# Preliminary Assessment of MARS-KS for the OECD-PKL G7.1 Test

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## 1. Introduction

The scenario of the OECD-PKL G7.1 test [1] is a hot leg SB-LOCA followed by additional system failures such as no high pressure safety injection (HPSI) and no automatic secondary-side cool down. These additional system failures cause the necessity of accident mitigation (AM) procedures to prevent a core melt-down. As a result, a secondary-side depressurization was adopted as an AM measure for restoration of the secondary side heat sink to induce accumulator (ACC) and the low pressure safety injection (LPSI). The secondary-side depressurization for an AM procedure begins when the measured core exit temperature (CET) is greater than 350 °C. However, there may be discrepancies between the CET and the peak cladding temperature (PCT).

The main objective of the test was to assess the reliability of the CET measurement and its correlation to the peak cladding temperatures (PCT). Also, the test G7.1 was designed as a counterpart test between the PKL and ROSA/LSTF test facilities to investigate the scaling effect. In this study, the PKL G7.1 test was simulated as part of a post-test calculation to assess the analysis capability of the MARS-KS code.

## 2. Conditioning Phase Simulation Results

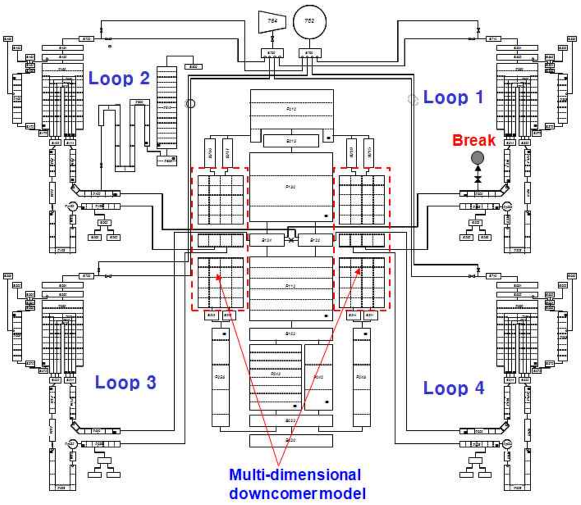

Fig. 1 MARS-KS model for PKL G7.1 test

The MARS-KS input deck for the simulation was based on the input used in the previous assessment [2] with some modification. As shown in Fig. 1, the upper downcomer region of the reactor vessel was composed of a single multid component in order to investigate the multi-dimensional hydraulic effect caused by an asymmetric loop flow. The heat structures in the core and SG tube are divided into three regions, inner, middle and outer region, respectively.

At the beginning of the conditioning phase, the entire reactor coolant system (RCS) was filled with water except for the pressurizer, all reactor coolant pumps (RCPs) were stopped, the RCP butterfly valves were closed to simulate the hydraulic resistance of the RCP, and subcooled natural circulation was established in the primary loop. The secondary side was completely isolated to reduce the primary-side subcooling and filled up to a level of 11.9 m at the initial state. For a transition to reflux condensation (RC) condition, the break valve (7.8 mm) in hot leg 1 was opened to reduce the primary coolant inventory. When the primary-side fill level was reduced to the SG inlet side, the break valve was closed and the primary pressure was controlled at 45 bars by the main steam relief control valve (MS-RCV) actuation.

After the completion of the conditioning phase in the primary side, the fill level of all secondary side was reduced to 8 m approximately for adjustment of scaling effect between the PKL and ROSA/LSTF test facility. After the reduction of the secondary fill level, all SGs were isolated again and the test phase would be started.

The core power was maintained as a constant of 565 kW for compensation of heat loss and the pressurizer heater was also in operation during the test.

All simulation procedures in the conditioning phase were similar way to the experimental procedures and the comparison of initial condition of start of test (SOT) between the simulation and the test is summarized in Table 1.

Table 1. Comparison of the initial conditions at SOT

| Parameters | Desired | Cal. | Remark |
|---|---|---|---|
| Core power (kW) | 565 | 567 | exp. data |
| Primary pressure (bar) | 45 | 45 | |
| Primary inventory (kg) | - | 1000 | |
| Core exit temperature (K) | 530 | 531 | |
| Loop flow rate (kg/s) | ~0 | < 0.1 | |
| PRZ level (m) | 0.8 | 0.52 | |
| S/G pressure | 43.7 | 43.9 | |
| S/G collapsed level (m) | 7.7 | 7.7 | average |
| Feedwater temperature (K) | 346 | 346 | constant |

## 3. Test Phase Simulation Results

First of all, it is noted that all the values in the result graphs are omitted because the experimental data can not be released by the restriction of the contraction between the OECD/NEA and KAERI.

