Thermal Stratification Phenomena in a Simulated IRWST during a TLOFW Accident

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1. Introduction

KAERI has conducted steam condensation tests to study the thermal mixing behavior in an IRWST of the SKN 3,4 NPPs [1]. This paper presents the test results on thermal stratification phenomena in an annular type vessel.

2. Test Description

The steam condensation tests were conducted at the COMA (Condensation Induced Mixing in Annulus) facility [2] at KAERI (Fig. 1). The annular vessel was a scaled-down model of the IRWST of the SKN 3,4 NPPs. To preserve the important phenomena in the thermal mixing process, a linear scaling method was adopted for the design of the steam supply system and annular vessel (1/10.7 scale). The inside/outside diameters and the height of the annular vessel were 3.0/4.06 m, and 0.5 m, respectively.

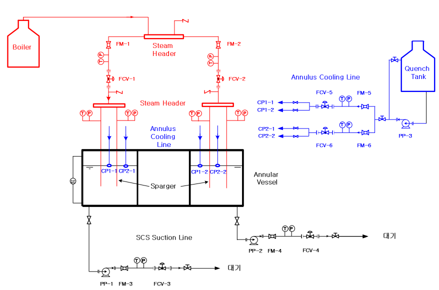

Fig. 1. Schematic Diagram of the COMA Facility

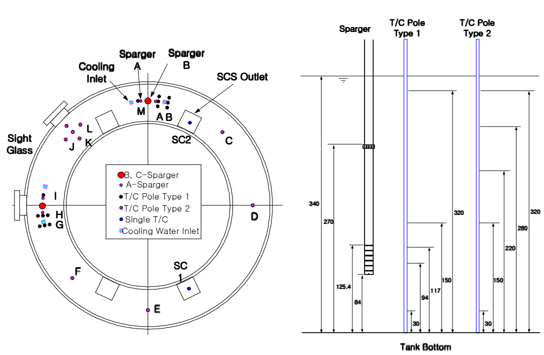

Fig. 2. Locations of the Thermocouple (T/C) Poles and T/Cs in the T/C Poles

Fifteen tests were performed to investigate the thermal mixing phenomena in an IRWST during TLOFW or IOPOSRV accident. Operation of the SCS (Shutdown Cooling System) was also simulated in the specific tests. A total of 115 thermocouples (T/C) were installed at 25 T/C poles and each T/C pole contained 5 T/Cs at five different heights (Fig. 2).

3. Analysis of the Test Results

Test T01 simulated TFLOW in the SKN 3,4 NPPs. Two spargers were installed at 0^o and 270^o locations in the annulus as shown in Fig. 2 and the SCS operation was not simulated.

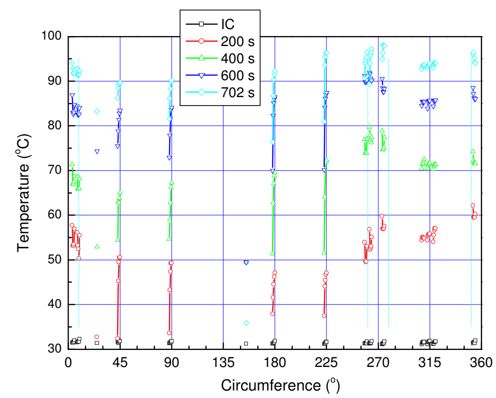

Fig. 3. Temperature Distribution during Test T01

Figure 3 shows the water temperature distribution at specific times. As shown in the figure, the initial water temperatures were almost the same, but, as the steam was continuously injected into the vessel, the thermal stratification phenomena occurred. These phenomena prevailed at the distant area from the spargers (between 45 and 225 degree of the vessel) and the temperature difference between TC1 and TC5 reached up to 21 ^{o}C at the 225 degree. Large vertical temperature differences were maintained until the end of the test.

Though the steam was injected near the bottom of the tank, the vertical water temperatures difference near the spargers (A, H, I, and M T/C poles) were small in comparison to the other locations. And the vertical water temperatures differences at the area between the spargers (J, K, and L T/C poles) were also very small. Therefore, it is considered that the thermal mixing phenomena violently occurred at these areas.

Figure 4 shows the temperatures at 600 s into the Test T01. The thermal stratification phenomena at the distant locations from the spargers are clearly shown at the lower part of the annulus tank (below 150 mm) and the temperature difference between T/C1 and T/C 2 reached 14 ^{o}C. But the temperature differences for the area near the spargers were less than 5 ^{o}C.

