# Assessment of the MARS-KS code by using the OECD-PKL III F1.1 Experiment

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## 1. Introduction

The large-scale test facility PKL is a scaled-down model of a 4-loop pressurized water reactor (PWR) of the 1300 MWe class. The PKL test facility models the entire primary system and essential parts of the secondary system without turbine and condenser. Though all elevations are scaled 1:1, volumes, power and mass flows are modelled by the scaling factor of 1/145. The maximum power of 2.5 MW corresponds to 10 % of the rated thermal power in commercial plants. The maximum pressure of the primary system is 45 bars.

In present study, the MARS-KS code[1] has been assessed by using the results of the PKL III F1.1[2] test of which objective is the investigation of the inherent boron dilution event due to the reflux-condensation at the primary side of the U-tubes in the steam generators (SGs) with the minimum safety injection during the small break loss of coolant accident (SB-LOCA).

## 2. Description of PKL III Test F1.1

### *2.1 Identification of Inherent Boron Dilution Accident*

Inherent boron dilution accident during SB-LOCA can occur in combination with reduced availability of the high pressure safety injection (HPSI) system. Under these conditions and at high system pressure, the blowdown flow rate is higher than the HPSI flow. This leads to a reduction of the primary coolant inventory and as a result, energy may temporarily be transferred from the primary to the secondary side under reflux-condensation. In this situation, only small amounts of boron are transferred from the hot side to the cold side of U-tubes by the vapour phase. Therefore, the condensate accumulated in the loop seals below the SGs is nearly free of boron. This boron-free condensate may enter the reactor pressure vessel (PRV) and lead to the re-critical state of the reactor core when natural circulation of the primary circuit starts after the refill of the reactor coolant system (RCS).

### *2.2 Procedure of PKL III Test F1.1*

The procedure of PKL III F1.1 is divided into two phases. One is 'Conditioning' phase to set the initial condition of reflux-condensation state by reduction of the coolant inventory and condensate build-up. The other is 'Test' phase to simulate the inherent boron dilution accident with SGs cooldown and reduced safety injection during SB-LOCA. Table 1 shows the major parameters in the end of 'Conditioning' phase or start of 'Test' phase (SOT).

Table 1. Major parameters of start of test (SOT)

| Parameters | Value |
|---|---|
| Primary inventory (kg) | 1280 (including PZR*) |
| Total heater power (kW) | 482 (compensating heat loss) |
| Pressure (bar) | 39 |
| Core exit temperature (°C) | 249 (0 subcooling) |
| Boron Concentration (ppm) | above 4000 (core top)<br>below 50 (loop seal) |
| Loop flow rate (kg/s) | ~ 0 |
| PZR level (m) | 0.9 |
| SG pressure** | 37.3 |
| SG collapsed level (m) | 12.2 |

*PZR; pressurizer, ** slightly different for each loop

'Test' phase begins by opening the break valve at the cold leg in the loop 1. At the same time, HPSI flow is delivered to four loops via only 1 safety injection pump (SIP) out of 2 SIPs and SGs cooldown starts with the rate of 56 K/h. The break size is equivalent to 21 $cm^2$ break are in a real plant.

## 3. Assessment of MARS-KS

The MARS-KS input for this assessment is based on the MARS input already used for PKL III E2.2 test assessment with some modifications because E2.2 test is very similar to the test F1.1. The RPV downcomer is modelled by multid components to investigate asymmetric loop behaviours and the other parts consist of the one dimensional components. Assessments procedure is also divided into two steps like an experiment, 'Conditioning' and 'Test' phases, respectively.

Table 2 shows comparison results of experiment and code assessment at the time of the SOT. As shown in the table, the calculated results agree with the experimental data very well.

Table 2. Comparison of experiment and calculation data(SOT)

| Parameters | Exp. | Cal. | Error(%) |
|---|---|---|---|
| Primary inventory (kg) | 1280 | 1276 | -0.8 |
| Pressure (bar) | 39 | 38.7 | -0.3 |
| Core exit temperature (°C) | 249 | 248.4 | -0.2 |
| Boron in loop seal (ppm) | < 50 | 1 | - |
| Loop flow rate (kg/s) | ~ 0 | ~0 | - |
| PZR level (m) | 0.9 | 0.73 | -18.9 |
| SG pressure | 37.3 | 36.9 | 0.4 |
| SG collapsed level (m) | 12.2 | 12.6 | 3.3 |

In 'Test' phase simulation, the original RELAP5 choking model has been used at the break valve and its discharge coefficients are set to 0.6, 1.99 and 1.99 for subcooled water, two phase flow and superheated steam, respectively. The break flow rate, calculated by the MARS-KS code, shows a good agreement with the experimental data during depressurization as shown in Figure 1. After the pressure build-up due to a recovery of RCS inventory, however, the break flow by MARS-KS is greater than the experimental data because system pressure, which strongly depends on the heater power, is higher than experimental data.

