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Test Results of Reactor Coolant System Natural Circulation using the SMART-ITL Facility

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1. Introduction

SMART (System-integrated Modular Advanced Reactor) [1] is an integral type reactor which major primary components such as the steam generator, the pressurizer, and the reactor coolant pump are installed inside one single reactor vessel and connecting primary pipes are removed. The TASS/SMR-S code is used to perform the performance and safety analysis of the SMART. To evaluate the capability of TASS/SMR-S code on the natural circulation and accident scenarios such as Small-Break Loss of Coolant Accident (SBLOCA) for predicting the thermal-hydraulic phenomena in steady state and transient operation [2], it is essential to perform a series of validation tests.

For the above objectives, the SMART Integral Test Loop (SMART-ITL) which is composed of Reactor Coolant System (RCS), Pressurizer, Steam Generator (SG), Safety Injection System (SIS), Stop Cooling System (SCS), Secondary System (SS), Passive Residual Heat Removal System (PRHRS) and Break Simulation System (BSS) had been constructed and finished its commissioning in 2012. In addition, using the SMART-ITL, a RCS natural circulation test, a PRHRS natural circulation test and SBLOCA tests have been conducted. Fig. 1 shows the schematic diagram of the SMART-ITL facility.

In this paper, the Sequence Of Event (SOE) and test conditions of RCS natural circulation test using SMART-ITL are presented, and the major measuring parameters and the test results will be introduced.

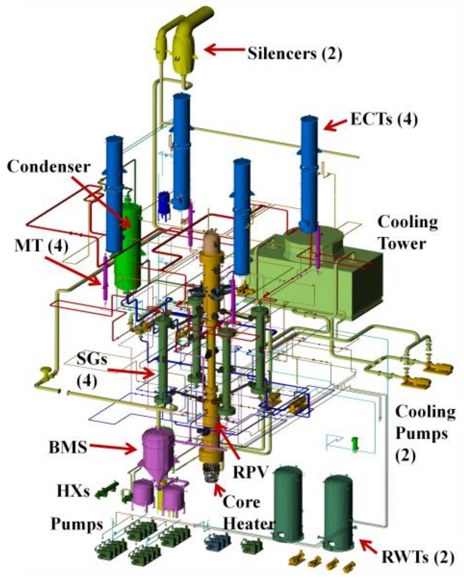

Fig. 1 Schematic diagram of SMART-ITL

2. Test procedures and conditions

The RCS natural circulation test was conducted in the manner of the prescribed test procedure [3]. The test procedure can be classified into the steady state and transient operations. In steady state operation, the initial and boundary conditions of this test were achieved and in succession RCS natural circulation test was started according to the SOE. Table I shows the SOE of RCS natural circulation test. Table II shows the initial and boundary conditions of this test.

Table I. SOE of RCS natural circulation test

Event	Trip Signal	Set Value
Steady state operation	-	Refer Table. 2
RCP stop	RCP STOP	RCP=OFF
Maintain the flow rate of feed water	-	0.1642 kg/s
Maintain core power	-	337 kW (w/o heat loss)
Achieving the stable condition	-	-

Table II. Initial and boundary conditions of RCS natural circulation test

Parameter	Target Value	Achieved Value
Core Power [kW]	337	474 (w/ heat loss)
SG Inlet/Outlet temperatures [℃]	323.0/316	318.13/ 294.47
Reactor Coolant Flow rate [kg/s]	8.531	8.079
Pressurizer pressure [MPa]	15.0	14.98
SG secondary side Inlet/Outlet temperatures [℃]	200/298.0	193.23/294.6
SS feed water flow rate [kg/s]	0.1642	0.1609
SG secondary side Inlet/Outlet Pressure [MPa]	5.29/5.2	5.128/5.07

Through the steady state operation, the target values were achieved for most of major parameters.

