Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

Test Facility Design for the Validation of SMART Passive Safety System

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1. Introduction

Standard Design Approval for SMART was certificated in 2012 at the Korea Atomic Energy Research Institute (KAERI). Safety improvement for SMART has been studied since 2012. Active safety systems such as safety injection pumps will be replaced by the passive system [1], which is actuated only by the gravity force caused by the height difference. All tanks for the passive safety systems are higher than the injection nozzle, which is located around the reactor coolant pumps (RCP).

An Integral Test Loop for the SMART design (SMART-ITL) [2] 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. The SMART-ITL has all fluid systems of SMART together with a break system and instruments. In this paper, fluid systems for the SMART-ITL facility are described briefly and the conceptual design of the test facility for the validation of the SMART passive safety system [3], which will be additionally installed in the existing SMART-ITL facility, will be introduced.

2. Methods and Results

2.1 Overview of SMART-ITL

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. The reactor coolant system of SMART-ITL was designed to operate under the same condition of SMART.

The reactor coolant pump (RCP) was designed geometrically by the volume scale law, which was applied to the diameter of suction and discharge, and the liquid volume. The scale ratio of the flow rate was in proportion to the related power ratio of the core heater. Four reactor coolant pumps were installed in the upper annulus side of the pressure vessel at an angle of 90 ^{o}.

Four once-through steam generators with a helical coil were installed at the same azimuth as the RCP outside the reactor pressure vessel of SMART-ITL. The steam generator consists of primary and secondary sides. The primary function of the SG is to remove the heat of the RCS. The heat of the primary side is transferred to the secondary side in the steam generator, while the hot reactor coolant is floating through the cell side and the feed water is traveling through the tube side. To simulate the characteristics of the heat transfer, it was designed such that the surface area of the tube was satisfied with the scale ratio.

The secondary system consists of a feed water supply system, steam supply system, and condensation and cooling system. It is important to supply the feed water with a constant temperature and to generate the super-heated steam as the boundary values.

The passive residual heat removal system (PRHRS) plays a role to remove the residual heat of the core when an accident that decreases the pressure of the RCS, for example an SBLOCA, occurs. It has four trains. Each train has an emergency coolant tank and heat exchanger for the condensation of the steam. One makeup tank per train was installed for the pressure compensation. Individual components were scaled down by the volume scale ratio, and the pipes were designed for conserving the similarity of the pressure drop.

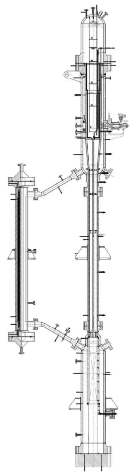

Fig. 1. Schematics of the SMART-ITL.

2.5 Passive Safety System

The passive safety system includes the core makeup tank (CMT) and safety injection tank (SIT). Individual tanks are connected with the pressure-balanced pipes on the top side and injection pipes on the bottom side. This system is operated when a small break loss of coolant accident (SBLOCA) or steam line break (SLB) occurs. There are no active pumps on the pipe lines to supply the coolant. This system is only actuated by the gravity force caused by the height difference because all tanks are higher than the injection nozzle around the reactor coolant pumps (RCP).

Fig. 2 shows schematics of one train for the passive safety system of SMART-ITL. Each pipe has an isolation valve and flow meter. Deferential pressure and temperature can be measured every pipe and tank. A level and pressure transmitter is installed in each tank.

The flashing and direct condensation is expected in the CMT, SIT, and pipes at the early stage. Appropriate thermo-couples have to be installed in the pipes and tanks to investigate the complex thermal-hydraulic phenomena after the system is operated by opening the isolation valve.

2.6 Scale Methodology

CMT and SIT is designed by the volume scale law of 1/49. Their heights are conserved. The diameter is scaled down to 1/7, and the area of the tank cross-section is scaled to 1/49. 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
Flow rate	$a_{0R}\, l^{1/2}_{0R}$	1/49
Pressure drop	l_{0R}	1/1

To maintain the characteristics of pressure drop in the pipes between a proto-plant and a facility, local phenomena scaling method was applied. First, a scale factor, k for the diameter to satisfy the volume ratio of pipes was assumed. A length ratio was derived by substituting the factor into the volume scale ratio. Using these two ratios, a temporary k_1 could be selected to satisfy the Friction Number and Orifice Number. Second, another k_2 was selected to satisfy the ratio of the pressure drop and flow rate and so on. Finally, through the best estimation, a specific k was determined to avoid the distortion of the real phenomena. The local scale variables are listed in Table II.

Table II: Local scale variables

Parameters	Scale Ratio	Value
Length, l_L	l_L	V_{OR} / k^2
Diameter, d_L	d_L	k
Area, a_L	d^2_L	k^2
Volume, V_L	V_L	V_{OR}
Time scale	$l^{1/2}_L$	$(V_{OR})^{1/2}$ / k
Velocity	$l^{1/2}_L$	$(V_{OR})^{1/2}$ / k
Flow rate	$a_{0R}\, l^{1/2}_{0R}$	k * $(V_{OR})^{1/2}$
Pressure drop	l_L	V_{OR} / k^2

3. Conclusions

A passive safety system, which is operated only by gravity force, has been designed to replace the active safety system for the SMART design. It is important that the tank elevation be higher than that of the injection nozzle. Appropriate instruments such as pressure transducers, flowmeter and thermo-couples have to be installed in the pipes and tanks to investigate the complex thermal-hydraulic phenomena. To simulate the accident, the height between the injection nozzle and the tank of the test facility is designed to be the same as SMART. Scale methodology is suggested to conserve the phenomena expected in the pressure-balanced pipes and injection pipes.

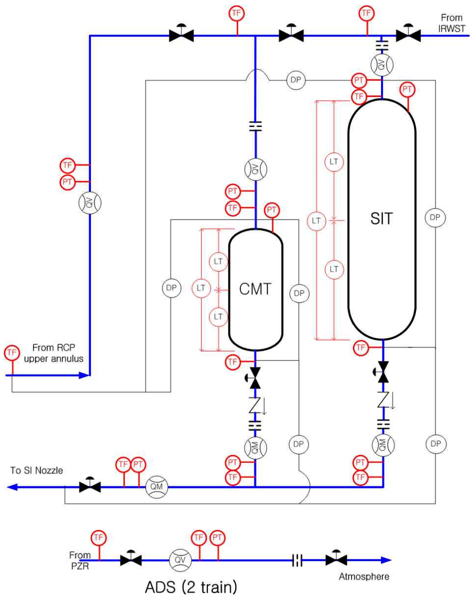

Fig. 2 Schematics of the test facility for SMART passive safety system

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2013M2B9A1020039)

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