Preliminary Test Results of Steady-State Operation and SBLOCA for SMART

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1. Introduction

Standard design approval for SMART was certificated in 2012 led by the Korea Atomic Energy Research Institute (KAERI). An Integral Test Loop for the SMART design (SMART-ITL) [1] has been constructed and its commissioning tests finished in 2012. SMART-ITL is scaled down by the volume scaling methodology. Its height is conserved and its volume scale ratio is 1/49. SMART-ITL has all the fluid systems of SMART, together with a break system and instruments. SMART-ITL has the same system as SMART, which consists of a reactor coolant system (RCS), steam generator (SG), passive residual heat removal system (PRHRS) and so on. Additional systems for the test have been designed and constructed, i.e., a break simulation system (BSS) and break measuring system (BMS). A series of pre-heating tests were executed after the SMART-ITL was constructed [2]. 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 pressurized vessel of a SMART-ITL including the steam generators was geometrically designed using the volume scale law. The height of the individual components is 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.

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

2.2 Systems of SMART-ITL

SMART is an integral type reactor. A single pressure vessel contains all major components, which are the pressurizer, core, steam generator, reactor coolant pump, and so on. The space of the annulus to locate the steam generator is too narrow to install itself inside SMART-ITL. The steam generator is connected with the hot-leg and cold-leg outside the pressure vessel. SMART is a 330 MW thermal power reactor, and its core exit temperature and PZR pressure are 323℃ and 15 MPa during normal working conditions, respectively. The maximum power of the core heater in SMART-ITL is 30% for the ratio of the volume scale.

Four reactor coolant pumps (RCP) were installed in the upper annulus side of the pressure vessel at an angle of 90 °. Four once-through steam generators with a helical coil were installed in the same azimuth as the RCP outside the reactor pressure vessel of SMART-ITL.

The passive residual heat removal system plays a role in removing the residual heat of the core during the SBLOCA. The safety system includes a safety injection system (SIS) and shutdown cooling system (SCS).

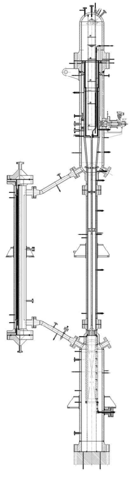

Fig. 1. Schematics of the SMART-ITL.

2.3 Sequence of Event

The safety injection line break, one of the small break loss of coolant accidents, was simulated. The accident simulation was begun by actuating the break simulation system. The signal of the low pressure of the pressurizer (LPP) was actuated when the pressure of reactor vessel arrived at the set point of the core trip. The supply of the feed water was stopped and the coastdown of RCP was started. The isolation valve of the passive residual heat removal system (PRHRS) was opened, and that of the feed and steam line was closed. The safety injection system was actuated by the safety injection actuation signal.

2.4 Steady State

The steady state was maintained for 600 sec before simulating the break accident. Table II shows the major parameters of the target value and results during the steady state. The test results show that most of the thermal-hydraulic parameters agree well with the target values.

Table II: Description of steady state

Parameter	Target Value	SMART-ITL
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

2.5 Transient of Event

Fig. 2 shows the pressure of the pressurizer. The overall trend of the primary pressure behavior agrees well with the typical pressure behavior of a loss of coolant accidents, in which the slope is stiff in the early stage and smooth in the late stage. Fig. 3 shows the temperature at the inlet and outlet of the steam generators, which is decreased separately. The flow rate of the safety injection is programmed as following the pressure of the RCS, and is well injected by the pressure behavior, as shown in Fig. 4.

3. Conclusions

SMART-ITL was constructed in KAERI and a preliminary test was performed for the SBLOCA scenario.

1. SMART-ITL was designed and constructed by the volume scaling methodology. Its height is conserved and its volume scale ratio is 1/49.
2. It consists of a primary system, secondary system, PRHRS, and safety system, and break simulation and measurement system.
3. All parameters were in good agreement with the target values during the steady state operation.
4. The pressures and temperatures show reasonable behavior during the preliminary test for the SBLOCA scenario.

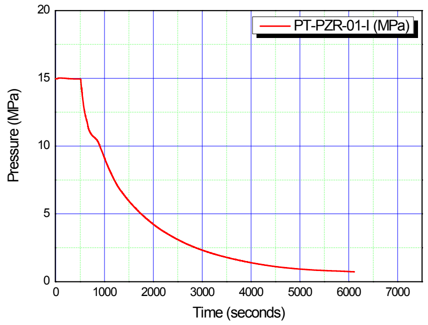

Fig. 2. Pressure of Pressurizer

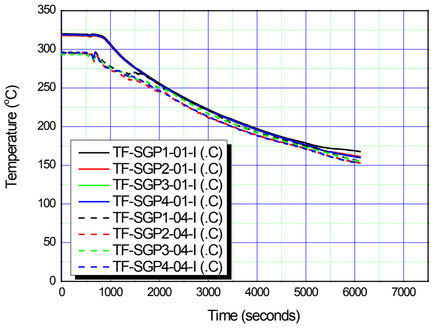

Fig. 3. Temperature in the inlet and outlet of steam generators

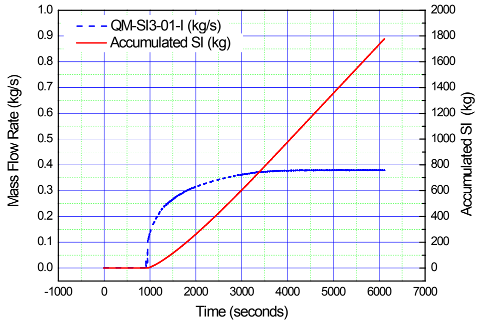

Fig. 4. Flow rate of the safety injection.

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