Major Results of SBLOCA Tests with VISTA-ITL for the SMART Design

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1. Introduction

A thermal-hydraulic integral effect test facility, VISTA-ITL [1], for the SMART design [2] has been constructed by the Korea Atomic Energy Research Institute (KAERI). The VISTA-ITL has the simulation capability of small-break loss of coolant accident (SBLOCA) [3], passive residual heat removal system (PRHRS) performance [4], and complete loss of RCS (Reactor Coolant System) flowrate (CLOF) [5], *etc*. The VISTA-ITL is a 1/2.77-height and 1/1310-volume scaled test facility based on the design features of SMART. The reference scale ratios of length (1/2.77) and area (1/472.9) are based on the elevation difference between the core and steam generator centers and the core flow area, respectively. According to the scaling law, the reduced height scaling results in time-reducing results in the model and the time scale ratio is 1/1.664. Three SBLOCA tests of safety injection system (SIS) line break, shutdown cooling system (SCS) line break and pressurizer safety valve (PSV) line break were successfully performed and its major results have been compared and discussed in this paper.

2. Test Facility

The break types are guillotine breaks, and their break locations are on the SIS line (nozzle part of the RCP discharge), on the suction line of the SCS (nozzle part of the RCP suction), and on the PSV line (safety valve line connected to the pressurizer top). The break nozzle diameter is 50 mm in the SMART design and the scaled-down value is 1.77 mm in the VISTA-ITL. Fig. 1 shows the schematics of the VISTA-ITL facility.

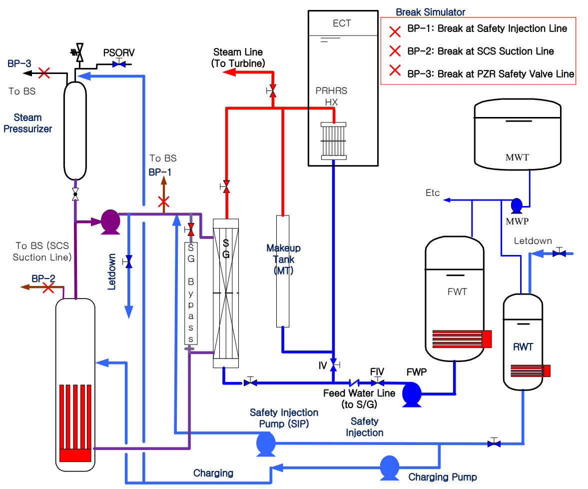


Fig. 1 Schematic diagram of the VISTA-ITL facility

3. Results and Discussion

3.1 Steady state

The initial steady-state conditions were well achieved for the SBLOCA scenarios. It should be noted that the core power is 100% for the SIS line break and 103% both for the SCS and PSV line breaks. The scaled full core power of VISTA-ITL is 419.3 kW. The scaled-down primary and secondary system flow rates are 2.65 kg/s and about 0.15 kg/s, respectively. The primary system pressure is 15.0 MPa, the pressurizer level is about 70%, and the inlet temperature of steam generator primary side is maintained at 295.7℃. The outlet pressures of the SG secondary side are 6.0 MPa.

3.2 Transient

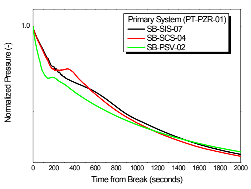
Table 1 shows the major test results of the SBLOCA tests. When a SIS line (or SCS line, PSV line) was broken, the RCS began to be depressurized during the SB-SIS-07 test. As the pressurizer pressure reached the LPP trip set-point after the line break, the feedwater supply stopped and the RCP began to coastdown. The reactor trip signal was generated about 1.0 s after the LPP signal, which was generated 140 s after the SIS line 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 was generated at 143 s after the SIS line break. The safety injection water was injected 18 s after the safety injection actuation signal (SIAS).

