IMPROVING SAFETY ANALYSIS METHODOLOGIES AND MOVING FROM TRADITIONAL TO HIGH-FIDELITY SAFETY ANALYSIS TOOLS FOR SMALL MODULAR REACTORS

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Dear Colleagues,

substantial advancements along the work programme of McSAFER have been achieved during the last two years for the majority of the work packages: Multi-physics Core Analysis (WP3), Multi-scale RPV-analysis (WP4) under Boron Dilution (NuScale) and ATWS conditions (SMART), Multi-physics/-scale plant (SMART, NuScale) analysis under Steam Line Break (SLB) conditions, and Dissemination and Education and Training (WP6).

The experimental program of the Work Package 2 (WP2) included two test series at each of the three facilities (MOTEL at LUT, COSMOS-H at KIT, and HWAT at KTH). The tests at MOTEL were conducted in time while the test series at the other facilities are facing delays due to unexpected leakage in the circuits and due to delays in the supply of key-parts. It is expected to perform the tests until the end of 2022 to assure that the code validation work is done in time.

Around 80% of the multi-physics core analysis for CAREM, F-SMR, NuScale and KSMOR is performed. A similar situation exists for the multi-scale RPV analysis (7 % done) while for WP5 around 40% is done. The gained knowledge and expertise of the McSAFER partners was actively disseminated by two very successfully training courses as well presentations and publications in conferences and journals. A User Group of five participants (NRG, ININ, FRAMATOME/Germany, IRSN and BME) was established. Two international experts (STUK, Uni Wisconsin) were gained to be part of the international advisory board (TAB).

I herewith express my deep thankfulness to the whole McSAFER Consortium for their dedication and passion making McSAFER a success history. I wish you the same energy, creativity, and commitment for the remaining year of a fruitful cooperation across different actors (universities, research centres, TSO, industry).

Victor Hugo Sanchez Espinoza
Coordinator

MOTEL EXPERIMENTS AT LUT

Two series of experiments were conducted with the MOTEL test facility in the LUT University nuclear safety research laboratory in Lappeenranta, Finland, in 2021-2022. The first series studied the behaviour of the helical coil type steam generator of MOTEL, and the second series focused on studying core crossflows applying asymmetrical radial core power distributions.

Steam generator experiments

The first test series consisted of two steam generator experiments, which were performed in the autumn 2021. Steady states with different uniform core heating power levels were run. In the first experiment, the used power levels were 250 kW, 500 kW, 750 kW and 1 MW, which is the maximum heating power of MOTEL. In the second experiment, lower power levels were used; 75 kW, 100 kW, 125 kW and 150 kW. Particularly, the temperature behaviour of the steam generator, both on the shell and tube sides, was studied. Temperature distributions along the steam generator tubes were measured. In the first experiment with higher core powers, there was a clear increasing trend of the temperatures apart from the lowest 250-kW power level, as can be seen in the example Figure 1. The figure shows the averaged secondary side steam generator temperatures on the middlemost level of the SG. Same kind of increasing temperatures on were detected on the shell side of the SG. Hence, not all the power steps can be considered as real steady states but more as quasi-steady states. Also, a clear fluctuating behaviour of the temperatures was observed, especially on the higher core power levels.

