Thermal Mixing In-plant Test in Shinkori Unit 3 IRWST

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1. Introduction

IRWST (Incontainment Refueling Water Storage Tank), which was firstly incorporated in SKN3&4 (Shinkori Nuclear Power Plant Units 3&4) among PWRs (Pressurized Water Reactors), is an evolutionary engineered safety feature to enhance the safety of reactor in such way that it eliminates the switch-over process from a RWST (Refueling Water Storage Tank) to a containment sump in the long term cooling operation of ECCS (Emergency Core Cooling System). In addition to the above function it increases the quenching efficiency of steam and alleviates probable pressure surge induced by the sudden discharge of the high pressure steam during plant transient such as IOPOSRV (Inadvertent Opening of Pilot Operated Safety Relief Valve) accident or TLOFW (Total Loss of Feedwater) accident.

The design of the IRWST seems originated from a suppression pool in BWRs (Boiling Water Reactors). However, the geometry and operational conditions of IRWST are far different from those of the suppression pool. Thus, in spite that there have been regulatory requirements on the design and operation of the suppression pool such as the local pool temperature limit concerning the pool mixing, the hydrodynamic load against the integrity of its structures, and so on, the direct application of the researches on the resolution of such regulatory requirements has not been fully accepted. Actually, domestic regulatory authority has required an in-plant test to check the appropriate thermal mixing and the validation of a mixing analysis tool since the design step of APR1400 (Advanced Power Reactor 1400MWe) which is a standard design of SKN3&4.

This paper provides a procedure and the results of the in-plant test on thermal mixing in IRWST of SKN3 which was carried out on November 2012. The objectives of the in-plant test are to give the insights on the short term mixing phenomena and to generate validation data for the thermal mixing analysis tool. And eventually, this in-plant test is expected to resolve the safety issues related with the adoption of IRWST

2. In-plant Test Conditions and Procedures

Initial conditions for the in-plant test were provided by KEPCO E&C[1]. The test was performed during a hot functional test period and the initial condition was hot standby operation mode in which the pressurizer pressure is 2,250psia and the cold leg temperature is 555˚F with secondary side isolated. For the stable initial conditions safety injection pumps, safety injection tanks, reactor coolant pumps, pressurizer heaters were all isolated. The in-plant test was initiated by opening a PORSV. And the steam from the pressurizer was discharged through the PORSV during 5 min. And the PORSV was closed.

Total 25 thermocouples were used to measure the local temperature, which were installed in 5 sensor poles. The sensor pole location is shown in Fig. 1. Fig. 2 shows the elevation of the thermocouple in each sensor pole.

The uncertainty of thermocouple was 1.49K, which consolidated all of the uncertainty elements such as a thermocouple calibration uncertainty, a calibrator uncertainty, a reference temperature error, and a data acquisition system error.

3. Review of CFD Analysis Results

Computational fluid dynamics (CFD) analysis was

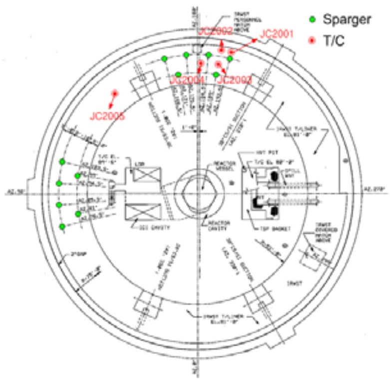

Fig. 1. Measurement locations

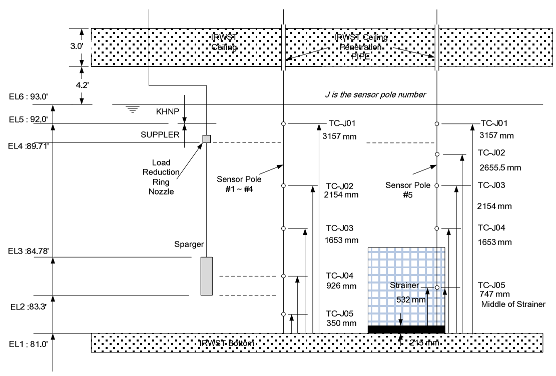

Fig. 2. Thermocouple installation in sensor pole

carried out by KEPCO E&C and FNC[2]. In the CFD analysis the condensation region model was used which was developed in KEPCO E&C in order to treat the steam in the domain of single phase water[3]. In this analysis a water clearing and an air clearing phase were not simulated, and only the steam discharge phase was assumed. Thus this prediction is thought to be less mixed, because the water clearing and air clearing are expected to expel the water near the spargers far away. The input of discharged steam mass and energy was provided in reference [1]. Initial condition of the water was 31℃ at atmospheric pressure. Pool surface was modeled as a free slip wall. The used CFD tool was ANSYS CFX11. The predicted temperature contour at 300 sec is shown in Fig. 3, and the local temperature trends in Fig. 4.

