Preliminary Analysis of Mixing Tests in a Cylindrical Tank

C. K. Park[a*], H. G. Jun[a], Y. J. Youn[a], C. H. Song[a], K. K. Lee[b], and H. J. Ko[b]
[a]*Korea Atomic Energy Research Institute (KAERI), Yuseong P.O. Box 105, Daejeon 305-600, Korea*
[b]*Korea Power Engineering Co., Inc, 360-9 Mabuk-dong, Giheung-gu, Yongin-si, Gyeonggi-do, 446-713, Korea*
[*]*ckpark1@kaeri.re.kr*

1. Introduction

KAERI is conducting a series of experiments to investigate the steam mixing phenomena in an In-Containment Refueling Water Storage Tank in the APR1400 [1]. Several thermal mixing tests were performed to study the characteristics of the mixing phenomena due to a steam injection orientation. Major test parameters were the steam mass flux and the water temperature in the tank, and 166 thermocouples were installed to investigate the thermal mixing phenomena.

This paper presents a preliminary analysis of the pool water temperature distribution due to the injection of steam into the water pool in a cylindrical tank.

2. Test Description

The mixing tests were conducted using a part of the B&C test facility [2] at KAERI. The test facility consisted of a steam boiler, a steam generator, two flow control valves, two vortex flow meters, spargers, a quench tank, and piping and instruments. The boiler can supply 1.0 MPa, saturated steam at a maximum rate of 0.4 kg/s. And the diameter and the height of the quench tank were 3 m and 4 m, respectively.

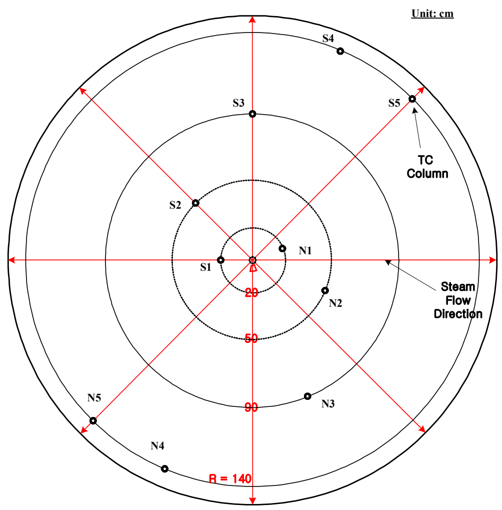

Fig. 1. Distribution of the T/C Poles in the Quench Tank

Three different spargers were used to investigate the thermal mixing phenomena. Type A sparger had 16 side discharge holes (5 mm diameter, 2 rows and 8 holes per row). Type B sparger simulated a LRR (Load reduction Ring) only, therefore the steam was injected vertically-downwards. Type C sparger had 16 side holes, a bottom hole, and LRR type discharge holes.

The spargers were installed in the center of the quench tank. Two flow control valves were used to control the steam flow rate through a sparger during the tests. Two vortex flow meters were installed to measure the volumetric steam flow rates, and several pressure and temperatures sensors were installed in the main piping system.

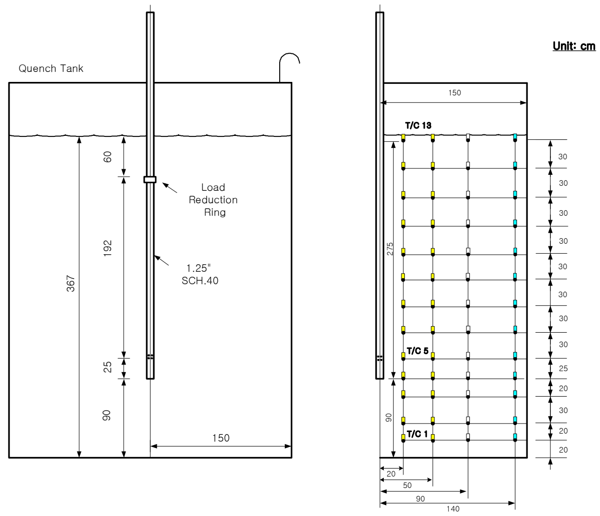

Fig. 2. Location of the Thermocouples at the T/C Poles

In the quench tank, 166 thermocouples (T/C) were installed to measure the water temperature during a test. Ten T/C poles were installed (Fig. 1) and each T/C pole contained 13 thermocouples to measure the water temperature distribution in the quench tank (Fig. 2).

The major test parameters for the thermal mixing tests were the steam mass flux and the water temperatures in the quench tank. The steam mass flux was varied from 300 kg/m^2-s to 900 kg/m^2-s, and the pool temperature was varied from 40 ^oC to 90 ^oC.