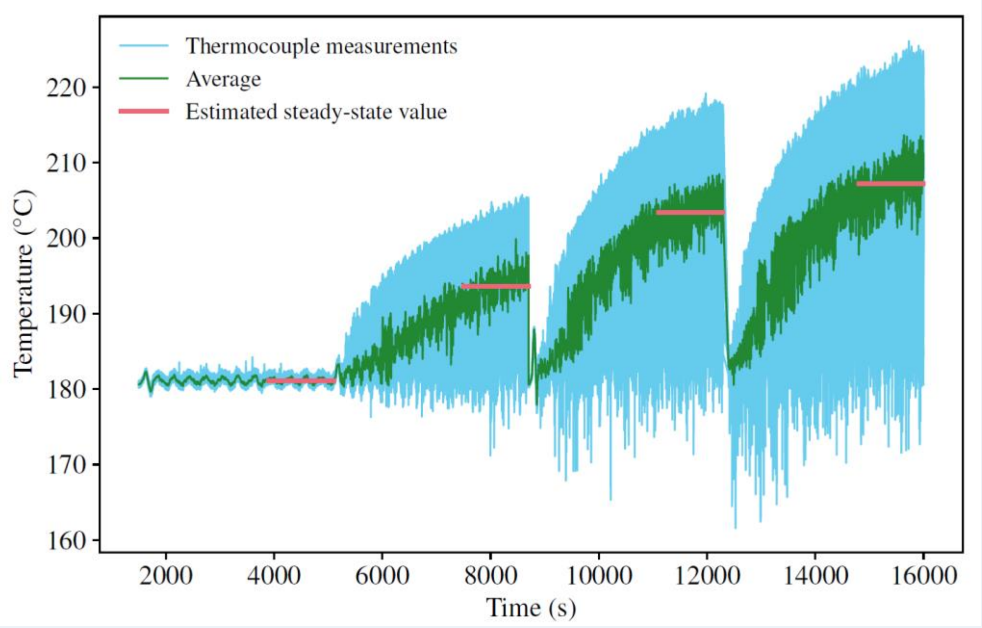

Figure 1: Averaged MOTEL steam generator middle level secondary side temperatures with core power levels 250 kW, 500 kW, 750 kW and 1 MW.

In the first series' second experiment with the lower power levels, the temperature behaviour was more stable in the sense that there was no such increasing temperature trend as in the first experiment. The secondary side feedwater reached the saturation temperature in the bottom region of the steam generator, and the temperatures stayed on the same level along the whole length of the SG. A slight fluctuating behaviour of temperatures was observed during the second experiment, albeit not nearly as strong as in the first experiment.

Core crossflow experiments

In the second MOTEL test series within McSAFER, MOTEL core crossflows were studied, using both symmetrical and different asymmetrical radial core power distributions. The MOTEL core is divided into twelve separately adjustable radial power regions as illustrated with different colours in Figure 2. This structure enables application of various radial core power distributions in the experiments.

