An Investigation on the Effect of Break Location on the Thermal-Hydraulic Characteristics of the SMART-ITL

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1. Introduction

Growing concerns about the safety and environment for nuclear power plants have led current nuclear engineering research to be focused on improving the safety systems. Nuclear power systems are now designed to run safely ever before, and passive and advanced safety systems have been included to enhance safety during accidents. Also, a safety of integral arrangement of reactor can be improved by removing large pipe connections between the major components [1]. It has an advantage in terms of safety issues due to essentially preventing a large-break loss of coolant accident. In order to design an enhanced safety system of the integral type reactors comprehensively, a small-break loss of coolant accident (SBLOCA) becomes more important issue. During a SBLOCA, the thermal hydraulic characteristics can be affected by break location. Therefore, it is necessary to fully understanding thermal-hydraulic characteristics under various SBLOCA situations. In this paper, the thermal-hydraulic characteristics were experimentally investigated during the various break situations.

2. SBLOCA Test Conditions

Two SBLOCA cases, the safety injection (SI) line break and the pressurizer safety valve (PSV) break, were selected and performed using the SMART Integral Test Loop (SMART-ITL) to investigate the thermal hydraulic phenomena. The SMART-ITL is an experimental simulation and validation facility to perform integral effect tests for the integral type reactor, SMART. The SMART-ITL has a capability to conduct tests for various thermal-hydraulic behaviors in primary, secondary, and safety systems[2].

2.1 Break on Safety Injection Line

Total four trains of the passive safety injection system (PSIS) are installed at the downstream of reactor coolant pump (RCP) located in reactor vessel (RV) (Fig.1). The individual emergency core coolant from the core make-up tank (CMT) and the safety injection tank (SIT) supplies into the RV through the three injection lines except a break simulation line during the accident. The test was started by heating up the primary and secondary system so that the same operating conditions as those of the reference plant, SMART, were established. When the whole system reached a specified initial condition, the steady-state conditions were maintained for more than 10 minutes. After that, the transient test was started by opening the break simulation valve which is connected to the SI line. With the start of the transient test, the pressure of the primary system decreased rapidly below the set point of the low pressurizer pressure (LPP) signal. When the LPP signal occurs, the core heater, reactor coolant pump, and pressurizer heater are stopped, and the main feed water isolation valves is actuated. Also, CMT injection is started at the time with CMT actuation signal (CMTAS). Further decreasing the primary pressure, below the set point of SIT actuation signal (SITAS), results a passive actuation of the SIT injection.

2.2 Break on Pressurizer Safety Valve

The PSV is located on the top of pressurizer (PZR) as shown in Fig. 1. In the second test case, the SBLOCA was tested with the break of PSV line. The test sequence of PSV break test is same to that of SI line break test.

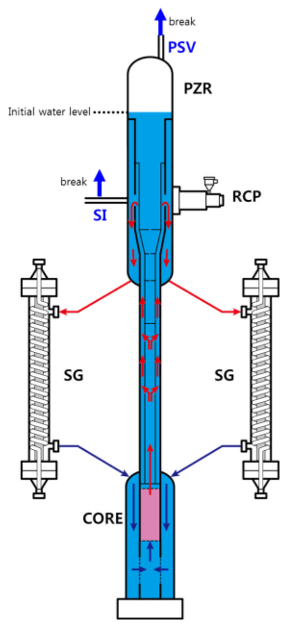

Fig. 1. Schematic for break locations of safety injection line and pressurizer safety valve

3. Comparison of Test Results

The results of two SBLOCA tests were summarized until SITAS was generated. Fig. 2 shows the measured PZR pressures of the PSV and SI break. The pressure behavior was similar for both simulation cases. The primary system pressure decreases rapidly after the break. The pressure is reduced more quickly when the PSV breaks than SI breaks. In case of the PSV break, the pressure reached LPP at 204 s, and SITAS at 4,127 s. In case of the SI break, the time to reach CMTAS is delayed to 704 s, but time to reach SITAS is 4,128 s which is almost same to the PSV break. The pressure is different between two break cases at the beginning of the break simulation, but it showed almost similar value around 5,000 s.

