Comparison of SBLOCA Test Results with the FESTA Facility for the SMART Design

Hyobong Ryu, Hyun-Sik Park [*], Hwang Bae, Sung-Uk Ryu, Young-Joo Ko and Sung-Jae Yi
Thermal Hydraulics Safety Research Division, Korea Atomic Energy Research Institute (KAERI)
989-111 Daedeokdaero, Yuseong, Daejeon, 305-353, Korea
**Corresponding author: hspark@kaeri.re.kr*

1. Introduction

Recently a large-scale integral effect test facility of FESTA [1] was constructed at KAERI and a set of integral effect test for design basis accident scenarios were also performed. The FESTA facility is a full height, 1/49-volume scaled test facility with four trains of a secondary system and PRHRS, and can be used to investigate the integral performance of the inter-connected components and possible thermal-hydraulic phenomena occurring in the SMART (System-Integrated Modular Advanced Reactor) design [2], and to validate its safety for various design basis accidents and broad transient scenarios. The role of FESTA can be extended to examine and verify the normal, abnormal, and emergency operating procedures required during the construction phases of SMART.

During the design of the FESTA facility, the height is preserved to the full scale, and its area and volume are scaled down to 1/49 compared with the prototype plant, SMART. The scaling ratios adopted in FESTA with respect to SMART are summarized in Table 1. The maximum core power is 2.0 MW, which is about 30% of the scaled full power. The design pressure and temperature of SMART-ITL can simulate the maximum operating conditions, that is, 18.0 MPa and 350°C.

A preliminary analysis of small-break loss of coolant accident (SBLOCA) tests using the MARS/KS code for FESTA was previously conducted [3]. In addition, major test results of SBLOCA scenarios with the VISTA-ITL facility for the SMART design were discussed [4]. In this research, three SBLOCA experimental tests of a safety injection system (SIS) line break, shutdown cooling system (SCS) line break