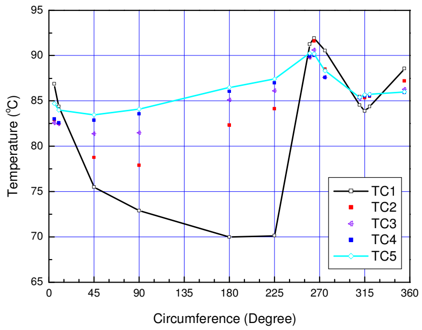

Fig. 4. Water Temperatures at 600 s in Test T01

Degree of thermal stratification phenomena was clearly reduced when the SCS was operated. Test conditions of the Test T02 are the same as those of the Test T01 except the SCS operation in the Test T02. Figure 5 shows the temperatures at 600 s into the Test T02. The vertical temperature differences were much smaller than those of the Test T01 and the maximum water temperature near the sparger (G T/C pole) at 600 s was also 8 ^oC lower than that of the Test T01. Thus the SCS seems to be a good method to lower the maximum temperature as well as the thermal stratification phenomena.

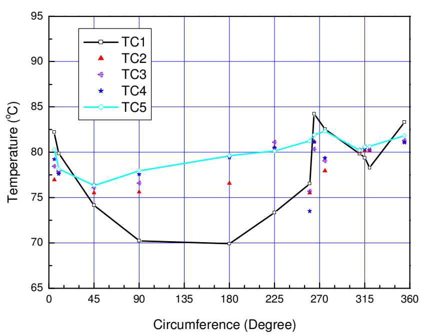

Fig. 5. Water Temperatures at 600 s in Test T02

For the mixing test program, three kinds of spargers were developed to see the effect of the scaling method for the number of spargers. Test T01 and T02 used two spargers and each sparger represented 6 unit cell spargers. But in the Test T09 and Test T10, four spargers were installed and each sparger represented 3 unit cell spargers. The general trend of water temperature distribution during Test T09 was similar to that of Test T01. However, the degree of the thermal stratification phenomena occurred at the distant locations from the spargers (45 - 225 degrees) was reduced.

Figure 6 shows the temperatures at 600 s in the Test T09. As seen in the figure, the temperature differences between TC1 and TC5 were smaller than those of the Test T01, and the temperatures at TC5 were also lower at the distant location from the spargers. But the water temperature near the steam spargers and at the area between the spargers (J, K, and L T/C poles) were much higher that those of the Test T01.

The steam mass flux and the size of the steam nozzle at the Test T01 were 32 % and 24 % bigger than those at the Test T09. Since the mixing phenomena depends on the Richardson number [3], lower steam mass flux, and a small nozzle diameter in the Test T09 resulted in the higher vertical temperature difference near the spargers and lower temperatures at the distant locations from the spargers. Thus, the increasing number of spargers in the simulation will increase the local temperature near the spargers and the unstable condensation phenomena at a higher water temperature may easily occur. A more experimental investigation of thermal stratification phenomena due to multiple spargers is needed.

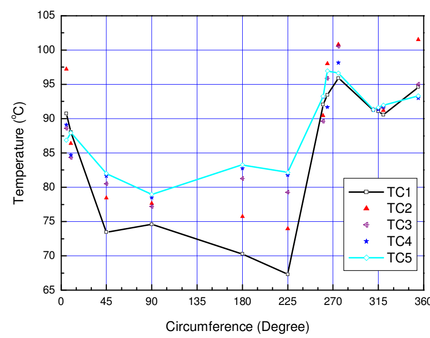

Fig. 6. Water Temperatures at 600 s in Test T09

4. Conclusions

A series of steam condensation tests were performed to investigate the thermal mixing phenomena in an annular type vessel. The test results show that a large temperature difference may exist at the large part of the annular vessel and the operation of the SCS is important to decrease the thermal stratification phenomena. In addition, proper scaling of a steam mass flux and the diameter of the sparger nozzle was important to simulate the thermal mixing in the annular type vessel.

REFERENCES

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[3] R. E. Gamble et al., “Pressure Suppression Pool Mixing in Passive Advanced BWR Plants,” *Nuclear Eng. & Design*, Vol. 204, pp. 321-335, 2001