower plenum and pressurizer

PMK-2 facility, HUN-REN

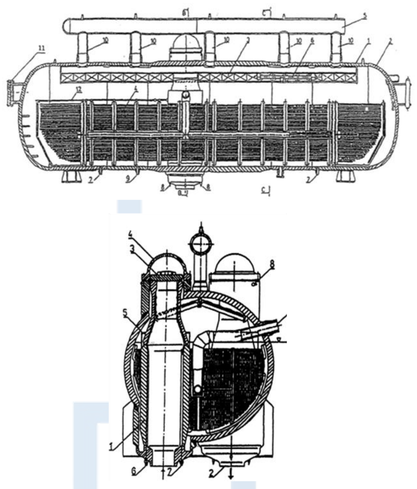
VVER-440 NPP vs PMK-2 facility



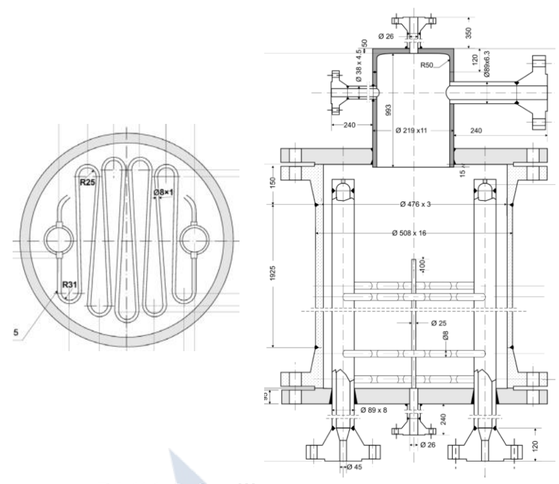
VVER-440 loop



Scheme of PMK-2 facility



VVER-440 Steam generator



PMK-2 facility steam generator

Nominal operating conditions:

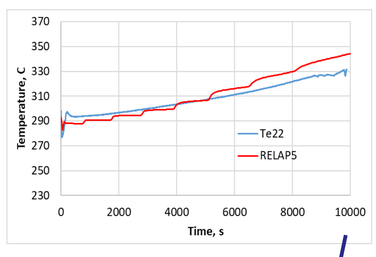
Parameter	Value	Unit
Primary pressure	12.3	MPa
Loop flow	4.5	kg/s
Core inlet temperature	267.9	°C
Core power	664	kW
Secondary pressure	4.6	MPa
Steam generator level	8.4	m
Pressurizer level	9.25	m
HA pressure	3.5	MPa
HA coolant temperature	20	°C

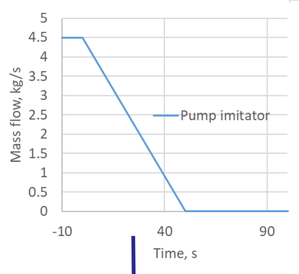
OAH-C2 experiment

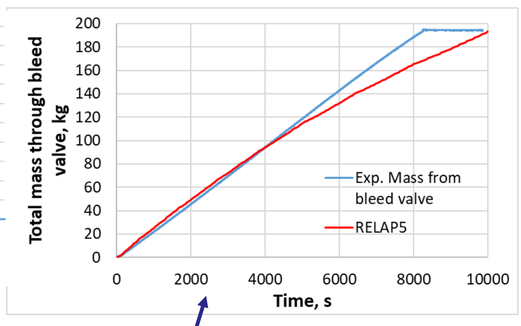
At experiment start:

- Pump trip and SCRAM.
- Secondary side isolation SG bleed valve opens, leading to a constant decrease in SG level.
- Primary pressure is kept constant by pressurizer heating.
- Test ends when SG is empty.