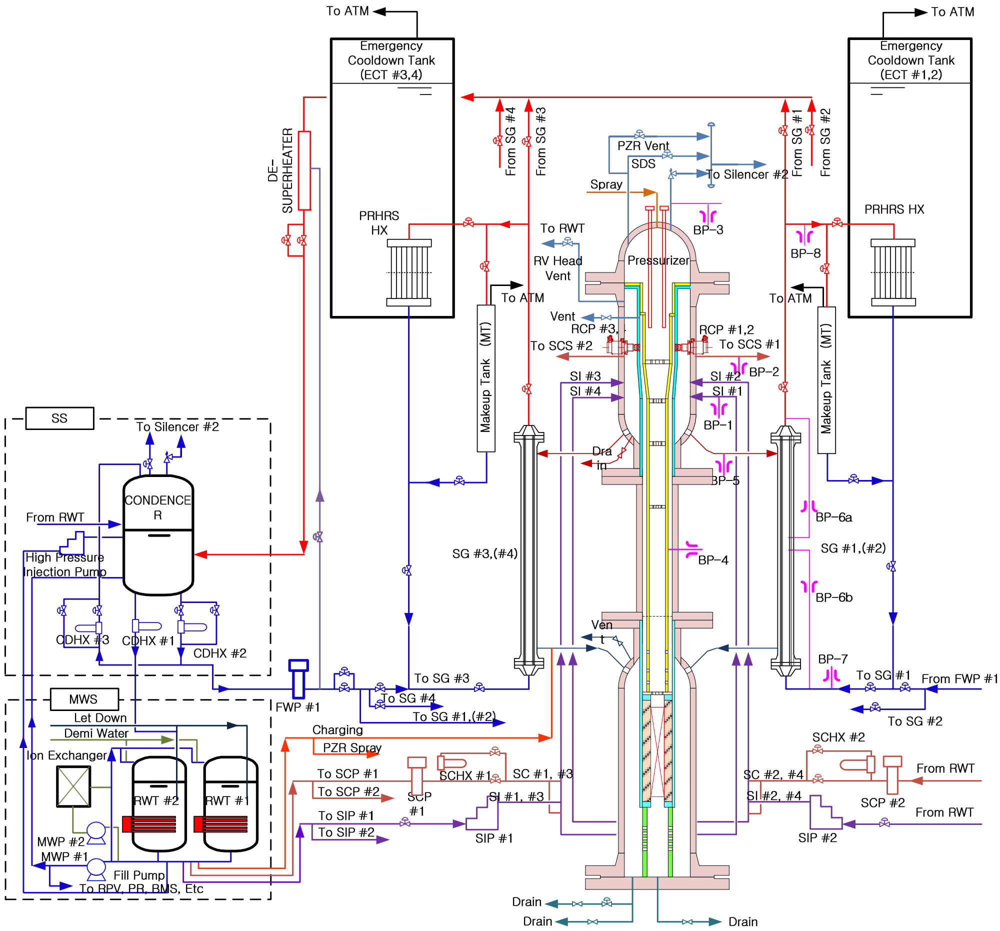

Fig. 1 Schematic diagram of the FESTA facility

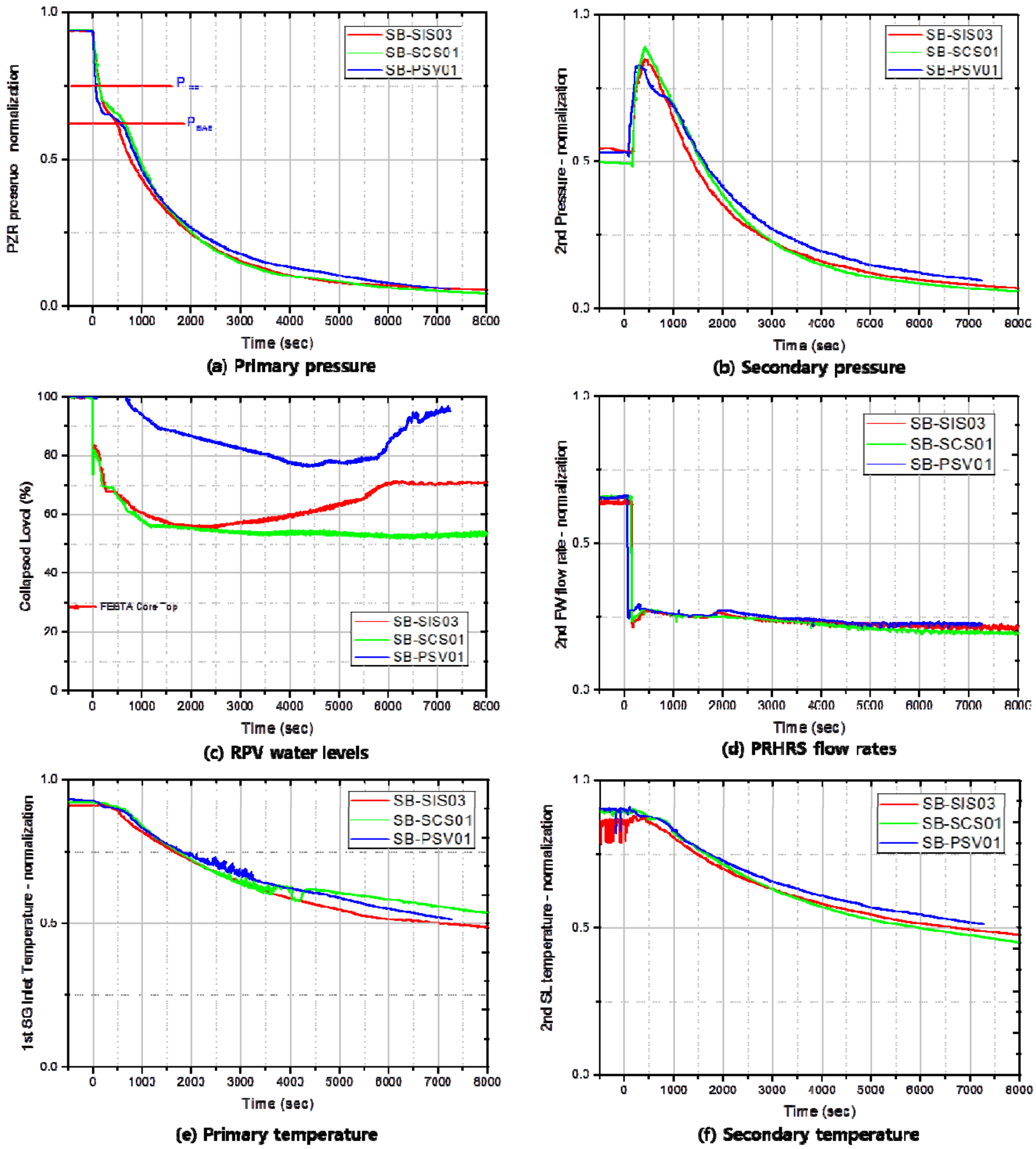

Fig. 2 Test results of major parameters

and pressurizer safety valve (PSV) line break for the SMART design were successfully performed and its major results have been compared and discussed.

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 values are 7.26 mm in the FESTA. Fig. 1 shows a schematic of the FESTA facility.

