An SBLOCA Test for Shutdown Cooling Line Break Using the SMART-ITL Facility

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1. Introduction

SMART (System-integrated Modular Advanced ReacTor) [1] which was designed by KAERI is an integral type reactor. The standard design approval for the SMART design was issued on July 4th of 2012 by a Korean regulatory body, the Nuclear Safety and Security Commission (NSSC). The main components including a pressurizer, steam generators, and reactor coolant pumps are installed in a reactor pressure vessel, and there are no large-size pipes. The safety systems could be simplified as an LBLOCA (Large-Break Loss of Coolant Accident) scenario is inherently excluded.

An integral-effect test loop for SMART (SMART-ITL, or FESTA) [2, 3, 4] was designed to simulate the integral thermal-hydraulic behavior of SMART. The SMART-ITL has been designed using a volume scaling methodology. The objectives of SMART-ITL are to investigate and understand the integral performance of the reactor systems and components, and the thermal-hydraulic phenomena occurring in the system during normal, abnormal, and emergency conditions, and to verify the system safety during various design basis events of SMART.

Its height was preserved and its area and volume were scaled down to 1/49 compared with the SMART prototype plant. The SMART-ITL consists of a primary system including a reactor pressure vessel with a pressurizer, four steam generators and four main coolant pumps, a secondary system, a safety system, and an auxiliary system.

The SMART was installed at KAERI and several transient tests were recently finished. In this paper, the test results for a steady-state operation and a transient of the small break loss of coolant accident (SBLOCA) are discussed.

2. Methods and Results

2.1 Scale Law

The reactor pressure vessel of a SMART-ITL including the steam generators was geometrically designed using the volume scaling methodology. The heights of the individual components are conserved between SMART and SMART-ITL. The flow area and volume are scaled down to 1/49. The ratio of the hydraulic diameter is 1/7. The primary scale variables are listed in Table I. Fig.1 shows a schematic of the SMART-ITL facility.

Table I: Primary scale variables

Parameters	Scale Ratio	Value
Length, l_{0R}	l_{0R}	1/1
Diameter, d_{0R}	d_{0R}	1/7
Area, a_{0R}	d^2_{0R}	1/49
Volume, V_{0R}	$d^2_{0R}\, l_{0R}$	1/49
Time scale	$l^{1/2}_{0R}$	1/1
Velocity	$l^{1/2}_{0R}$	1/1
Power/Volume	$l^{-1/2}_{0R}$	1/1
Heat flux	$l^{-1/2}_{0R}$	1/1
Core power	$a_{0R}\, l^{1/2}_{0R}$	1/49
Flow rate	$a_{0R}\, l^{1/2}_{0R}$	1/49
Pump head	l_{0R}	1/1
Pressure drop	l_{0R}	1/1

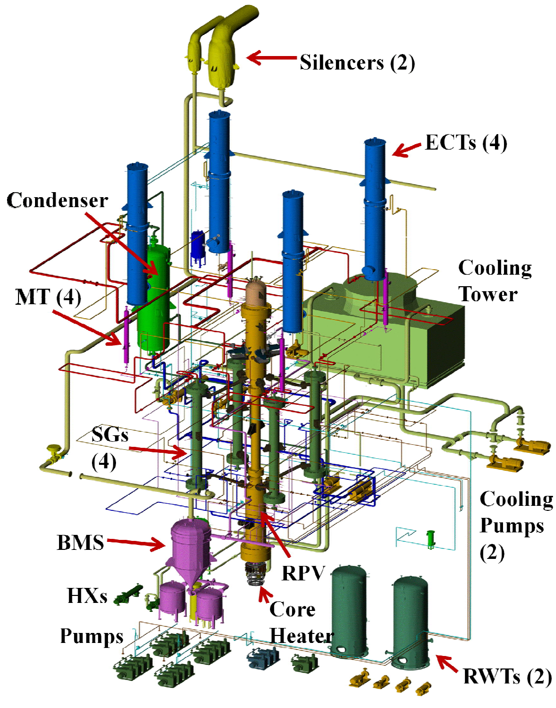

Fig. 1. Schematic of the SMART-ITL facility.

