An Experimental Study on a Small Break Loss of Coolant Accident of the Pressurizer Safety Valve Line Break with the VISTA-ITL

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1. Introduction

The VISTA-ITL [1] is a modified version of an existing VISTA facility to have the simulation capability of Small-Break Loss Of Coolant Accident (SBLOCA) for the System-integrated Modular Advanced ReacTor (SMART) design. The VISTA-ITL has been used to investigate various thermal-hydraulic phenomena during the SBLOCA. The break flow rate, safety injection flow rate, and thermal-hydraulic behaviors of major components are measured for a typical break size and break locations. The acquired data will be used to validate the related thermal-hydraulic models of the safety analysis code, TASS/SMR [2], which can assess the capability of SMART to cope with the SBLOCA scenario. As it is capable of simulating various transient and accident conditions for the SMART design, it will greatly contribute to the enhancement of its safety and performance. In order to perform the safety analysis and performance analysis of a SMART, SBLOCA test of the Pressurizer Safety Valve (PSV) line break was performed by the Korea Atomic Energy Research Institute (KAERI) using the Experimental Verification of by Integral Simulation of Transients and Accidents (VISTA) Integral Test Loop (ITL).

2. Description of the VISTA-ITL

The VISTA-ITL has been designed following the three-level scaling methodology of Ishii and Kataoka [3] which consists of integral scaling, boundary flow scaling, and local phenomena scaling. In formulating the design concept, we have to consider the existing VISTA facility, which is being operated to simulate the SMART-P design.

Fig. 1 shows the schematic diagram of the VISTA-ITL facility. The major components of reactor pressure vessel, steam generator, PRHRS and secondary system are preserved, but some changes are given to the simulate the SBLOCA behavior of the SMART design: the steam pressurizer, the safety injection system, the steam generator bypass, the hot leg, the cold leg, the PRHRS makeup tank, the break simulator and the break measuring system were revised during the VISTA-ITL program. The major scale ratios are as follows.

- Reference plant: SMART-330
- Length scale ratio: 1/2.77
- Area scale ratio: 1/472.9
- Volume scale ratio: 1/1310

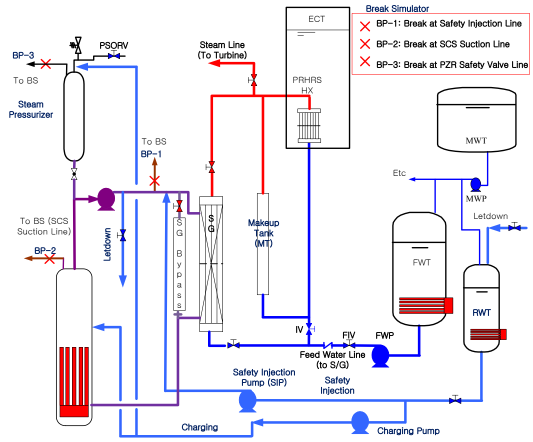

Fig. 1. Schematic diagram of the VISTA-ITL facility

3. Discussion and Results

Table 1 shows the major sequence of events for the SBLOCA test of PSV line break (SB-PSV-01). The primary system flow rate in the normal status of core power 103% is 2.68 kg/s and inlet/outlet temperature of reactor core is maintained at 296℃ and 318℃ respectively. The primary system pressure of 103% core power status is 15.0 MPa and pressurizer level is about 70% and inlet/outlet temperature of steam generator primary side is maintained at 323℃ and 294℃ respectively. When PSV line was broken, the RCS began to ne depressurized. As the pressurizer pressure reached the LPP trip set-point (12.13 MPa) 64 s after the PSV line break (Das time: 387 s). The reactor trip was generated about 1.0 s after the LPP signal. 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 at 66 s after the break. With the operation of PRHRS, two-phase natural circulation occurred inside the two-phase PRHRS natural circulation loop. The decay heat generated from the core reactor was transferred through the SG and eventually removed by the PRHRS heat exchanger located in a water-filled ECT. The safety injection water was injected 19 s after the Safety Injection Actuation Signal (SIAS).