Table 1. Major Scaling Parameters of FESTA

Parameters	Scale Ratio	Value
Length	l_{0R}	1/1
Diameter	d_{0R}	1/7
Area	$d_{0R}^{\ 2}$	1/49
Volume	$l_{0R}\ d_{0R}^{\ 2}$	1/49
Time scale, Velocity	$l_{0R}^{\ 1/2}$	1/1
Power, Volume, Heat flux	$l_{0R}^{\ -1/2}$	1/1
Core power, Flow rate	$d_{0R}^{\ 2}\ l_{0R}^{\ 1/2}$	1/49
Pump head, Pressure drop	l_{0R}	1/1

3. Results and Discussion

3.1 Steady state

Table 2 shows a comparison of the major parameters under steady state conditions. The initial steady-state conditions were well achieved for the SBLOCA scenarios. It should be noted that the core power is 20% of the scaled value, 1.347 MWt, for the SIS, 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 8.531 kg/s and 0.633 kg/s, respectively. The primary system pressure is 15.0 MPa and the inlet temperature of the steam generator primary side is maintained at 295.7℃. The outlet pressures of the SG secondary side are 6.0 MPa.

Table 2 Comparison of the major parameters at a steady state condition

Parameter	SB-SIS-03	SB-SCS-01	SB-PSV-01
Power (MW)	1.514	1.52	1.512
PZR pres.(MPa)	14.94	15.0	14.97
1st flowrate(kg/s)	8.482	8.871	7.748
SG 1st inlet temp.(℃)	207.99	195.35	200.88
SG 1st outlet temp.(℃)	306.07	314.55	316.84
F.W. flow-rate(kg/s)	0.6368	0.6577	0.6557
SG 2nd inlet P.(Mpa)	5.413	5.03	5.35
SG 2nd outlet P.(Mpa)	5.38	4.96	5.29

Table 3 Major test results of SBLOCA tests

Sequence	Time after Break (seconds)		
Event	SB-SIS-03	SB-SCS-01	SB-PSV-01
Break	0	0	0
LPP set-point	134	125	58
LPP trip signal	135	128	61
PRHRS IV open	141	135	67
MSIV/FIV close	172	150	82
Safety injection signal	481	641	541
Safety injection start	512	671	572

3.2 Transient

Table 3 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 each test. As the pressurizer pressure reached the LPP trip set-point after the line break, the feedwater supply stopped and the RCP began to coast down. The reactor trip signal was generated at about 1.0 s after the LPP signal, which was generated about 130 s after the line break except for the PSV line break. During the PSV line break, the pressure decreases very rapidly and the LPP trip signal is generated at around 60 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 was generated at 136 s after the SIS line break. The safety injection water was injected about 30 s after the safety injection actuation signal (SIAS).

Figure 2 shows some results of the major parameters. The decay power curve and the safety injection flow rate are successfully given for the test. Fig. 2(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 the pressure then decreased gradually during the single-phase steam blowdown period. The behaviors of the pressure slow-down were different between three cases. The retardation of the pressure decrease is the largest in the case of SB-PSV-01. Fig. 2(b) shows the pressure behavior of the secondary system. The pressure increased rapidly and then decreased gradually with the proper operation of the PRHRS. Additionally, it is interesting that there is a pressure decreasing delay region after the pressure peak for the SB-PSV-01. This may be related with the pressurizer (PZR) pressure behavior, as shown in Fig. 1(a). Fig. 2(c) shows the water level behavior of the RPV. The final water level was closely related to the height and connected location of a break line. The test of SB-PSV-01 shows the highest level as it is connected to the upper part of riser section of the RPV. The final water level of the SB-SIS-03 test was around the height of the safety injection line and that of SB-SCS-01 test showed the lowest final level, which is the similar level as the Lower Support Plate (LSP) of the RPV.

Fig. 2(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 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. Figs. 2(e) and 2(f) show the inlet temperature of the steam generator (SG) primary side and the secondary system temperature, respectively. The decay line of the primary side temperature had a similar profile with each other and the secondary system temperature also slowly decreased during the 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, a two-phase natural circulation flow formed inside the two-phase PRHRS natural circulation loop. It was judged that the experimental results on the SBLOCA scenarios of SIS, SCS, and

PSV line breaks simulated the accident conditions of the SMART design properly.

4. Conclusions

An integral effect test has been performed for the SBLOCA scenario for the SMART design with the FESTA facility. 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 the SBLOCA scenario in the SMART design were investigated using the FESTA 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

[1] H. S. Park, et al., "SMR Accident Simulation in Experimental Test Loop," Nuclear Engineering International, November 12-15, 2013.
[2] Kim, K. K. et al. “SMART: The First Licensed Advanced Integral Reactor,” Journal of Energy and Power Engineering, 8, 94-102, 2014.
[3] Y.S. Cho, et al., “A Preliminary Analysis for SMART-ITL SBLOCA Tests using the MARS/KS Code”, Transactions of the Korean Nuclear Society Autumn Meeting, October 24-25, 2013
[4] H.S. Park, et al., “Major Results of SBLOCA Tests with VISTA-ITL for the SMART Design”, Transactions of the Korean Nuclear Society Autumn Meeting, May 17-18, 2012