2.2 Steady-State Test Results

The steady-state condition was maintained for 600 seconds before simulating the sequence of event of SBLOCA. Table II shows the major parameters of the target values and test results during a steady-state condition. The steady-state conditions were operated to satisfy the target values presented in Table II, and its boundary conditions were properly simulated.

Table II: Description of steady state

Parameter	Target Value	SMART-ITL	Difference (%)
Power [MWt]	1.347	1.491	
PZR pres. [MPa]	15.0	15.0	
SG 1st inlet T. [°C]	323	318	
SG 1st outlet T. [K]	295.7	294	
FW flowrate [kg/s]	0.6334	0.6604	
FW temp. [K]	200	201.96	

2.3 Transient Test Results

An SBLOCA test (SB-SCS-01) for the shutdown cooling line break was successfully performed. The break location is at the suction line of the shutdown cooling system (SCS) (nozzle part of the RCP suction). Fig. 2 shows the pressure behavior of the primary system. The primary pressure decreased rapidly during the single-phase liquid blowdown period. The pressure decrease was slowed down during a two-phase discharge period, and then the pressure decreased gradually during the single-phase steam blowdown period. Fig. 3 shows the secondary system flow rate. As the PRHRS was operated, the feed-water flow rate showed a dramatic change at the beginning, and the natural circulation was achieved within a few seconds. After that, the natural circulation flow rate showed a gradual decrease at a constant rate. The flow rate under a natural circulation condition was dependent on the heat balance between the heat exchanger and the SG, as well as and the hydraulic resistance in the loop. With the operation of the PRHRS, a two-phase natural circulation flow formed inside the two-phase PRHRS natural circulation loop. It was judged that the experimental results of the SBLOCA of an SCS line break simulated the accident conditions of the SMART design properly. The flow rate of the safety injection is programmed by following the pressure of the RCS, and is well injected according to the pressure, which are programmed into the control logic, as shown in Fig. 4.

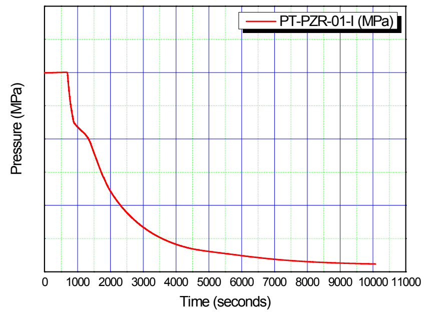

Fig. 2. Pressure of Pressurizer

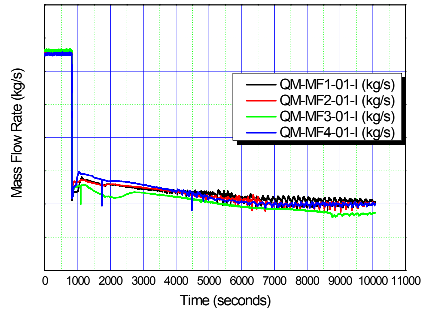

Fig. 3. PRHRS flow rate

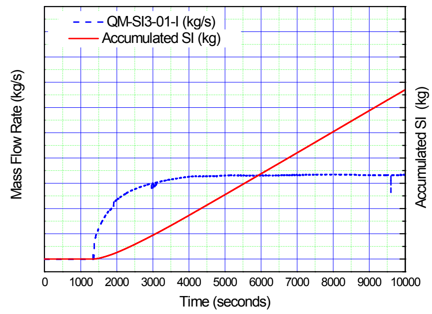

Fig. 4. Flow rate of the safety injection system.

3. Conclusions

An SBLOCA test simulating the shutdown cooling line break was performed using SMART-ITL properly.

1. All parameters were in good agreement with the target values during the steady-state operation period.
2. The pressures and temperatures show reasonable behaviors during the SBLOCA test.

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