Experimental Investigation of Thermal Mixing Phenomena in an IRWST during a TLOFW Accident

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1. Introduction

KAERI has conducted a series of experiments to investigate the steam condensation and mixing phenomena in an APR1400 reactor [1]. Recently, thermal mixing tests were performed to study the characteristics of the mixing phenomena in an IRWST of the SKN 3,4 NPPs. This paper presents the thermal mixing test results in an annular type vessel.

2. Test Description

The thermal mixing tests were conducted in the COMA (Condensation Induced Mixing in Annulus) facility at KAERI (Fig. 1) [2]. The test facility consisted of a steam boiler, an annular vessel, spargers, and piping and instruments. 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, linear scaling method was adopted for the design of the annular vessel (1/10.7 scale) and the inside/outside diameters and the height of the annular vessel were 3.0/4.06 m, and 0.5 m, respectively.

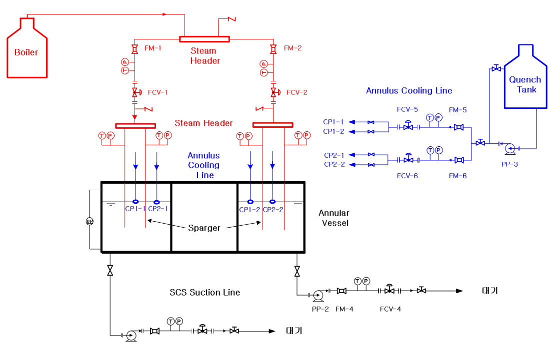

Fig. 1. Schematic Diagram of the COMA Facility

Fifteen tests were performed to investigate the thermal mixing phenomena in an IRWST during accidents. Three different spargers were used to simulate the prototype steam spargers in the SKN 3,4 NPPs. Three prototype spargers was simulated by a A-type sparger and six prototype spargers was simulated by a B-type sparger. The scaling law for the design of these spargers was developed by KOPEC [3].

C-type sparger simulated a single prototype sparger, and was designed to preserve transient distance from the jet to buoyant plume. Two types of accidents, TLOFW and IOPOSRV, were simulated using three different spargers. 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 (Fig. 2) and each T/C pole contained 5 T/Cs at five different heights. In addition, two T/Cs were installed at the SCS sumps (SC1 and SC2 in Fig. 2). Two sight glasses were installed to observe the steam condensation and thermal mixing phenomena during the thermal mixing tests (Fig. 2).

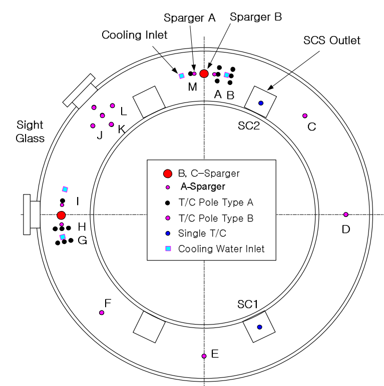

Fig. 2. Locations of the Thermocouple (T/C) Poles

3. Analysis of the Test Results

Test T09 simulated TFLOW in the SKN 3,4 NPPs. Four A-type spargers were installed at ± 4.5° and 270 ± 4.5° locations in the annulus as shown in Fig. 2 and the SCS operation was not simulated so that the fundamental thermal mixing phenomena due to the steam injection into an IRWST can be reproduced.

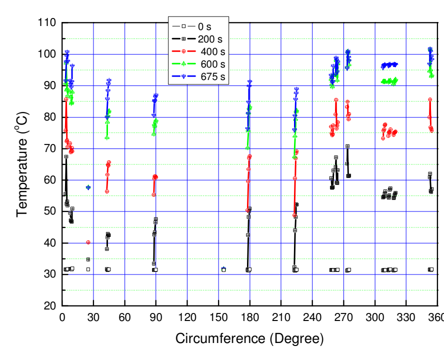

Fig. 3. Temperature Distribution during T09 Test

Figure 3 shows the water temperature distribution at specific times. As shown in the figure, the initial temperatures were almost the same, but, as the steam was injected into the vessel, the temperature distributions were varied. The water temperatures near the spargers were much higher than the average water temperature and the vertical water temperatures between spargers (300°–330°) were uniformly distributed. However, the vertical water temperatures at T/C poles between 30°-240° were not uniform and larger temperature differences existed between the top and the bottom of the vessel. The same pattern of the spatial temperature distribution were maintained until the end of the test

