LOFT L9-1 Experiment Simulation using the SPACE Code

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1. Introduction

The Korea nuclear industry has developed a best-estimated two-phase three-field thermal-hydraulic analysis code, SPACE (Safety and Performance Analysis Code for Nuclear Power Plants), for safety analysis and design of a PWR (Pressurized Water Reactor). As the first phase, the demo version of the SPACE code was released in March 2010. The code has been verified and improved according to the Verification and Validation (V&V) matrix prepared for the SPACE code as the second phase of the development.

In this study, LOFT L9-1 experiment has been simulated using the SPACE code as one aspect of the V&V work. The results from this experiment were compared with tests of the SPACE codes.

2. Facility and Test Description

2.1 Facility Description

The LOFT facility is a 50 MWt pressurized water reactor (PWR) with 1/60 power-to-volume scale with the Westinghouse 4-loop PWR. It has various instrumentations to measure and to provide data from the thermal-hydraulic and nuclear condition throughout the system. The LOFT facility consists of five major system : reactor system, primary coolant system, blowdown suppression system, emergency core cooling system and secondary coolant system.

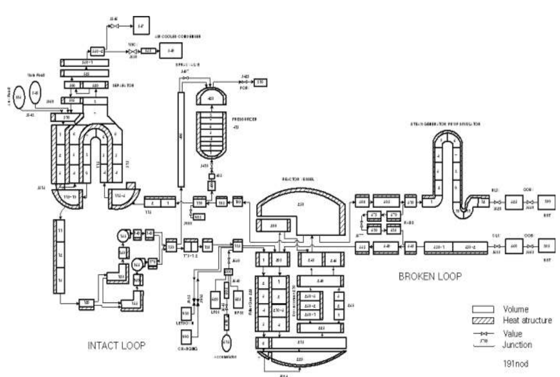

Fig. 1. SPACE Nodal Diagram for LOFT L9-1 Test.

2.2 Test Description

Experiment L9-1 was the first anticipated transient with multiple failures performed in the LOFT, and simulated a loss-of-feedwater accident with delayed reactor scram and no auxiliary feedwater injection. The loss-of-feedwater accident led to a loss-of-coolant accident through the PORV. In Experiment L9-1, the transient was initiated by loss-of-feedwater due to the failure of the main feedwater pump.

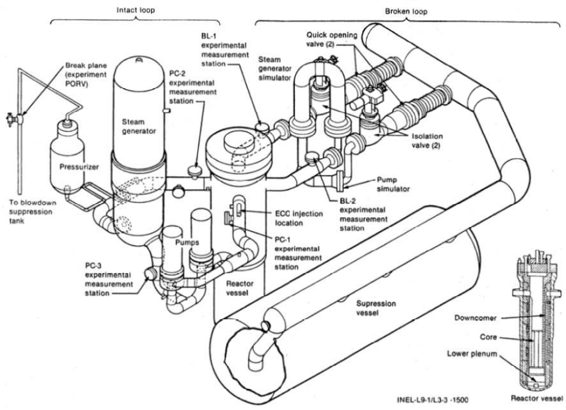

Fig. 2. LOFT Test facility.

The reactor scrammed on the indication of high pressure (15.745MPa) in the intact loop hot leg approximately 65 seconds after the main feedwater pump was tripped. The auxiliary feedwater injection into the steam generator was prevented, as was scram on the indication of low liquid level in the steam generator. The main steam control valve (MSCV) of the steam generator started to close automatically on the reactor scram and finished closing 12.2 seconds later (at 77.2 sec). The pressurizer spray valve cycled automatically at its close (15.05 MPa) and open (15.338 MPa) set points from 30 seconds until it was closed by the operators at the 1,246.0 seconds to allow the PCS pressure to increase to the PORV set point.

The PORV started cycling operation at 1,467.9 seconds to control primary system pressure, until it was manually latched open at 3,270 seconds. The open and close set points of the PORV were 16.20 MPa and 16.06 MPa, respectively.

3. SPACE Modeling

3.1 Steady-state of LOFT L9-1 using the SPACE code

At first, SPACE code deck was made using the RELAP5 code deck of LOFT L9-1 for SPACE code capability evaluation. Generally, all initial conditions and assumptions used in REALP5 code were equally adapted to LOFT L9-1 SPACE input deck. LOFT L9-1 SPACE input deck was ran from 0 sec. to 1000 sec. for steady-state confirmation.

Table 1. LOFT L9-1 Initial Conditions

Parameter	Measured	Predicted
Primary Coolant System		
Mass flow rate(kg/s)	479.1	479.3
Hot leg pressure(MPa)	14.9	14.96
Cold leg temperature (K)	558.9	560.7
Hot leg temperature (K)	578.2	577.9
Reactor Vessel		
Power level (MWt)	49.6	49.6
Pressurizer		
Liquid temperature(K)	614.9	614.55
Pressure (MPa)	14.93	14.98
Steam Generator Secondary Side		
Liquid temperature(K)	545.0	545.0
Pressure (MPa)	5.67	5.89
Mass flow rate(kg/s)	27.0	24.7

Major parameters modeled by space code are presented from Fig.2 to Fig.5 at steady-state.

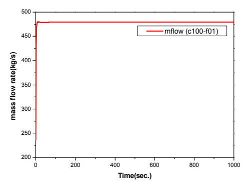

Fig. 2. mass flow rate

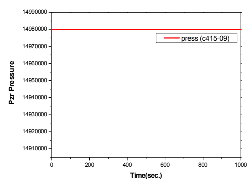

Fig. 3. Pzr Pressure

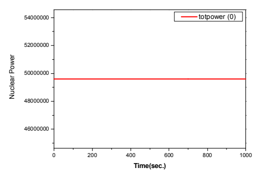

Fig. 4. Core Power

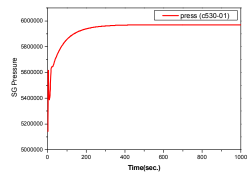

Fig. 5. SG pressure

3.2 Transient of LOFT L9-3 using the SPACE code

LOFT L9-1 SPACE transient input deck was made based from steady-state deck of SPACE code. For verification of SPACE code, basic assumptions and conditions used in experimentation were identically adopted to transient SPACE code deck.

The pressure trend of the PCS together with that of the SG secondary side is compared with experimental data. As the heat removal capability in the SG secondary side degraded due to the trip of the main feedwater pump, the pressure of the PCS gradually increased. When the PCS pressure reached the set pressure of 15.338 MPa, it was controlled by the pressurizer spray valve activation in experimentation. As the heat generation in the reactor core exceeded the heat removal capability by both the SG secondary side and the pressurizer spray valve actuation, the PCS pressure continued to increase up to the reactor scram set pressure of 15.745 MPa. Following the scram, the PCS pressure decreased because the power input to the PCS dropped sharply to the decay power level. After that, the pressurization of the PCS due to decay heat was controlled by pressurizer spray actuation and subsequent steam condensation.

3. Conclusions

The Korea nuclear industry has been developing the SPACE code for safety analysis and design of a PWR. The LOFT L9-1 experiment has been simulated for the SPACE code V&V. The results have been compared with those of the experiment.

Through the evaluation of LOFT L9-1 experiment using the SPACE code, it is concluded that the SPACE code has a capability to predict the system response caused by a loss-of-feedwater accident.

Acknowledgements

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