3. Test results

3.1 Steady state operation

As seen in Table II, the total power input was 474 kW and this value contains the given electric power of core heater and pressurizer heater. The difference between the target value (337 kW) and achieved value (474 kW) can be explained with the heat loss to ambient due to high temperature surface of the heat structures of the facility. The pressure of pressurizer was maintained at 14.98 MPa, which the value was almost the same with the target value. The inlet and outlet temperatures of core were maintained at 314.5 and 322.4 ^{o}C, respectively. The water level in pressurizer was about 70% and the inlet and outlet temperatures were maintained at 321 and 316 ^{o}C, respectively. The sub-cooled feed water supplied from the bottom of SG was changed to super-heated steam by the thermal energy from the primary side of SG. Also the flow rate of feed water was similar with the target value.

3.2 Transient operation

In this test, the RCPs were tripped at 600 s after achieving steady state condition and the coast-down operation was started. The test had been conducted until the pressure, temperature and flow rate of RCS and SS were maintained in the target conditions. Fig. 2 shows the inlet/outlet temperatures of the core. When the RCPs were stopped, the coolant flow rate significantly decreased. Thus, the outlet temperature of core considerably increased and the inlet temperature decreased. And as the natural circulation flow in RCS was fully developed, the inlet/outlet temperatures of core were uniformly maintained.

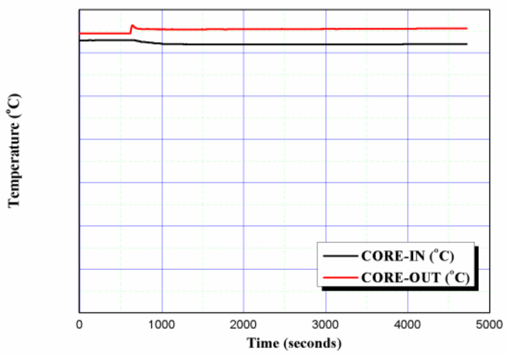

Fig. 2 Inlet/outlet temperatures in core

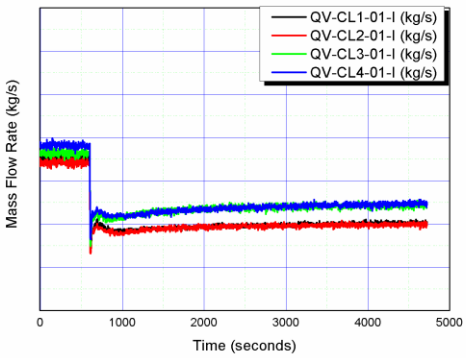

Fig. 3 Flow rate of RCS coolant

Fig. 3 shows the RCS coolant flow rate measured in the cold legs. After RCPs stop, the flow rates significantly decreased and then, by the generation of natural circulation flow, it gradually increased and maintained in a stable condition.

Fig. 4 shows the temperatures of the inlet feed water and outlet super-heated steam in the SG secondary side. After the RCPs stop, the feed water temperature gradually decreased and the outlet super-heated steam temperature slowly increased. It can be explained that the RCS temperature distribution is changed due to the stop of RCPs and the following natural circulation flow influenced on the temperature behavior of SS.

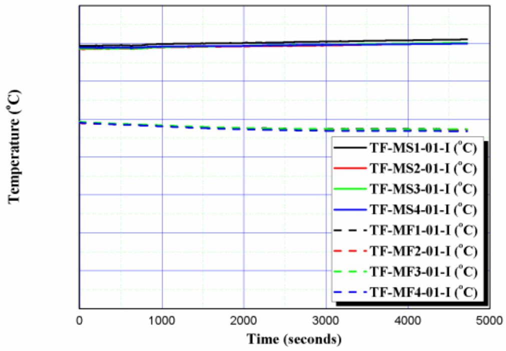

Fig. 4 Temperatures of inlet feed water and outlet super-heated steam in SG secondary side

4. Conclusions

In this test, the steady state operation satisfied the initial condition of the prescribed test procedure and the boundary conditions were properly simulated. After the RCPs stop, the RCS natural circulation flow was generated by heating in the core region and cooling in the SG heat exchanger region, and the major thermal-hydraulic parameters reached at a stable condition. Through this experiment, it has been validated that the SMART-ITL facility can adequately simulate the RCS natural circulation behavior. In addition, it is expected that the experimental data can be used for the code assessment of the TASS/SMR-S code and experiences from this test can be utilized to the subsequent SBLOCA simulation test.

ACKNOWLEDGEMENT

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