4. RELAP5 model of PMK-2 facility and results

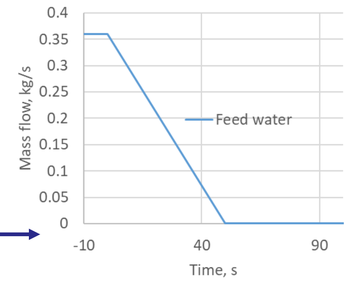


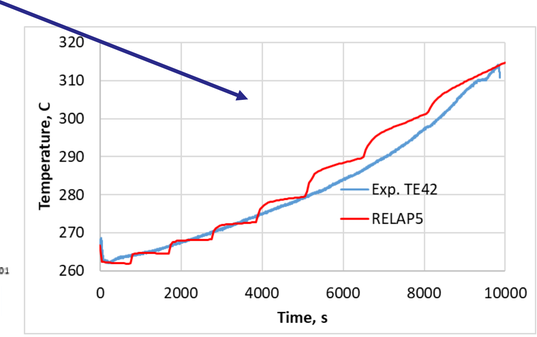


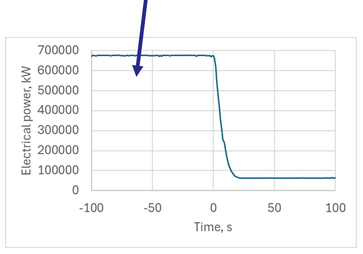


Facility hall, to simulate the heat loss of the steam generator

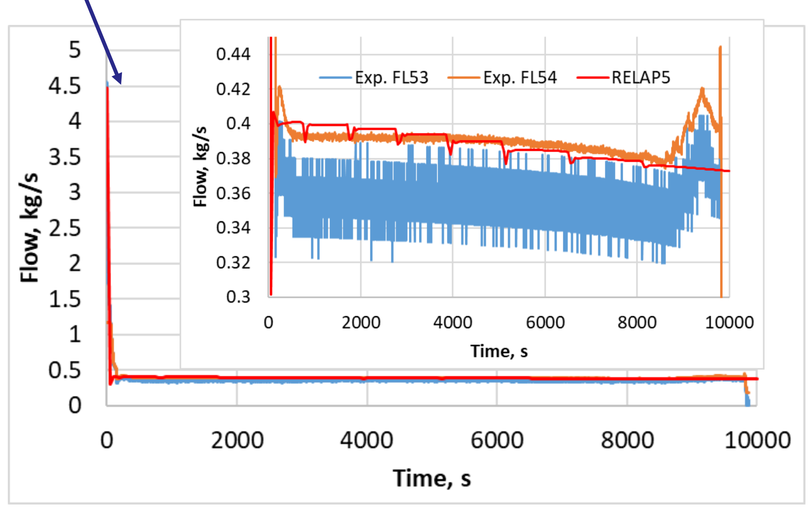
Secondary side of the steam generator was modeled by two components “003” and “005” with cross flow connections to simulate real behavior - water mixing, heat up and boiling.







Power was reduced by ~10% compared to the experiment to model the heat loss of the facility



5. Discussion and Conclusions

The collaborative research and knowledge exchange initiative holds significant promise for addressing energy self-sufficiency challenges faced by scientific organizations in both Lithuania and Hungary. HUN-REN presented experimental experience with natural circulation (PMK-2 experimental facility, OAH-C2 test) which could be applicable for the SMR thematic. From LEI side the modeling experience of the physical processes using RELAP5 code were empowered in this work.

Calculation results shows more intensive mass loss in the first 4000 s compared to the experimental results, but later this starts to decrease, and the calculation underestimates the experimental data. This is related to the water level decrease, less water contact with the hot surfaces (heated pipes) causes less steam to be produced and released from the steam generator. Calculations, as well as experiment, were terminated, when the steam generator became empty.

Calculated water temperature in the primary circuit, at the steam generator cold collector outlet, are in good agreement with experimental data. However, in the calculation the curve has a stepped profile which is due to the nodalization of the steam generator – sharp temperature increase is due to the emptying nodes.

After the pump trip and reactor SCRAM the natural circulation in the primary circuit were observed, calculation results are in good agreement with measurements.

Overall conclusion - RELAP5 code are validated against experiment results, and it is capable to simulate the natural circulation in investigated conditions.

Acknowledgments

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