Technical Issues for Validation Tests of SMART Passive Safety Injection System

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1. Introduction

The Standard Design Approval (SDA) for SMART [1] was certificated in 2012 at the Korea Atomic Energy Research Institute (KAERI). To satisfy the domestic and international needs for nuclear safety improvement after the Fukushima accident, an effort to improve its safety has been studied, and a Passive Safety System (PSS) for SMART has been conceptually designed [2].

In addition, an Integral Test Loop for the SMART design (SMART-ITL) [3] has been constructed and finished its commissioning tests in 2012. A set of Design Base Accident (DBA) scenarios is being simulated using the SMART-ITL. In addition, a test program to validate the performance of SMARS PSS was launched at an additional test facility to scale down the SMART PSS, which will be added to the existing SMART-ITL facility. [4]

In this paper, several technical issues for the validation of the SMART passive safety system will be summarized in terms of the phenomenological, analytical, and design viewpoints to help in assessing the performance of the SMART PSS.

2. Methods and Results

2.1 SMART-ITL

SMART is an integral type reactor. A single pressure vessel contains all of the major components, which are the pressurizer, core, steam generator, reactor coolant pump, and so on.

SMART-ITL is scaled down by the volume scaling methodology and has all the fluid systems of SMART together with the break system and instruments, as shown in Fig. 1. 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.

As the space of the annulus to locate the steam generator is too narrow to install itself inside the SMART-ITL, the steam generator was connected to the hot-leg and cold-leg outside the pressure vessel where the instruments are installed.

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 the SMART-ITL is 30% for the ratio of the volume scale. The reactor coolant system of the SMART-ITL is designed to operate under the same conditions of SMART.

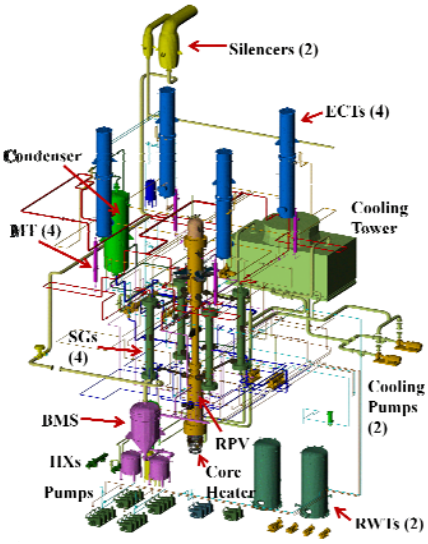

Fig. 1 Schematics of the SMART-ITL.

2.2 SMART Passive Safety System

The SMART passive safety system design is composed of four Core Makeup Tanks (CMTs), four Safety Injection Tanks (SITs), and two-stage Automatic Depressurization Systems (ADSs) [2]. 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 the small break loss of coolant accident (SBLOCA) or the 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 the tanks are higher than the injection nozzle around the reactor coolant pumps (RCP).

CMT and SIT were designed based on the volume scale methodology. Their heights are conserved, their diameters are scaled down to 1/7, and the area of the tank cross-section is done to 1/49.

Fig. 2 shows a schematic of one train for the passive safety system of the SMART-ITL. Each pipe has an isolation valve and a flow meter. The differential pressure and temperature can be measured at every pipe and tank. Level and pressure transmitters are installed in each tank.

The flashing and direct condensation are expected in the CMT, SIT, and pipes in 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.

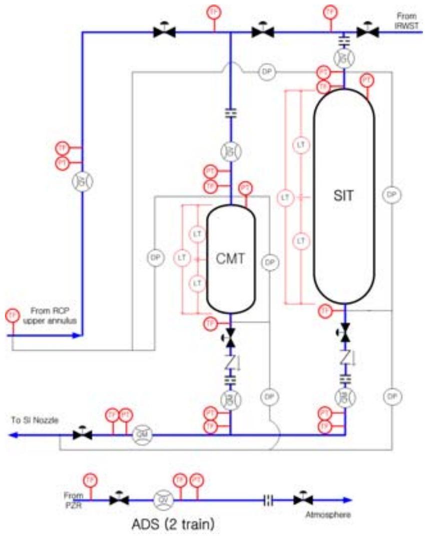

Fig. 2 Schematic of the test facility for SMART PSS

2.3 Validation Tests for SMART Passive Safety System

The objectives of this research are to construct a scaled-down test facility and to assess and analyze the performance of CMT and SIT for SMART and the physical phenomena occurring inside of the tank, for example, direct contact condensation and flashing. [5]

An experimental facility design for validating the SMART PSS was introduced. Through the validation tests, the general thermal-hydraulic performance of the passive safety injection system can be understood, and the performance of the sparger nozzle geometry, break size and tank geometry could be assessed. Thus, the quantitative data would be obtained, which could be applied to a real system design and safety analysis code. Furthermore, by analyzing the experimental data, the existing model for direct contact condensation occurring in CMT and SIT will be assessed.

2.4 Technical Issues from SMART PSS Development

Several technical issues arise from phenomenological, analytical, and design viewpoints.

From a phenomenological viewpoint, several important phenomena occurring in the CMT were listed and assessed to understand the most important phenomena in the CMT. They show that the condensation in the complicated multi-dimensional geometry in the upper part of CMT, the thermal stratification, and injection flow into the RPV are the most important phenomena to be investigated during the validation tests.

From the viewpoint of a code analysis, the analysis capability of the thermal-hydraulic computer code, MARS for the behaviors of the core make-up tank (CMT) was assessed for KAIST CMT tests [7]. A sensitivity study on the nodalization to simulate the CMT was conducted, and the MARS calculations were compared with KAIST experimental data and RELAP5/MOD3.3 calculations. The node number used to simulate the CMT was fixed through a node sensitivity study. The sensitivity studies on various parameters such as the water subcooling of CMT, steam pressure, and natural circulation flow show that the injection time and the effects of several parameters on the CMT behaviors were reasonably simulated even though the mesh-dependency should be properly treated for reactor applications.

From a viewpoint of PSS design, the effect of distributer (or sparger) geometry, the orifices' sizing of pressure balancing line (PBL) and injection line (IL), and the types of safety injection tank (SIT), which means accumulator and pressure balancing types, should be assessed. In addition, the effects on the accident scenario of the break size and the different shape of the CMT should be evaluated through the validation tests.

3. Conclusions

A test program to validate the performance of SMARS PSS was launched at an additional test facility to scale down the SMART PSS, which will be added to the existing SMART-ITL facility.

In this paper, several technical issues for a validation of the SMART passive safety system were summarized from phenomenological, analytical, and design viewpoints to help assess the performance of the SMART PSS. The considered phenomena include the condensation in the upper CMT region, the thermal stratification, and the injection flow. The MARS code should be carefully assessed for its simulation capability against the test data, and several design issues should be solved through this validation test program.

ACKNOWLEDGEMENT

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