An SBLOCA Test of Pressurizer Safety Valve Line Break with SMART-ITL Facility

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1. Introduction

An integral-effect test loop for SMART, SMART-ITL, was constructed at KAERI. SMART-ITL [1, 2, 3] was designed using a volume scaling methodology. Its height was preserved and its flow area and volume were scaled down to 1/49 compared with the prototype plant, SMART [4]. The maximum power of the core heater in SMART-ITL is 2 MW, with 30% of the scaled full power, and its core exit temperature and pressurizer pressure are the same as SMART during normal working conditions. The objectives of SMART-ITL are to investigate and understand the integral performance of the reactor systems and components, and the thermal-hydraulic phenomena occurring in the system during normal, abnormal, and emergency conditions, and to verify the system safety during various design basis events of SMART. A small-break loss-of-coolant accident (SBLOCA) test [5, 6] was performed using SMART-ITL. This paper presents the major results of an SBLOCA test for a pressurizer safety valve (PSV) line break. The break nozzle is located at the top of the pressurizer, and its size has been scaled down to 7.26 mm, which has a scale ratio of 1/49. The main objectives of this paper are to understand thermal-hydraulic behavior physically during the transient simulation, and to present integral effect test data for validation of the thermal-hydraulic system code to assess its simulation capability on the SBLOCA scenario for the SMART design.

2. Methods and Results

For the SBLOCA scenario of the PSV line break, the break is a guillotine break, and its location is on the PSV line of the pressurizer top. The safety injection flow rate of SMART-ITL is 1/49 that of SMART with the same pre-specified safety injection pump characteristics. The break size is set to be reduced according to an area scale ratio of 1/49.

2.1 Steady-State Test Results

The steady-state condition was maintained for 600 seconds before simulating the sequence of events of an SBLOCA. Table I shows the major parameters of the target values and test results during a steady-state condition. The steady-state conditions were operated to satisfy the target values presented in Table II, and its boundary conditions were properly simulated.

The primary system flow rate of the target and measurement for a 20% core power are 8.53 kg/s and 7.75 kg/s, respectively. The secondary system flow rate of the target and measurement are 0.6334 kg/s and 0.656 kg/s, respectively. The primary system pressure of a 20% core power condition is 14.97 MPa. The inlet/outlet temperatures of the steam generator's primary side in the test are 324 ℃ and 293.8℃, respectively, and those in the simulation are 324℃ and 295.7℃, respectively.

The steady-state conditions were operated to satisfy the initial test conditions presented in the test requirement, and its boundary conditions were properly simulated.

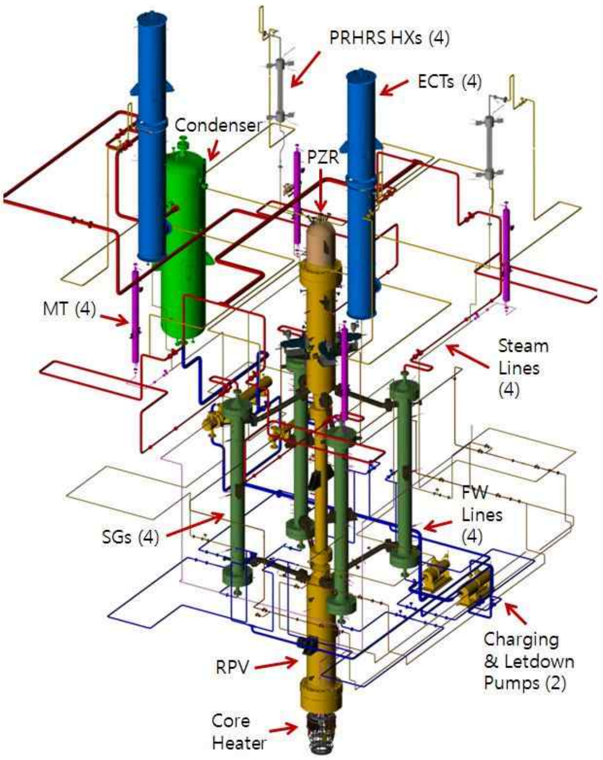

Fig. 1. Schematic of the SMART-ITL facility.

