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Experimental Facility Design for an Assessment of SMART Passive Safety System Concept

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1. Introduction

For the SMART design of which Standard Design Approval (SDA) was certified in 2012 led by the Korean Atomic Energy Research Institute (KAERI), a passive safety system has been developed and the conceptual design has been deducted in early 2013. 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) [1]. In the design process of AP600/AP1000 [2] (developed in US) and CR600/CR1000 (developed in China), various thermal hydraulic tests for validating a passive safety system were performed, but open literatures are limited. In VTT energy of Finland, the validation tests of passive safety system related to an AP600 had been performed using the PACTEL test facility [3]. They focused on the thermal stratification effect by the steam injection into the CMT tank. In the NPIC of China, CMT characteristic tests had been performed [4]. In the tests, the SBLOCA (Small Break of LOCA) condition was simulated and the transient characteristics of CMT were analyzed. They focused on the size of the break. In the JAEA of Japan, CMT characteristic tests were performed using the ROSA/LSTF facility [5]. They also focused on the thermal stratification in the CMT tank.

The objectives of this research are to construct the scaled-down test facility and 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. In this paper, the experimental facility design for achieving these objectives is proposed.

2. Methods and Results

For an assessment of the SMART passive safety system concept, downscale designed pressure vessel and CMT/SIT tanks, the devices for measuring the temperature, pressure and level, and various pipes. In this section, the experimental facility design will be described.

2.1 Scaling of pressure vessel and CMT/SIT tanks

This experimental facility was designed to perform the experiments at the same temperature and pressure condition with SMART (Max. Temp.: about 320 °C, Max. Pres.: 15 MPa). The scaling factor of the test facility to the SMART was determined with linear scaling law considering the volume ratio of the existing Pressure Vessel. The volume ratio of the PV was determined to 1/990 considering the size of the water heating vessel previously installed at KAERI. Calculating the inner diameter (ID) and height (H) of the downscaled PV with the value, the ID and H can be evaluated as 375 mm and 2650 mm, respectively. The volume ratios of CMT and SIT tanks were determined with a PV volume ratio. For simulating 3 Train of the passive safety injection system of SMART maintaining the aspect ratio of the original SMART CMT and SIT tanks, the volume ratios were identically determined to be 1/330. In the case of the CMT tank, downscaled ID and H can be evaluated to 430 mm and 870 mm, respectively.

$$\text{Aspect ratio} = \frac{\mathrm{H}}{\mathrm{ID}} = AR \qquad (1)$$

$$\frac{\pi D^2}{4} \times H = \frac{\pi \times ID^2}{4} \times ID \times AR \times R \quad \text{R:Scale ratio}$$

Also, in the case of the SIT tank, with same methodology used in the CMT tank scaling, down scaled ID and H can be calculated as 510 mm and 1670 mm, respectively.

Also, in this experiment, the SIT tank is used as a different test section of CMT for observing the geometrical effect of the phenomena occurring in CMT. Table.1 shows the dimensions and scaling ratios of PV and CMT/SIT tanks.

Table. 1 Dimensions and scaling ratios of PV and CMT/SIT tanks

Parameter	PV	CMT	SIT
ID (mm)	375	430	510
H (mm)	2650	870	1670
AR = H/ID	7.1	2.0	3.3
Volume ratio	1/990	1/330	1/330

2.2 Experimental Facility Design

Fig. 1 shows the schematic diagram of the experimental facility for an assessment of the SMART passive safety system concept. As shown in this figure, the experimental facility is composed of PV, CMT and SIT, valves, pipes, and measuring devices for pressure, temperature, water level, and flow rate. Additionally, for simulating a break system, the break simulation loop containing a heat exchanger and circulation pump was designed to attach to the PV. This loop is composed of a break hall, piping, measuring devices, and a heat exchanger that can cool down the steam from a break hall and then recirculate to a PV.