There was an axis of the symmetry in the vessel (165° and 315 °). Near the 315° region, the symmetric temperature distributions ware observed. However, the spatial water temperature distributions were not symmetric for the axis of 165°. This result indicates that the thermal mixing phenomena did not uniformly occur and the calculation of temperature distribution using the symmetry condition may produce the wrong temperature distribution.

The USNRC requires that the local water temperature should not exceed 93.3 °C [4]. However, at 600 s into the test, the local water temperature near the steam spargers exceeded this temperature limit, while the water temperature far from the sparger were maintained at less than 83 °C. Therefore, the water in the vessel was cool enough to condense the steam safely if the thermal mixing occurred uniformly or effectively.

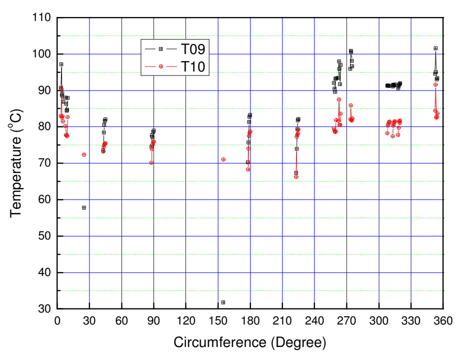

Fig. 4. Effect of SCS Operation on Water Temperatures at 600 s in Two Different Tests

T10 test simulated the same accident as the test T09, but a SCS operation was simulated. The test result shows that the operation of the SCS promoted the thermal mixing and the overall water temperatures with the SCS operation were much lower than those of the test case without the SCS operation as shown in Fig. 4. At 600 s into the test, the water temperatures in the T10 test were at least 10 °C lower than those in the T09 test. In addition, the highest temperatures and the vertical water temperature differences at the given T/C poles were smaller than those in the test without the SCS operation.

Figure 5 compares the water temperature at 800 s into the test for two different test cases. The test conditions were identical, but T02 test used two B-type spargers and 4 A-type spargers were used in the T10 test. The figure shows that the water temperatures in the T10 tests were much higher in the 265°-305° region, while, for other locations, the water temperatures in the T10 tests were little higher than those in the T02 test. More studies are needed to investigate the local temperature distribution near the spargers in the IRWST.

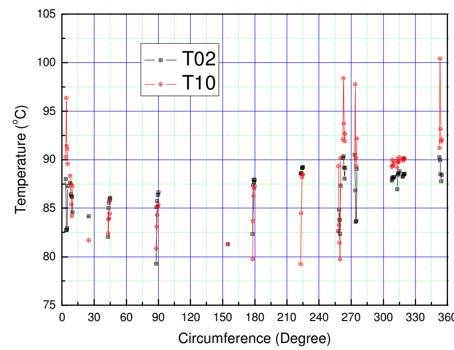

Fig. 5. Effect of Sparger Distribution on the Thermal Mixing Phenomena

4. Conclusions

A series of thermal mixing tests were performed to investigate the thermal mixing phenomena in an annular type vessel. The test results show that thermal mixing phenomena do not occur symmetrically and the operation of the SCS is important to slow down the increase of the water temperature during an accident.

ACKNOWLEDGMENTS

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REFERENCES

[1] C. H. Song, W. P. Baek, and J. K. Park, "Thermal-Hydraulic Tests and Analyses for the APR1400's Development and Licensing," Nuclear Engineering and Technology, Vol. 39, No. 4, August 2007.
[2] C. K. Park, et al., Analysis of Thermal Mixing Phenomena in an Annular Type Vessel (1), KAERI/TR-3807/2009, August 2009.
[3] H. J. Ko, et al., Optimized 3-D Evaluation of IRWST Thermal Hydraulics, R-205-A-045, October 2008.
[4] USNRC, Suppression Pool Temperature Limits for BWR Containment, NUREG-0783, 1981.