Test phase simulation was initiated by opening the break valve located in hot leg 1 to simulate the SB-

LOCA. The primary pressure slowly decreased due to an inventory loss through the break valve, whereas the secondary pressure slowly increased at the beginning of transient due to a complete isolation. As shown in Fig. 2, overall trends show good agreements with the experimental data but the depressurization began earlier than experiment due to early heat-up in the simulation (Fig. 3).

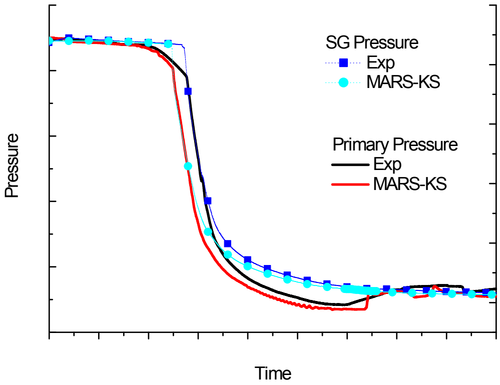

Fig. 2 Break flow and S/G pressure

Continuous inventory loss in the primary side results in the reduction of the core level and boil-off. As a result, the superheated steam starts to be formed at the top of the core. As shown in Fig. 3, the CET increases earlier than experiment. This discrepancy may result from either the difference of the initial coolant inventory or the different definition of the CET. In the simulation, the CET is represented as a steam temperature at the top region of the average core (inactive core), whereas the CET is measured by thermo-couples (TCs) located at the top of the inner core in the experiment.

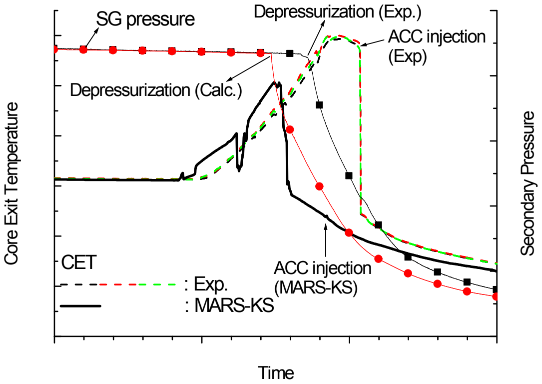

Fig. 3 Comparison of CET and SG pressure

As a result of depressurization, the primary pressure drastically decreases and finally, all ACCs are injected into the cold legs at 10 bars. In the experiment, the CET slowly decreases during the depressurization phase but decreases rapidly after the ACC injection. On the other hand, the CET in the simulation decreases sharply just after the secondary depressurization is started as the core mixture level increases as a result of flashing. In addition, the delayed depressurization in the experiment resulted in the higher CET compared with the MARS-KS result. From Fig.3, it is clearly found that the CET in the experiment is much higher than in simulation when the SG pressure starts to decrease sharply.

Fig. 4 shows the difference between the PCT and CET in both cases. There are two peaks in the MARS-KS simulation. The first one is due to a sudden decrease of the CET (see Fig. 3) and the second is due to depressurization effect. Despite these differences, the simulation result is very similar to the experimental data until the depressurization operation starts.

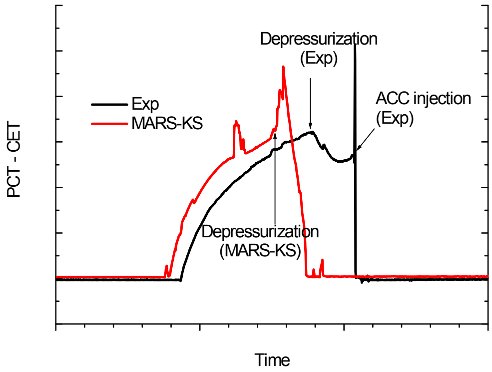

Fig. 4 Comparison of difference of PCT and CET

## 4. Conclusions

The OECD-PKL G7.1 test was simulated by using the MARS-KS code. The overall simulation results agreed well with the experimental data but some mismatches were found such as an early core heat-up, early depressurization and rapid CET decrease. A less initial coolant inventory caused an earlier core heat-up as well as an earlier depressurization. Due to a flashing effect followed by depressurization, the core mixture level increased up to the top of the core and finally, the CET decreased rapidly by interfacial heat transfer between superheated steam and saturated liquid water. In spite of these mismatches, however, it seems that the AM procedure based on the CET is still effective because the trend of difference between the PCT and CET showed a good agreement with the experimental data.

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## REFERENCES

[1] Bernhard Schoen, "PKL III G7.1: SB-LOCA with Total Failure of HPSI – Quick Look Report", PTCTP-G/2011/en/ 0008 (rev. B), AREVA, March 2012.

[2] S. W. Lee, *et al.*, "Post-Test Analysis of PKL G3.1 Test using MARS-KS", KNS Spring Meeting, Korean Nuclear Society, May 2010.