Analysis of Thermal-Hydraulic Behavior of PSIS in the SMART-ITL Facility during SBLOCA Test of Pressurizer Safety Valve Line Break

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1. Introduction

The SMART [1] (System-integrated Modular Advanced ReacTor) is the only licensed SMR in the world since the Nuclear Safety and Security Commission (NSSC) issued officially the Standard Design Approval (SDA). The SMART-ITL (Integral test loop for the SMART) has been designed and constructed by the Korea Atomic Energy Research Institute (KAERI). The test facility of SMART-ITL was used to investigate thermal-hydraulic phenomena during design basis accident scenarios such as SBLOCA, CLOF and FLB.

The SMART-ITL is equipped with the passive safety injection system (PSIS). The PSIS is composed of four core makeup tank (CMT) and four safety injection tank (SIT). It was designed to work by gravity force. The pressure balance is its core principle because the passive injection is started after pressure equalization between two components, the injecting tank and the injected vessel. The thermal-hydraulic behaviors of PSIS have been identified through test. [2-3]

A small-break loss of coolant accident (SBLOCA) test was performed using SMART-ITL. In this paper, the test result of a pressurizer safety valve (PSV) line break simulation was analyzed to evaluate the thermal-hydraulic phenomena of the PSIS. The thermal-hydraulic phenomena such as fluid behavior in PBL and PSIS injection characteristic were investigated during the SBLOCA test of PSV break.

2. Test facility and test scenario

2.1 Test facility

The SMART-ITL has full height, the ratio of the hydraulic diameter is 1/7, and the flow rate and volume are scaled down to 1/49. The maximum core power is 2.0 MW, which is about 30% of the scaled full power and simulation capability of scenarios including the SBLOCA, CLOF and FLB.

Fig. 1 shows the schematic drawing of PSIS. The PSIS includes the CMT and SIT. Individual tanks connected with pressure balance line on the top side and injection pipes on the bottom side. Each pipe has an isolation valve and a flow meter. The pressure and temperature can be measured at the pipe and tank. The level and pressure transmitters are installed in each tank.

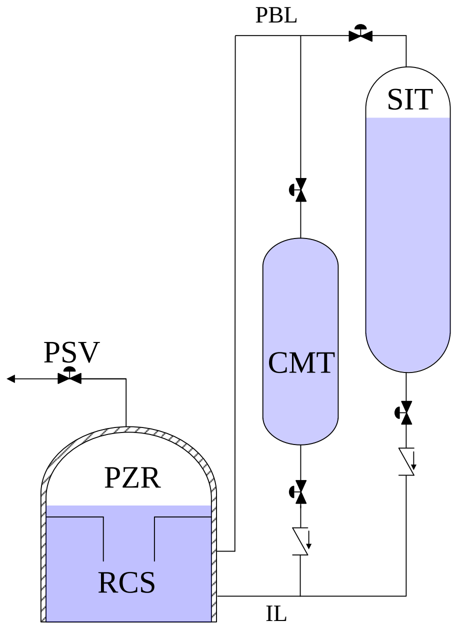


Fig. 1. Schematic drawing of SMART-ITL PSIS

Table I: Major sequence of events for the SBLOCA

Events	Time (sec)
Break	0
LPP set-point	204
Reactor trip signal	205
CMT injection start	206
PRHRS IV open	214
SIT injection start	4,127
ADS #01	24,093
stop	261,326

2.1 SBLOCA-PSV scenario

An SBLOCA scenario was simulated using the SMART-ITL facility. The break nozzle is located at the top of the pressurizer, and its size is scaled down to the volume-scaled ratio for 2 inch break. Table 1 shows the major sequence of events for the SBLOCA test of PSV break.

3. Results

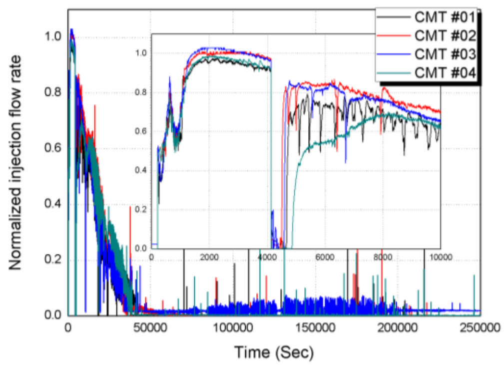
Figures 2 (a) and (b) show the CMT and SIT injection flow rates, respectively. After opening an isolation valve of the CMT, the injection of the core makeup water begins. The initial injection flow rate showed unstable behavior. After about 6,000 seconds, the mass flow rate decreased. When it reaches about 40,000 seconds, cooling water in CMT was not injected to the reactor vessel (RV). On the other hand, for the SIT, the mass flow rate is decreased gradually for the entire transient test.

