Assessment of SPACE Code Using the LSTF 10% MSLB Test

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1. Introduction

The Korea Nuclear Hydro & Nuclear Power Co.(KHNP) has developed a multipurpose nuclear safety analysis code called the Safety and Performance Analysis Code for Nuclear Power Plants (SPACE). The SPACE is a best-estimated two-phase three-field thermal-hydraulic analysis code used to analyze the safety and performance of pressurized water reactors (PWRs). As in the second phase of the project, the beta version of the code has been developed through the validation and verification (V&V) using integral loop test data or plant operating data and the complement of code to solve the SPACE code user problem & resolution reports.

In this study, the Large Scale Test Facility (LSTF) 10% main steam line break (MSLB) test, SB-SL-01, was simulated as a V&V work. The results were compared with the experimental data and those of the RELAP5/MOD3.1 code simulation.

2. LSTF MSLB Test Description

2.1 LSTF

The LSTF was designed as a 1/48 volumetric scale integral test facility to simulate the response of a typical Westinghouse 4-loop PWR under the Rig Of Safety Assessment (ROSA)-IV Program presented by the Japan Atomic Energy Research Institute (JAERI). The height of each component and relative elevations, however, were full scale to simulate the coolant flows under natural circulation conditions. The flow areas were also scaled to 1/48 in the pressure vessel. The core power was scaled by 1/48 at a power equal to 14% of the reference plant power, 3423 MWt. The LSTF core consists of 1104 full length electrical heater rods placed in a 17X17 array. The rated thermal output of the core was 10 MW. For the steam generators (SGs), two generators at a scale of 1/24 were installed and the corresponding steam lines or feed lines were scaled by 1/24. The 141 U-tubes in each SG were arranged in a square array, and they consist of nine groups of U-tubes with different heights.

2.2 MSLB Test

The SB-SL-01 test was conducted in 1990 to experimentally simulate a 10% MSLB transient in a PWR. The break event was simulated through the manual operation of a break unit. The break unit consisted of a venturi flow meter, a spool piece to measure the two phase break flow rate and density, a break orifice and a break valve. The break was located in the main steam line of the B-loop. The orifice diameter was 31.9 mm which corresponds to 10% steam line. The test was performed at the rated full power of 10 MWt. The reactor trip was manually initiated at the beginning of the break. The main steam isolation valve (MSIV) was manually also closed after 2 seconds. The auxiliary feedwater and the safety injection flow were manually started at 28 and 1156 seconds, respectively. The sequence of the main events for the test is summarized in Table 1.

Table 1. Sequence of events for the MSLB test

Event	Time (s)
MSLB Break Initiation	0
Reactor Trip	0
Main Steam Isolation Valve Closure	2
Feedwater Valve Closure	2
Auxiliary Feedwater Injection	28
High Pressure Safety Injection	1,156
Power Operated Relief Valve Open	3,312

3. Modeling & Simulation

3.1 SPACE Code Modeling

The SPACE code package has a function that enables the conversion of the inputs from other system analysis codes (*e.g.*, RELAP, MARS, RETRAN or TRACE) into SPACE code input. In this study, to overcome the limited research resources, the conversion function was used to develop premature inputs based on the RELAP5 input mentioned in Reference 2 (NUREG/IA-0148). The deck was appropriately modified for the SPACE code (Fig. 1)

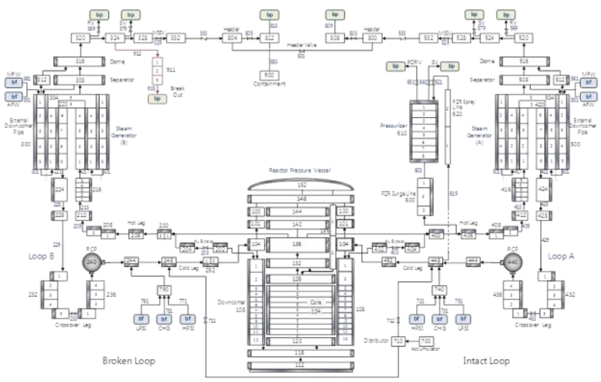

Fig. 1 LSTF model to simulate the MSLB test

The model was composed of 27 cells, 19 faces, 23 pipes, 20 temporal face boundary conditions, 24 branches, 2 separators, 14 valves, 2 pumps and 1 safety injection tank. In order to simulate the structures, 180 heat structures were modeled. The break unit was modeled using a face, a pipe and one temporal face boundary condition. The Ransom-Trapp (RT) model and Henry-Fauske-Moody (HFM) model were used to simulate the critical flow with various discharge coefficients (Cd) for the sensitivity study.