Figure 2 shows a comparison of coolant flow rate at the loop seals in the loop 2 and 4. Though asymmetric behaviour between loops is shown in the experimental data, there is no difference in the MARS-KS results. Similar to flow rate, boron concentration of the loop seal in the experimental data also shows the asymmetric behaviour as shown in Figure 3 but it is not shown again in the MARS-KS result. The PKL test report[2] said that these asymmetric behaviours resulted from the driving force due to out-surged steam from the pressurizer but the MARS-KS code estimates only negligible amount of vapour flow from the pressurizer, which has no effect on the loop flow.

Figure 4 shows the boron concentration in the loop seal and core inlet region. Though boron concentration at core inlet is reduced by the incoming of boron-free flow, its minimum value at the core inlet is 1650 ppm, which may be enough to prevent the reactor core from being re-critical.

## 4. Conclusions

The assessment of the MARS-KS code has been performed by using PKL III F1.1 experiment data. From the assessment results, it is found that the overall behaviours of major parameters such as pressure, level, natural circulation flow rate and boron concentration in the result of the MARS-KS assessment shows a good agreement with the experiment data except for the asymmetric loop behaviours. However, the further works are also required for the specific thermal-hydraulic model such as an interfacial drag model.

## ACKNOWLEDGEMENTS

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## REFERENCES

[1] S. W. Lee, "Development of the MARS-KS code (draft version)", internal report, MARS-095, KAERI, 2007.
[2] Test PKL III F1.1: Inherent Boron Dilution during SB-LOCA(Break: $21cm^2/145$ in Cold Leg, ECC Injection by 1 HPSI Pump via Header into all 4 Cold Legs, Cooldown at 56 K/h) in a Non-German Design PWR, Framatome ANP, FANP GNTT1/05/en/05, Dec. 2005.

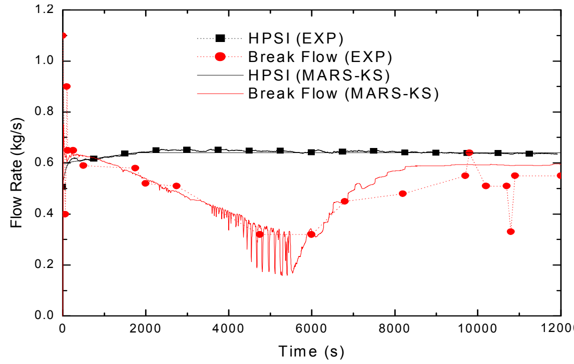

Figure 1. Comparison of HPSI and break flow

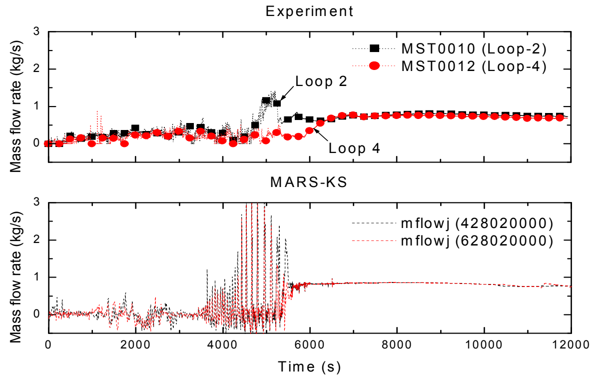

Figure 2. Mass flow rate at RPV inlet in loop 2 and 4

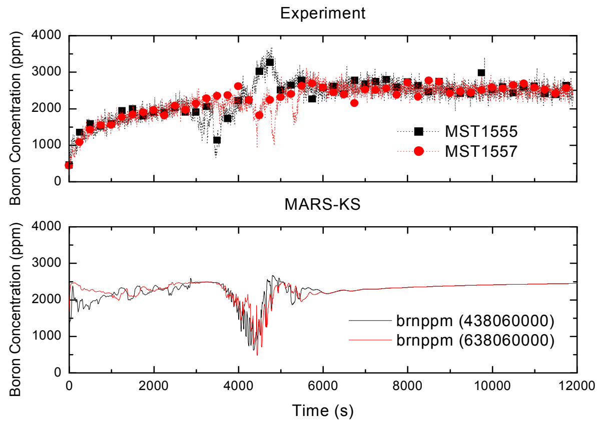

Figure 3. Boron concentration at RPV inlet in loop 2 and 4

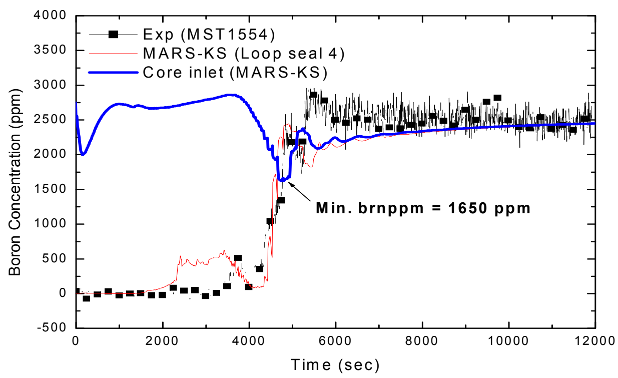

Figure 4. Boron concentration of loop seal and core inlet