Figure 3 (a) and (b) show the CMT and SIT water level, respectively. For the SIT, the water level is decreased gradually until the end of test. However, for the CMT, the water level is decreased until about 40,000 seconds, and then water level is maintained by 90,000 seconds. After 90,000 seconds, water level is increased same as the staircase form until the end of transient test. It is expected that the reactor coolant in the upper down comer (UDC) moves to the CMT through the PBL.

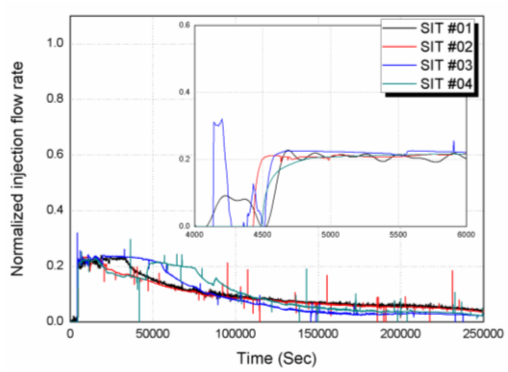
Figure 4 shows the temperatures of pressure balance line and reactor vessel (RV). The reactor coolant temperature (TF-RV) indicates the saturation temperature. The temperatures in the PBL of the CMT #1 and SIT #1 reveal the subcooled state. Temperature in the PBL of CMT #1 is increased and decreased repeatedly. It is expected that this oscillation is caused by the coolant moving from RV to CMT. It is because the oscillating period of the fluid temperature in the PBL of the CMT #1 is well agreed with the CMT temperature stepwise increase. That is, peak points in the PBL of CMT appear coincidently in the increasing points in the CMT water level. On the hands, the temperature in PBL of SIT #1 is decreased below the saturation temperature after a certain time, around 30,000 s and not oscillated to the end of the test.

4. Conclusions

The thermal-hydraulic phenomena such as fluid behavior in PBL and PSIS injection characteristics were investigated during the SBLOCA simulation test of PSV break. For the SIT, the cooling water was injected smoothly until the end of the test transient. On the other hand, for the CMT, the water level was increased by refiling the cooling water into the PBL during the SBLOCA test of PSV break. During the transient test of CMT injection, the water is injected inefficiently.

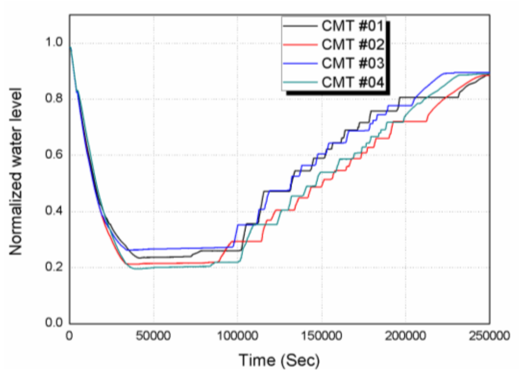


(a) CMT

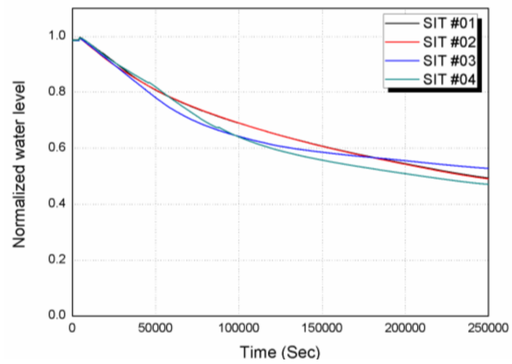


(b) SIT

Fig. 2. Normalized injection flow rate



(a) CMT



(b) SIT

Fig. 3. Normalized water level

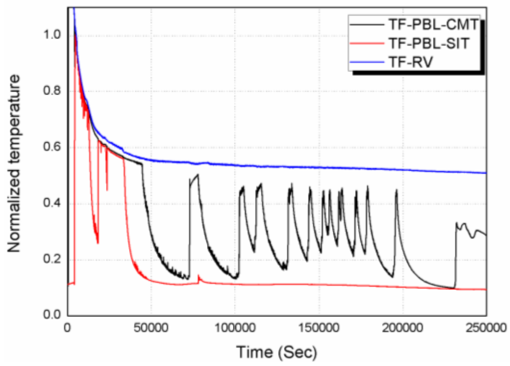


Fig. 4. Normalized temperature in PBL and RV

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