Thermal-Hydraulic Behavior of SMART-ITL under Feedwater Line Break Accident

Byong Guk Jeon[a*], Hwang Bae[a], Sung-Uk Ryu[a], Yong-Cheol Shin [a], Jin-Hwa Yang[a], Kyoung-Ho Min[a], Eun-Koo Yun[a], Jae-Min Kim[a], Jong-Kuk Park[a], Nam-Hyun Choi[a], Yun-Gon Bang [a], Chan-Jong Seo[a], Sung-Jae Yi [a], Hyun-Sik Park [a]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeokdaero, Yuseong, Daejeon, 305-353, Korea*
**Corresponding author: bejeon@kaeri.re.kr*

1. Introduction

Diverse passive systems are now being adopted in advanced nuclear power plants in favor of their independence to external powers. In SMART, an integral small modular reactor developed by Korea Atomic Energy Research Institute, 4-trains of passive residual heat removal systems (PRHRS) and passive safety injection systems (PSIS) were adopted and their performance is being evaluated in an integral test loop, SMART-ITL [1]. SMART-ITL has been built in a full height scale and a 1/49 area and power scale with numerous instrumentations to scrutinize the relevant phenomena [2]. Several tests have been conducted so far [3-4].

In this paper, the feedwater line break accident simulated with SMART-ITL was discussed focusing on the thermal hydraulic behavior.

2. Description on the experiment

The schematic of SMART-ITL facility is displayed in Fig. 1. The facility comprises of a primary system, a secondary system, 4 trains of a PRHRS, 2 trains of PSIS, 2 trains of automatic depressurization systems (ADS), a break simulator, a break flowrate measuring system, and etc.

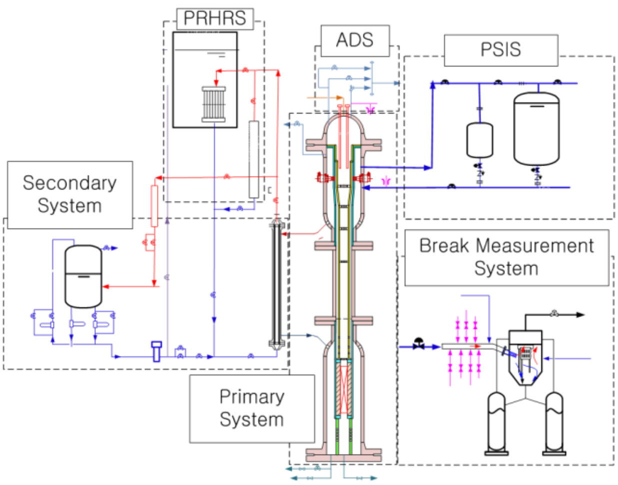

Figure 1. Schematic of SMART-ITL (Simplified).

Table 1. Major Sequence of SBLOCA Tests

Event	Trip signal and Set-point
Break	-
HPP set-point	PZR Pressure = P_{HPP}
HPP reactor trip signal - FW stop, RCP Coast down - CMTAS (CMT actuation signal) triggering - PRHR actuation signal (PRHRAS)	HPP+1.1 s
Control rod insert	LPP+1.6 s
CMT injection start	CMTAS+1.45 s
PRHRS Isolation Valve open, Main Feedwater/Steam Isolation Valve close	PRHRAS+5.0 s
Test end	-

Test scenario is shown in Table 1. After break at a feedwater line occurred, main feedwater flow rate was reduced. Consequently, heat transfer through the steam generators was reduced leading to pressure rise in the reactor vessel. When the high pressurizer pressure was reached, trip signal was actuated after a delay time. We assumed turbine trip as well as loss of offsite power. As a result, reactor coolant pump and feedwater pump did not work. CMT and PRHRS started to operate to supplement water and remove decay heat, respectively. Their operation was enabled by opening corresponding isolation valves.

3. Results

Figures 2-4 represent the main thermal-hydraulic parameters in the SMART-ITL under the FLB accident scenario.

As shown in Figure 2, right after the break, the reactor vessel pressurizer increased until it reached the high pressurizer pressure. After reaching the set pressure, trip signal was actuated leading to control rod insertion and subsequent decay heat generation. 3 trains of PRHRS operated delivering the decay heat into the ultimate heat sink, ECT. The pressure was rapidly decreased proving the adequacy of PRHRS performance.