Table 1 Major sequence of events for SB-PSV-01

Event	Set-point	DAS time(s)	Time after break (s)
Break occur	-	323	0
Reach LPP set-point	12.13 MPa	387	64
Reach LPP set-point	PZR Pres. = 12.13MPa		
- FW Stop	-	388	65
- Pump Coastdown	-	388	65
Reactor Trip - Curve Start	LPP+0.96 s	389	66
PRHR actuation signal	LPP+1.32 s	389	66
PRHRS IV open	PRHRSAS+3.0 s	393	70
MSIV/FIV close	PRHRSAS+9.0 s	401	78
Safety injection signal	BPV Pres. = 10.0 MPa	757	434
Safety injection start	SIAS+18.03 s	776	453

Fig. 2 shows the pressure behavior of the primary system. As shown in figure, the pressure decreases up to 11.4 MPa after the break and then increases up to 11.9 Mpa again during a short period and then decreases gradually. It seems that the cooling water of PRHRS system does not thoroughly remove the heat through the steam generator and therefore, the system pressure increases temporarily

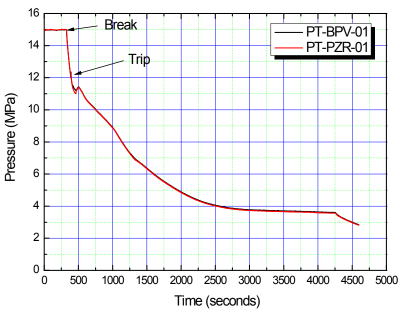

Fig. 2. Primary system pressures

Fig. 3 shows the primary system flow rate. The flow rate was 2.68 kg/s in the steady-state. As PSV line break, the primary flow rate decreases dramatically and it was lowered to less than a measurable flow range.

Fig. 4 shows the secondary system flow rate. In the 103% power condition, the initial flow rate is about 0.152 kg/s and its 100% flow rate corresponds to 0.148 kg/s. The PRHRS actuation signal occurred at 66 s after the break. As the PRHRS system operates, there is a dramatic change in the flow rate at the beginning and natural circulation is achieved within a few seconds. After that, the natural circulation flow rate shows a gradual to decrease at a constant rate. The initial maximum value of natural circulation flow rate is about 0.0165 kg/s and was 11.1% of the rate feedwater flow rate in maximum

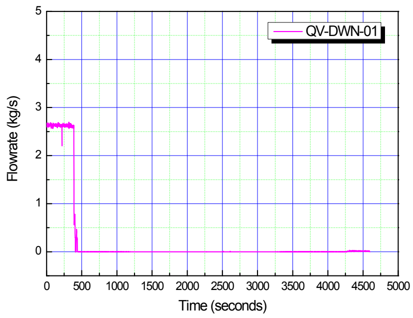

Fig. 3. Primary system flow rate

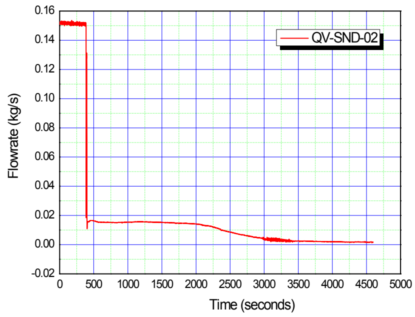

Fig. 4. Secondary system flow rate

4. Conclusions

Steady-state conditions were operated to satisfy the initial test conditions presented in the test requirement and its boundary conditions were properly simulated. PRHRS's natural circulation flow was 11.1% of the rate feedwater flow rate in maximum and then a stable natural circulation flow was formed during the entire test period. It is judged that the experimental results on the SBLOCA of PSV line break simulate the accident conditions of the SMART design properly.

References

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2. M. Ishii and I. Kataoka, Similarity Analysis and Scaling Criteria for LWRs under Single-Phase and Two-Phase Natural Circulation, NUREG/CR-3267, ANL-83-32, 1983.
3. H. S. Park, et al., Construction Report of the VISTA-ITL, KAERI integral report, KAERI, March 2011.