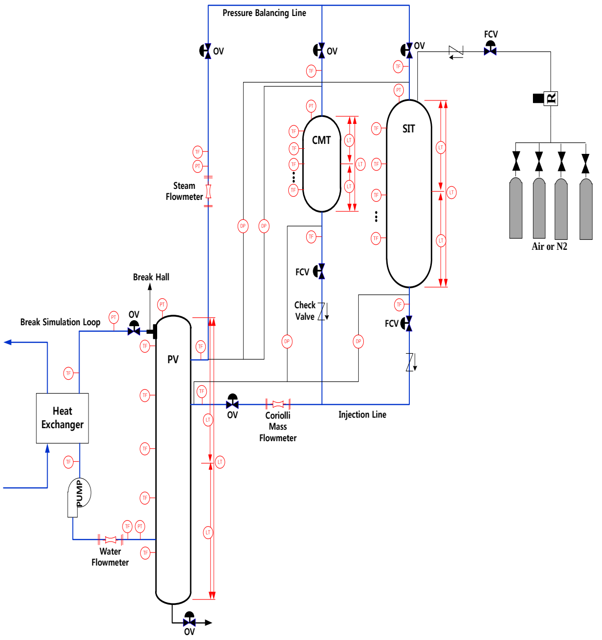

Fig. 1. Schematic diagram of the experimental facility for an assessment of the SMART passive safety system concept

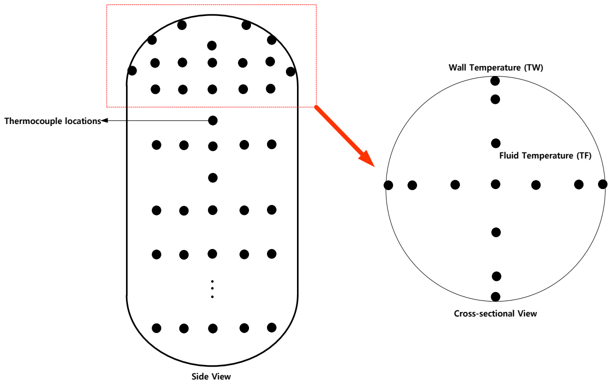

Fig. 2. Thermocouple locations in CMT and SIT

In a PV, the pressure, axial temperature distribution, water level and heating power should be measured. Also, in CMT and SIT, for analyzing the steam condensation phenomena, several thermocouples for measuring the radial and peripheral temperature distributions would be located inside CMT and SIT. Fig. 2 shows the locations of the thermocouples in the CMT and SIT. As shown in this figure, the axially located thermocouples are arranged more finely in the upper section than in the lower section, for concretely analyzing the thermal hydraulic phenomena occurring in the upper section of the tank. Also, the radial and peripheral temperatures were designed to observe and analyze three-dimensional thermal hydraulics. Also, in this experimental facility, the SIT tank is used as a different test section of CMT for observing the geometrical effect of the phenomena occurring in CMT. That is, using two tanks, the experiments for the CMT geometrical effects and SIT can be performed in a single test loop. In this experimental loop, the automatic control valves, pressure transmitters, thermocouples and flow meters (for steam/liquid water) are attached and using these measuring devices, the thermal hydraulic conditions of the loop can be checked and analyzed.

3. Conclusions

In this paper, the experimental facility design was introduced. Through the experiments using this facility, we will assess not only the general thermal-hydraulic performance of passive safety injection, but also the performance of a sparger nozzle geometry, break size, and tank geometry. Thus, the quantitative data would be obtained and these can be applied to real system design and safety analysis code. Also, through analyzing the experimental data, the existing model for direct contact condensation occurring in CMT and SIT will be assessed.

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REFERENCES

[1] Y. M. Bae, Report of Passive Safety System, SER-410-FS403-SD, 2012.
[2] B. Sutharshan, M. Mutyala, R. P. Vijuk, A. Mishra, The AP1000TM Reactor: Passive Safety and Modular Design, Energy Procedia, Vol. 7, p. 293, 2011.
[3] J. Tuunanen, R. Munther, J. Vihavainen, PACTEL experiments for investigation of passive safety injection systems of Advanced Light Water Reactors, Proceedings of 4th International Conference on Nuclear Engineering (ICONE-4), New Orleans, Louisiana, USA, 1996.
[4] Natural circulation data and methods for advanced water cooled nuclear power plant designs, IAEA-TECDOC-1281.
[5] Y. Sibamoto, T. Yonomoto, Summary on Natural Circulation Phenomena Observed in ROSA/AP600 Tests, IAEA's Third Research Coordination Meeting, CEA, Cadarache, France, Sep.11-15, 2006.