As shown in Figure 3, the reactor vessel water level remained high throughout the test. It has to do with effective passive water injection and low amount of coolant loss through the break. Because the main feedwater and steam isolation valves at the broken train were closed after PRHRAS, loss of reactor vessel coolant was minimized.

Figure 4 shows the comparison of decay heat and PRHRS heat removal rate. At early phase before 20,000 s, heat transfer via PRHRS was significantly higher than the decay heat. It explains why the pressurizer pressure was decreased rapidly until 20,000 s.

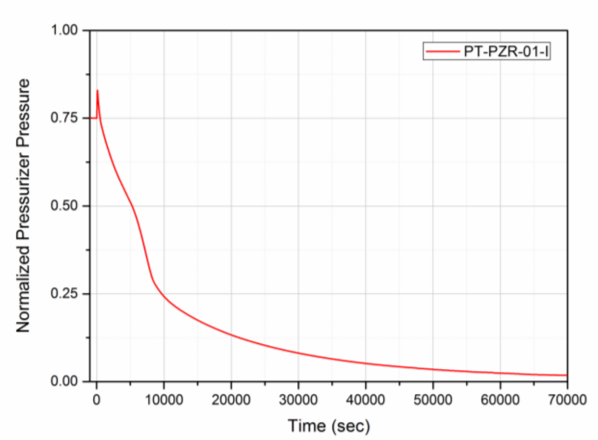

Figure 2. Normalized pressurizer pressure trend

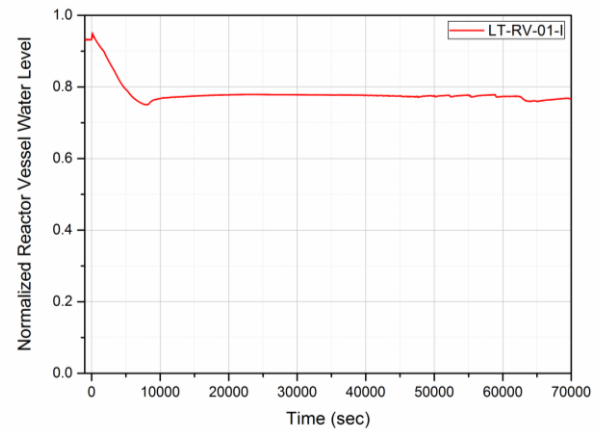

Figure 3. Normalized reactor vessel water level trend

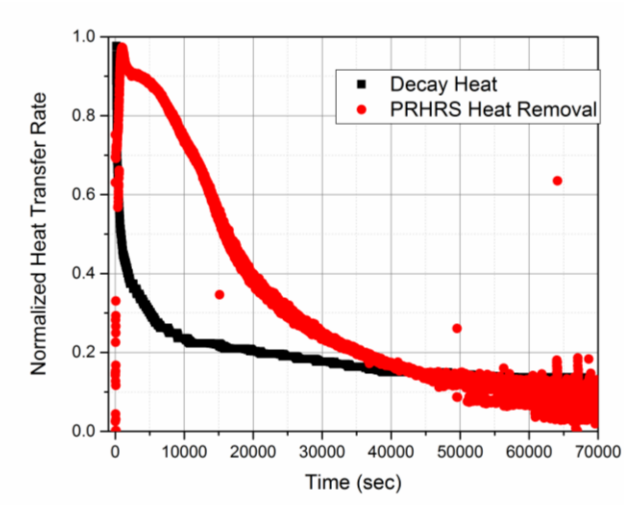

Figure 4. Normalized decay heat and PRHRS heat transfer rate

4. Conclusions

In the SMART-ITL, 4 trains of PRHRS and PSIS were installed to evaluate their performance and a series of tests have been conducted. In this paper, the feedwater line break accident scenario is investigated. Because of the break, heat transfer through the SG was reduced and pressurizer pressure rose to actuate the trip signal. After the trip, 3 trains of PRHRS and 4 trains of CMT operated to remove decay heat and supplement reactor vessel water. As a result, reactor vessel was depressurized successfully and the reactor vessel water level remained high. 3 trains of PRHRS could remove decay heat efficiently.

Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (No. 2016M2C6A1004894)

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