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Comparison of 1-train and 2-train Passive Safety Injection Systems in the SMART-ITL Facility

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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) are designed 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 using 1-train and 2-trains of PSIS [3-4]. In this paper, the effect of the PSIS train number is discussed for a representative case.

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. Fig. 2 shows the schematic of 1 train PSIS. For CMT, The top of CMT is connected to the upper downcomer of the reactor vessel (RV) through a pressure balance line (PBL). This feature allows prompt injection of cooling water regardless of reactor pressure. Once a reactor is tripped because of low pressurizer pressure (LPP) under a small break loss of coolant accident (SBLOCA), an isolation valve below the CMT

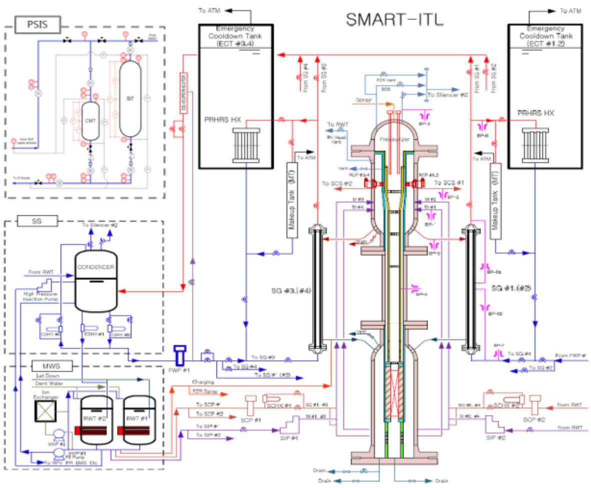

Fig.1 Schematic of SMART-ITL facility

is opened to begin CMT injection. For SIT, we examined two types in different tests: a pressure balance type same with the CMT, or the conventional nitrogen pressurized type. In this paper, for evaluating the effect of a PSIS train number, we selected the tests with pressure balanced CMT and the pressurized SIT.

Test scenario is as follows. After simulating a break at a safety injection line, coolant is released into the atmosphere reducing the RV pressure. At a set pressure, the reactor is tripped signaling operation of passive safety systems including PRHRS and PSIS. The tests have been progressed until the injection is completed.

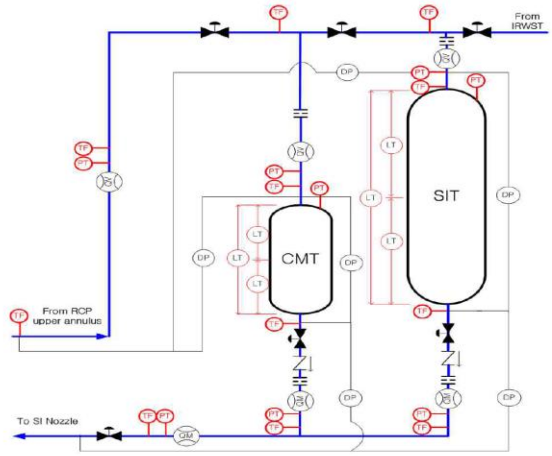

Fig.2 Schematic of SMART-ITL PSIS

3. Results

Table 1 represents the major sequence of the SBLOCA tests for both 1 train and 2 trains of PSIS. The overall process is very similar each other. Many of the logics, e.g. reactor trip and SITAS, are dependent on RV pressure while the pressure is determined by steam inventory inside the RV, or break flow rates and PRHRS heat removal rates. As shown in Figure 3, the pressure histories of 1 train and 2 trains are similar regardless of the number of PSIS trains because the injected water does not contribute to the condensation of steam. Only when the break area or the number of PRHRS trains changes, the time sequence of major events will be significantly shifted. On the other hand, the RV water level is lifted noticeably at 2 trains (Fig. 4). Considering the fact that the coolant inventory inside RV is the most important parameter in terms of safety of nuclear fuels, we can assure that the effect of multiple PSIS trains is distinct. Fig. 5 represents the emergency condenser tank (ECT, final heat sink of PRHRS)

Table 1 Major Sequence of SBLOCA Tests (1 train and 2 trains)

Events	Set-point	Time (s)	
		1 train (S201)	2 trains (T201)
Break	-	0	0
LPP set-point	PZR Press = P_{LPP}	766	704
LPP reactor trip signal - FW stop, Pump Coastdown - CMTAS (CMT actuation signal) triggering	LPP+1.1 s	768	706
Main Steam High Pressure set-point	LPP+4.1 s	771	709
PRHR actuation signal (PRHRAS)	LPP+5.2 s	772	710
PRHRS Isolation Valve open, Feedwater Isolation Valve close	PRHRAS +5.0 s	777	715
Main Steam Isolation Valve close	PRHRAS +20.0 s	792	730
SIT actuation signal (SITAS)	PZR Press = P_{SITAS}	6,040	5,642
SIT injection start	SITAS+1.1 s	6,045	5,643
ADS #1 open	CMT level < 35%	25,242	28,885
Test end			49,321

temperature. The temperature trend directly shows the heat removal trend via PRHRS. The effect of the number of PSIS trains is marginal because the number of PRHRS trains is preserved. Fig. 6 and Fig. 7 show the CMT and SIT injection flow rates, respectively. The train number effect is negligible. Because the pressure of CMT is equalized to the RV by pressure balance lines, the injection flow rates are solely determined by the water level inside the CMT. On the other hand, for the pressured SIT, the flow rates are determined by two factors: pressure difference between RV and SIT, and SIT water level. Only when the pressure of RV is influenced by some parameters, such as different break area, the pressured SIT flow rates can be affected.