Figure 1 shows the variations of the major parameters. The decay power curve and the safety injection flow rate are successfully given for the test. Fig. 1(a) shows the pressure behavior of the primary system. The primary pressure decreased rapidly during the single-phase liquid blowdown period. The pressure decrease was slowed down during two-phase discharge period and then the pressure decreased gradually during the single-phase steam blowdown period. For the SB-SCS-04 and SB-PSV-02 cases the pressure did not decrease during a short period due to the insufficient heat removal through the steam generator. Fig. 1(b) shows the pressure behavior of the secondary system. The pressure increased rapidly with the PRHRS operation and then it decreased gradually with the proper operation of PRHRS. It is interesting that two pressure peaks were found during the SB-SCS-04 test. Fig. 1(c) shows the water level behavior of the RPV. The water level was the highest for the SB-SIS-07 test due to the break location. The break at the pump discharge could increase the pump speed and natural circulation flowrate. The water level of the SB-PSV-02 test decreased the fastest due to the liquid holdup in the pressurizer during the initial period but the final level was very similar to the SB-SCS-04 test due to the similar break elevation. Fig. 1(d) shows the secondary system flow rate. As the PRHRS was operated, the feed-water flow rate showed a dramatic change at the beginning, and the natural circulation was achieved within a few seconds. After that, the natural circulation flow rate showed a gradual decrease at a constant rate. The flow rate under a natural circulation condition was dependent on the heat balance between the heat exchanger and the SG, and the hydraulic resistance in the loop. The initial maximum value of the natural circulation flow rates were between 10.9 and 11.7% of the rate feed-water flow rate at maximum during three SBLOCA tests.

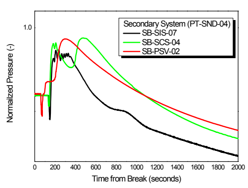
For three SBLOCA tests for SIS line break, SCS line break and PSV line break the steady-state conditions were operated to satisfy the initial test conditions presented in the test requirement, and its boundary conditions were properly simulated. With the operation of PRHRS, two-phase natural circulation flow formed inside the two-phase PRHRS natural circulation loop. It was judged that the experimental results on the SBLOCA of SIS line break simulated the accident conditions of the SMART design properly.

Table 1 Major test results of SBLOCA tests

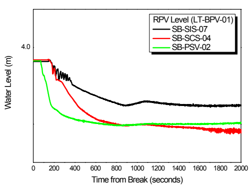
Event	SB-SIS-07		SB-SCS-04		SB-PSV-02	
Sequence	DAS time (seconds)	Time After break (seconds)	DAS time (seconds)	Time After break (seconds)	DAS time (seconds)	Time After break (seconds)
Break	355	0	401	0	332	0
LPP set-point	495	140	530	129	391	59
LPP trip signal	496	141	531	130	392	60
Reactor trip-curve start	497	142	534	133	393	61
PRHR actuation signal	498	143	535	134	394	62
PRHRS IV open	501	146	538	137	397	65
MSIV/FIV close	508	153	547	146	405	73
Safety injection signal	760	405	880	479	616	284
Safety injection start	778	423	903	502	636	304



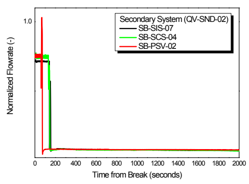
(a) Primary pressures



(b) Secondary pressures



(c) RPV water levels



(d) PRHRS flow rates

Fig. 2 Test results of major parameters

4. Conclusions

An integral effect test has been performed for the SBLOCA scenario for the SMART design. Three break locations of SIS, SCS, and PSV line were simulated. The steady-state conditions were successfully achieved to satisfy the initial test conditions presented in the test requirement and its boundary conditions were properly simulated. The behaviors of major thermal-hydraulic parameters of SBLOCA scenario in the SMART design was investigated using the VISTA-ITL facility. The natural circulation flows were successfully achieved to cool-down the core decay heat transferred to the SG secondary side with the proper operation of the PRHRS.

REFERENCES

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