3.2 MSLB Simulation

The test was performed at the conditions of 15.52 MPa pressurizer (PZR) pressure, 598.1 K and 562.4 K hotleg (HL) and coldleg (CL) temperatures, respectively, and 24.3 kg/s mass flow. The secondary system conditions were 7.3 MPa pressure and 495.2 K temperature at the SGs. The initial conditions are listed in Table 2.

Table 2. Initial conditions for the simulated MSLB test

Parameters	Values	
	Meas.	Cal.
Core Power, MW	10.0	10.0
PZR Press., MPa	15.52	15.58
Hotleg Temp., K	598.1	599.4
Coldleg Temp., K	562.4	564.1
Primary Coolant Flow, kg/s	24.30	24.60
PZR Level, m	2.70	2.64
RCP Speed, rpm	800	768
SG Shell-side Press., MPa	7.30	7.30
SG Feedwater Flow, kg/s	2.740	2.746

In this simulation, the HFM model was used as the base critical flow model with a Cd of 0.875. The reference model of RELAP5 used the Henry-Fauske model and had a Cd of 0.85. The results of simulations are as depicted in Figs. 2 through 9.

For the break flow and void fraction (Figs. 2 and 3), the results exhibited similar trends to those of the experiment or RELAP5.

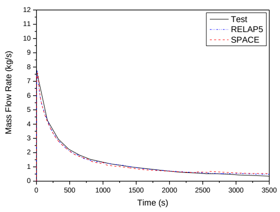

Fig. 2 Break flow

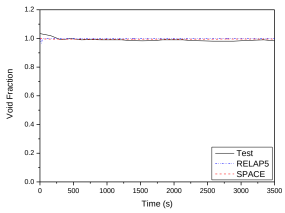

Fig. 3 Break void fraction

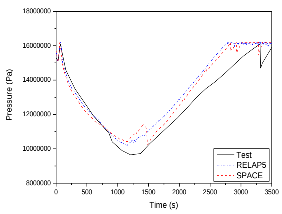

Fig. 4 PZR pressure

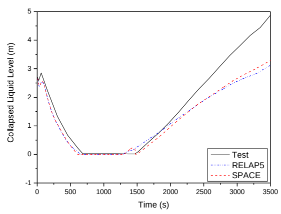

Fig. 5 PZR level

The PZR pressure and level (Figs. 4 and 5) exhibited differences to the experimental data. The results from the SPACE code exhibit a fluctuation around 1400 s caused by the end of auxiliary feedwater.

Figures 6 and 7 show the CL temperature during the transients. In the broken loop (BL), the results and data exhibited similar trends between the SPACE and RELAP5 data due to the higher driving force caused by the break. The intact loop (IL) exhibited more different trends than BL.

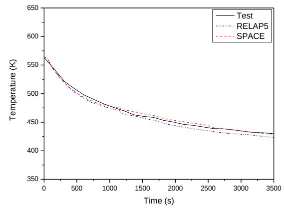

Fig. 6 BL-CL temp.

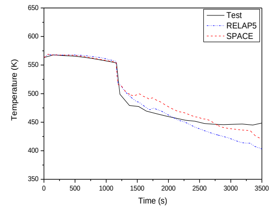

Fig. 7 IL-CL temp.

As stated above, the break led to similar trends in the BL SG pressures (Figs. 8 and 9). The IL SG pressure exhibited partial difference.

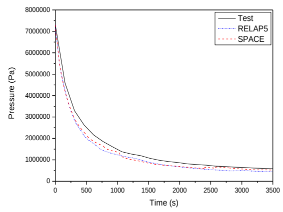

Fig. 8 BL-SG press.

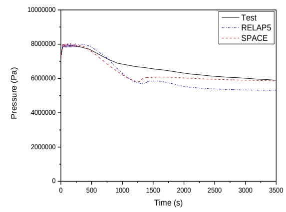

Fig. 9 IL-SG press.

3. Conclusions

The LSTF 10% MSLB test, SB-SL-01, was simulated using the SPACE code. The results were compared with experimental data and those from the RELAP5 code simulation. Through the simulation, it was concluded that the SPACE code can effectively simulate MSLB accidents.

Acknowledgements

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