3. Preliminary Analysis of the Test Results

Test results show that the steam was condensed very shortly after its injection into the tank and a hot liquid jet moved towards the tank wall. When a jet hits a vertical wall, it will usually expand into a radial jet moving out along the wall in all directions. However, the test results show that much of the hot jet moved into a lower part of the quench tank. Figure 3 compares the local water temperature at the S1 T/C pole to the average pool temperature during a test. The figure shows that the temperature below the level of the side discharge hole was higher than that at a higher level. The same phenomena was observed at the other T/C poles.

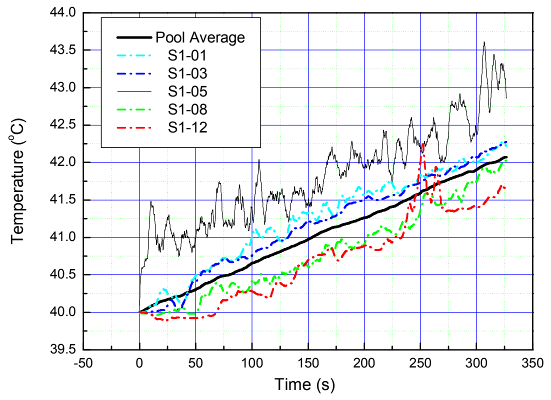

Fig. 3. Vertical Pool Temperature Distribution (Type C Sparger)

A minor part of the wall impingement moved upwards along the wall. The water, then either moved along the wall up to the surface of the water or crossed the upper part of the quench tank to the center of the quench tank.

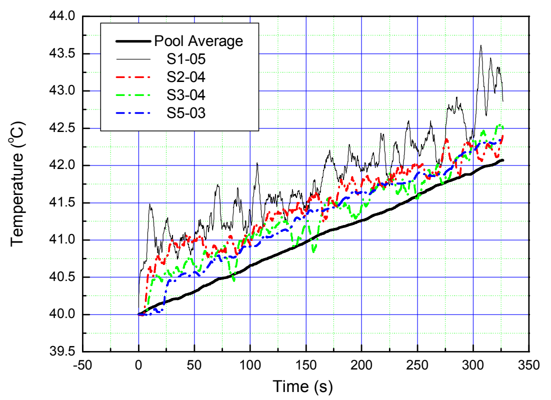

Fig. 4. The Highest Jet Temperature Measured at the T/C Poles for the Type C Sparger

It seems that the downward flow from the LRR disturbed the horizontal jet flow from the side discharge hole. The vertically downward jets from the LRR changed the direction of the jet from the side hole and the jet took a curved downward trajectory. Unlike the test results with a side hole only sparger (type A), the test results show that the highest temperatures at selected TC poles were measured at lower elevations than those with the type A sparger (Fig. 4)

The existence of a LRR and a bottom hole seems important to lower the temperature around the side discharge holes. Figure 5 compares the temperature difference between the thermocouple at S1-05 and the average pool temperature for two different spargers (type A and C). The heat input for the integral type sparger (type C) was 2 times larger than that for the type A sparger. However the temperature difference for the integral type sparger was about a half of that for the type A sparger. The lower temperature near the steam discharge hole decreases the possibility of the occurrence of an unstable condensation, therefore the limit of the operational temperature for a quench tank [3] can be increased.

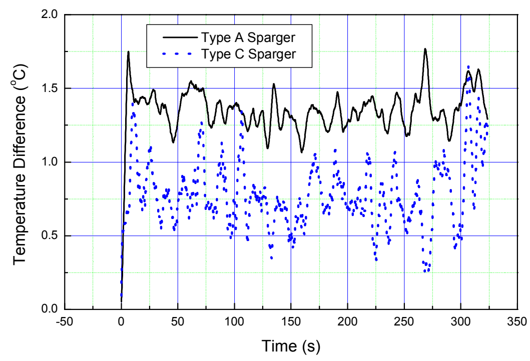

Fig. 5. Local to Bulk Temperature Difference at T/C S1-05

4. Conclusions

A series of thermal mixing tests were performed to investigate the thermal mixing phenomena in a cylindrical tank. It is concluded that the test results provided detailed information of temperature distribution in a cylindrical tank and that the test data can be used to develop and validate a thermal mixing model. The test results also show that a LRR and a bottom hole are important to increase the temperature limit for an unstable condensation in a tank.

ACKNOWLEDGMENTS

This paper has been prepared based on R&D work sponsored by KOPEC.

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, C. H. Song, M. K. Chung, et al., Construction of Blowdown and Condensation Loop, KAERI/TR-941/98, 1998.
[3] USNRC, Suppression Pool Temperature Limits for BWR Containment, NUREG-0783, 1981.