2.2 Sequence of Event

Table II shows the test results of the major sequence for the SBLOCA simulation test. When a PSV line was broken, the RCS began to be depressurized. As the pressurizer pressure reached the LPP trip set-point (P_{LPP}) after the PSV line break, the reactor trip was generated about 0.5 s after the LPP signal, which was generated 58 s after the break. Consequently, with the reactor trip signal, the feed water was stopped and the reactor coolant pump started to coast-down. It was shown that the PRHRS actuation signal occurred. The safety injection water was injected 30 s after the safety injection actuation signal (SIAS). The individual signal is sequentially actuated.

Table I: Description of the steady state condition

Parameter	SMART-ITL (Target)	SB-PSV-01 (Measurement)
Power (kW)	1346.9	1.512
PZR pres.(MPa)	15.0	14.97
1st flowrate(kg/s)	8.53	7.75
SG 1st inlet temp.(℃)	323.0	324
SG 1st outlet temp.(℃)	295.7	293.8
F.W. flow-rate(kg/s)	0.66	0.63
SG 2nd outlet P.(Mpa)	5.2	5.29

Table II: Test results of major sequence for SBLOCA

Event	SB-PSV-01 Time After Break (seconds)
Sequence	Test
Break	0
LPP set-point	58
LPP trip signal	61
- FW stop	
- Pump coastdown	
Reactor trip-curve start	61
PRHR actuation signal	62
PRHRS IV open	67
FIV close	67
MSIV close	82
Safety injection signal	541
Safety injection start	572

2.3 Transient Test for PSV Line Break

Figs. 2 through 8 show the variations of the major parameters. The decay power curve and safety-injection flow rate were provided well as the boundary conditions for the test and code analysis. Fig. 2 shows the decay power curves, which were well matched between the given and measured powers.

Fig. 3 shows the pressure behavior of the primary system. The primary pressure decreased rapidly during the single-phase steam blowdown period. The pressure decrease was slowed down during the two-phase discharge period, and the pressure then decreases gradually during the single-phase steam blowdown period.

Fig. 4 shows the primary steam generator temperature. As the PSV line break occurs and the primary pressure decreases dramatically, the primary temperature in the inlet of the SGs also decreases along with the saturation temperature. Between 1000 s and 4000 s, it is partially above the saturation temperature. The temperature range in the outlet is under the saturation temperature.

Fig. 5 shows the secondary system pressure. At the beginning of the transient, the pressure increases rapidly. It decreases gradually after arriving at the peak pressure. As a feed-water pump was stopped, the PRHRS was actuated, the feed-water isolation valve and main steam isolation valve were closed, and the secondary pressure increased. After a natural circulation of the secondary system by the balance between the steam generators and PRHRS starting up, the pressure decreased.

Fig. 6 shows the temperature of the secondary SG. The inlet temperature is decreased gradually for the entire transient stage. The outlet temperature is decreased rapidly after stopping the feed water and actuating the PRHRS, and is maintained at a constant after 4000 s. This shows that the heat removal by the PRHRS and natural circulation of the secondary system were successfully performed.

Fig. 7 shows the secondary system flow rate. As the PRHRS system operates, the feed-water flow rate shows a dramatic change at the beginning, and natural circulation is achieved within a few seconds. After that, the natural circulation flow rate shows a gradual decrease at a constant rate

The flow rate of the safety injection is programmed by following the pressure of the RCS, and is well injected according to the pressure programmed into the control logic, as shown in Fig. 8.

3. Conclusions

An SBLOCA test of PSV line break was successfully performed using the SMART-ITL facility. The SBLOCA break is a guillotine break, and its location is on the PSV line (top of the pressurizer).

The steady-state conditions were achieved to satisfy the initial test conditions presented in the test requirement, and its boundary conditions were properly simulated. The scenarios of SBLOCA in the SMART design were reproduced well using the SMART-ITL facility. The pressures and temperatures of the test and simulation show reasonable behaviors during the SBLOCA test.