Fig. 3 shows the behavior of collapsed water levels in the core. The collapsed water levels in the reactor vessel showed typical trends which were expected during both SBLOCA tests. However, the decreasing rate is quite large different between two test cases. The decrease of water level in the PSV break is slower than that in the SI break. The PZR pressure is rapidly decreased but water level is slowly decreased in case of the PSV break. The initial water level for both cases is about 90% of full RV height, but the difference between the SI and PSV break is about 27% at the stating time of SIT injection. The core is located below the 25% level of full RV height. The core is safely maintained until SIT injection. Also, the result showed that it has different trends compared with PZR pressure. The water level of the SI break is lower than that of the PSV break. On the contrary, the PZR pressure of the SI break is higher than that of the PSV break. Because the PZR pressure is directly associated with mass of pressurized steam, while water level is reflected mass of break flow.

Fig. 4 shows the measured total mass of break flow for the PSV and SI break. Total mass of break flow in the SI break is approximately 67% larger than that in the PSV break. In case of the PSV break, saturated steam is discharged because of location of PSV. Meanwhile, the water is discharged in SI break test. The break flow rate is highly associated with fluid density. Therefore, mass flow rate of SI break is larger than that of PSV break.

4. Conclusions

Two SBLOCA tests were performed with the same sequence and initial conditions except for different break locations of the SI and PSV with the same discharge area of break line. The results showed that the pressure is reduced more quickly when PSV breaks than SI breaks, and the decrease of water level of PSV break is slower than that of SI break. Also, SI break mass flow rate is larger than PSV break. The comparison results could be used to understand the thermal-hydraulic phenomena expected to occur in the SI and PSV during the SBLOCA scenario.

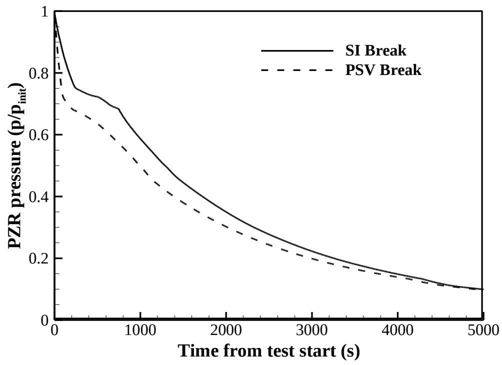

Fig. 2. Behavior of pressurizer pressures

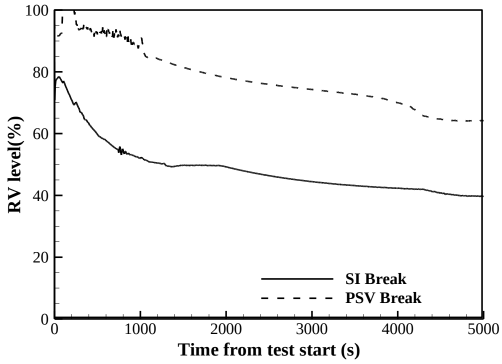

Fig. 3. Behavior of collapsed water levels in reactor vessel

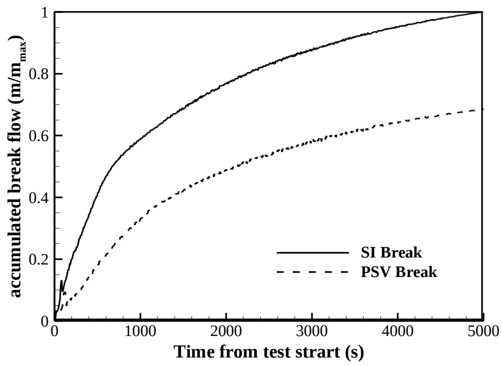

Fig. 4. Behavior of mass of break flow

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REFERENCES

[1] K. K. Kim et al., SMART: The First Licensed Advanced Integral Reactor, Journal of Energy and Power Engineering, Vol.8, pp. 94-102, 2014.
[2] H. S. Park, S. J. Yi, and C. H Song, SMR accident simulation in experimental test loop, Nuclear Engineering International, Vol.58, pp.12-15, 2013.