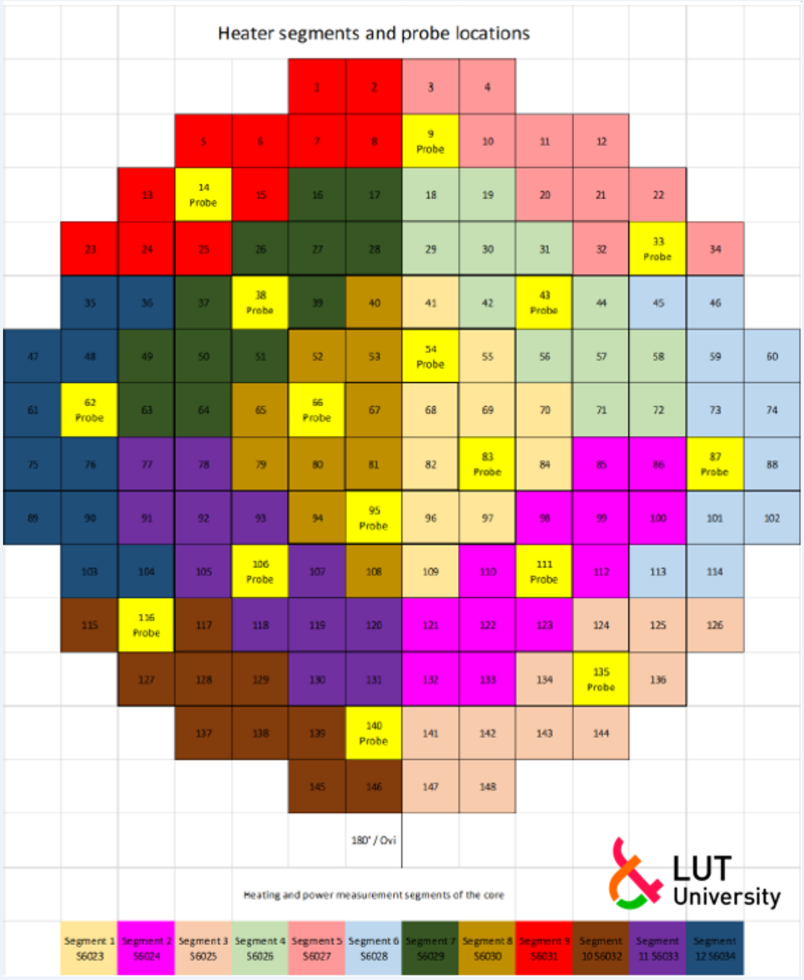

Figure 2: Radial power segments of the MOTEL core. Each square represents one heater rod, except the yellow measurement rods. Different colours represent the adjustable heating segments.

In the two experiments of the second series, the aim was to achieve as large temperature differences in the radial directions of the core as possible by means of applying asymmetrical power distributions. Uniform power distributions were run for reference in the beginning of the experiments. In the first experiment, asymmetrical distributions with the core divided into two halves (left- and right-hand sides in Figure 2) were tested. The following configurations were tested: one half 31 %, the other half 16 % of the maximum power; 37 % and 10 %; 48 % and 0 %. The total core power on these runs was approximately 230 kW, and the duration of each step was one hour. In addition, a power distribution with 92 % power in two segments and 0 % in all the other segments was run, the total power being approximately 170 kW.

In the second experiment, ring-shaped radial power distributions were tested. First, a power distribution with 100 % power in the middle and 0 % power in the inner and outer rings (see Figure 2) was run, the total power being approximately 150 kW. Then, the power was increased to approximately 235 kW and a reference run was conducted with a uniform power distribution. After that, a ring-shaped power distribution with 100 % power in the middle and 10 % power in the other regions was run. Finally, a power distribution with 52 % power in the middle, 31 % in the inner ring and 10 % in the outer ring was run, the total power being 235 kW. The duration of the reference runs was half hour, and the duration of the actual runs was one hour.

The maximum used power in the crossflow experiments was approximately 235 kW. This was because the experiments were desired to be run as steady state as possible. With higher powers, the temperatures in the facility would have an increasing trend, as can be seen above in Figure 1. Increasing temperatures would make the interpretation of the core region radial temperature differences difficult.

The analysis of the data from the core crossflow experiments is not ready yet. Nevertheless, it can be concluded that the temperature differences in the core in the radial direction were fairly low. This is most probably due to the structure of the MOTEL facility and the consequent relatively high mass flow compared with the height of the core. It seems that with these experiments, not as large temperature differences were achieved as desired.

COSMOS-H EXPERIMENTS AT KIT

Preparations for the flow boiling and critical heat flux experiments at KIT are now progressing well. After several delays in delivery due to market conditions, many systems have been completed now. After the completion of the high-pressure loop of COSMOS-H and the first set-up of the test section, the strength tests for approval according to the Pressure Equipment Directive were carried out at the end of May.

Figure 3: Ground floor and test section of COSMOS-H during the pressure test

The pressure test was carried out at 328 bar and 20°C. The test section and test loop were completely filled with demineralised water using the plant's water management system. Then the circuit was filled with two external pumps to a pressure of 329 bar at the lowest point. The test section and the system withstood this pressure under the supervision of the expert inspector. This means that the system can be stressed to conditions of up to 370°C and 170 bar in the subsequent test operation.

In the meantime, the inspection of the inside of the test section and the vessels has also been successfully completed. Systems such as the trace heating and thermal insulation were applied to the test loop and all sensors were applied. A small leakage that the electric steam generator showed during the pressure test at the heater entries from 260 bar is currently being sealed and the test section with the first test arrangement is being set up. The "hot" commissioning of the facility and the test section will begin shortly.

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COORDINATION
Dr. V. H. Sanchez-Espinoza (Victor.sanchez@kit.edu) · Karlsruhe Institute of Technology, Germany · Institute of Neutron Physics and Reactor Technology (INR)

CONTACT
Karlsruhe Institute of Technology (KIT) · Research Office (FOR) · email: mcsafer@for.kit.edu · www.mcsafer-h2020.eu