ACKNOWLEDGEMENT

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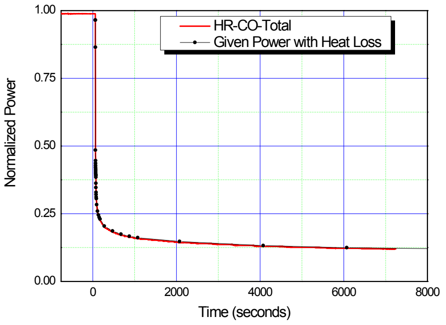

Fig. 2. Decay power curve

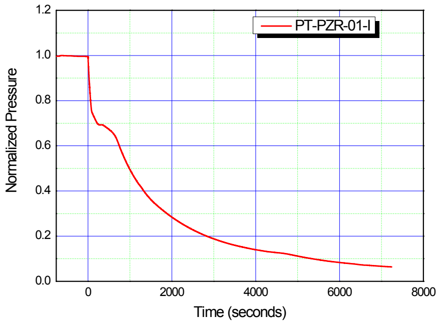

Fig. 3. Pressure of pressurizer

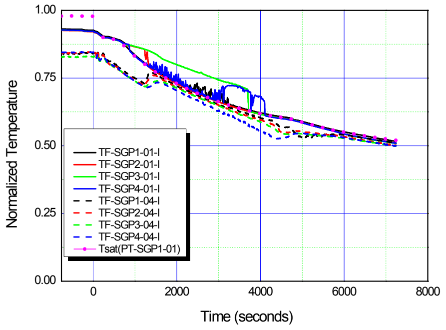

Fig. 4. Primary steam generator temperature

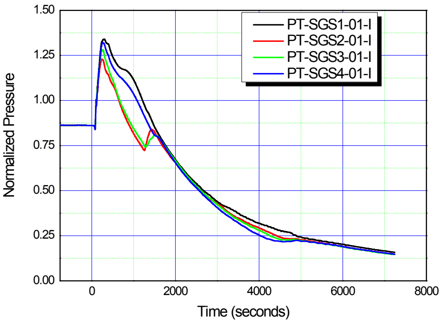

Fig. 5. Pressure of the secondary system

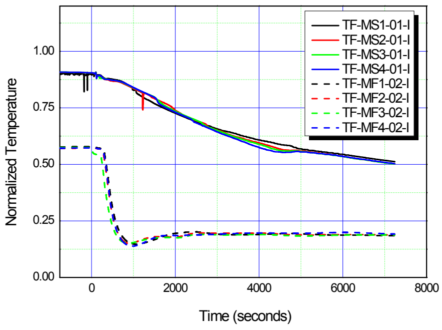

Fig. 6. Secondary steam generator temperature

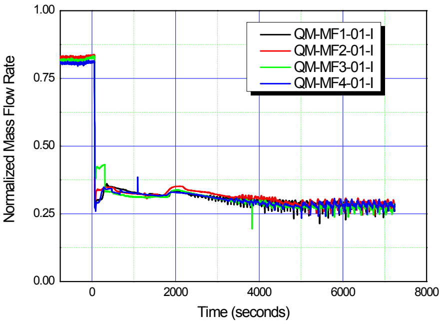

Fig. 7. Flow rate of feedwater line

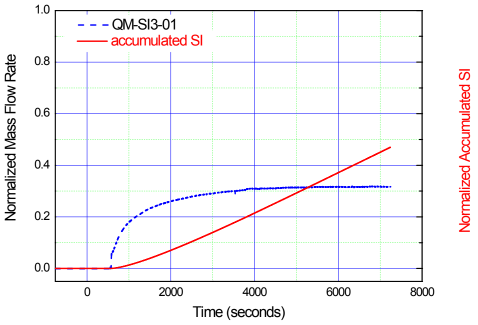

Fig. 8. Flow rate of the safety injection system