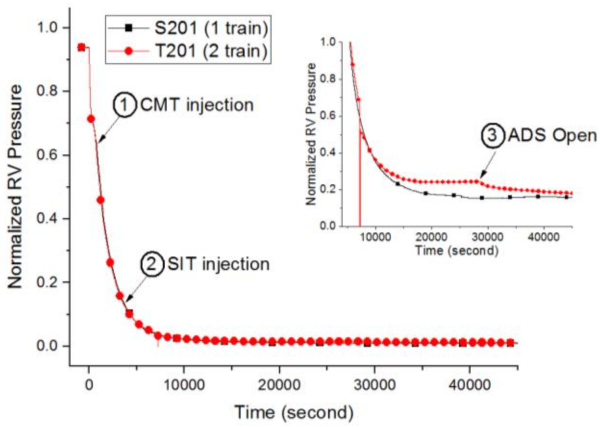

Fig.3 Normalized RV pressure

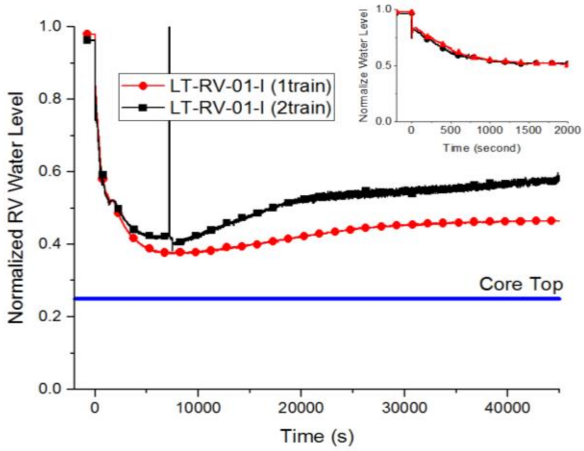

Fig.4 Normalized RV water level

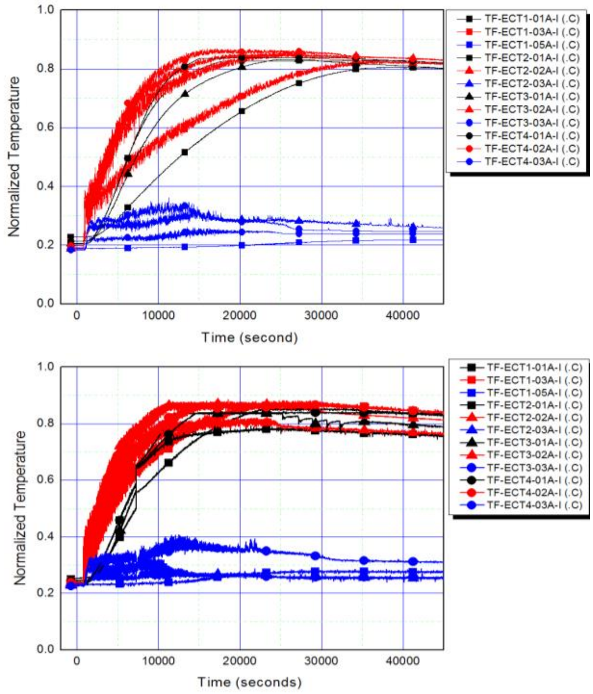

Fig.5 Normalized ECT water temperature

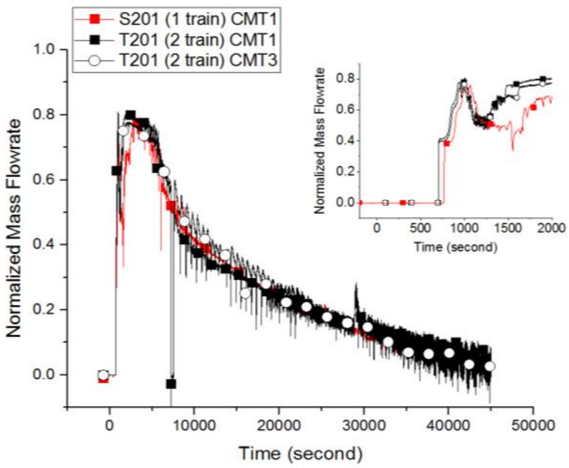

Fig.6 Normalized CMT injection rates

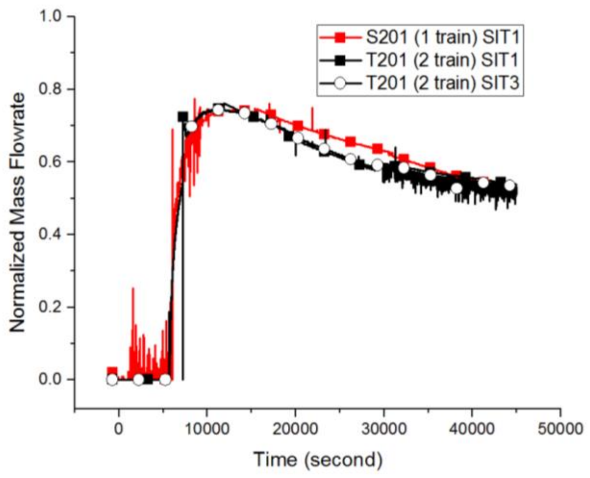

Fig.7 Normalized SIT injection rates

4. Conclusions

PSIS are added into SMART for better treatment of accidents under prolonged station blackout. In the SMART-ITL, 2 trains of PSIS are installed to evaluate their performance and a series of tests have been conducted. In this paper, the effect of the train number of PSIS is investigated. The increased injection rates from PSIS raised the RV water level ensuring safety of nuclear fuels. Because the number of PSIS trains has little effect on the steam condensation inside the RV, the RV pressure, sequence of major events, as well as PSIS injection rates are not affected a lot.

Acknowledgments

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