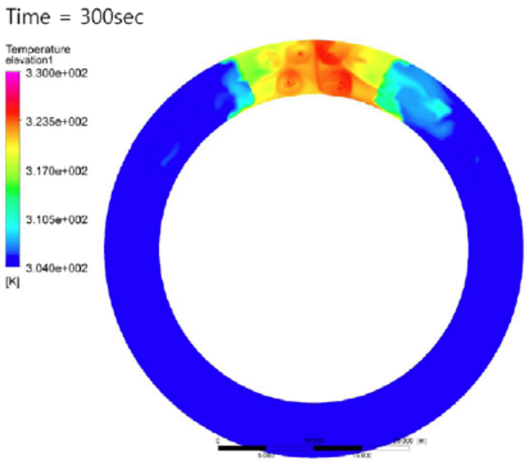

Fig. 3. CFD Prediction on the Water Temperature on the Plan of Elevation 0.35m at 300sec

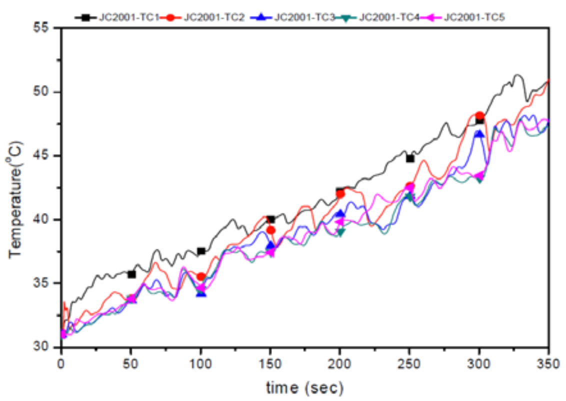

Fig. 4. CFD Prediction on Temperature Trend at the Location of JC2001

Judging from the calculation results shown in Figs. 3 and 4 the water forms a hot water cluster, and the hot water moves in the form of cluster. So the temperature trend shows the approximate cyclic behaviors. In order to compare the in-plant test result with this CFD prediction, a volume and time average concept seems a good approach.

4. Test Results and Discussions

By opening one POSRV the pressurizer pressure decreased as shown in Fig. 5. And the comparison of test results with the CFD prediction is provided in Fig. 6 with the treatment of volume and time average. Initial trend shows excellent agreement, but the later part shows considerable difference, which mean that the hot water in the test goes away more rapidly than in CFD, and resultantly that the mixing in actual plant is more vital than in analysis. Such lager gap needs more intensive discussion in further study.

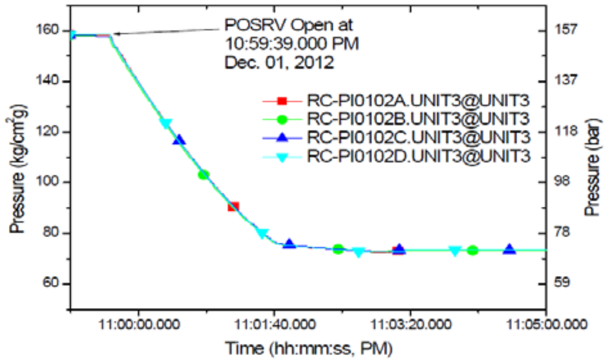

Fig. 5. Pressurizer Pressure Trend in In-plant Test

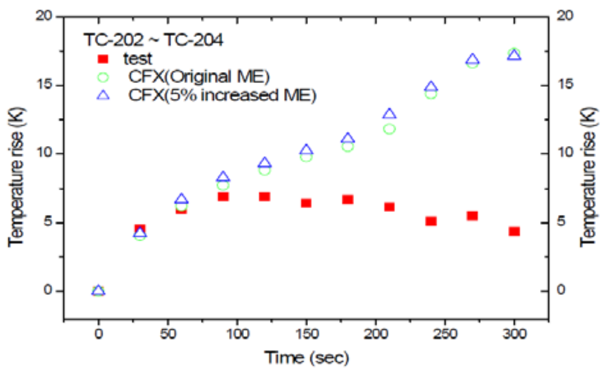

Fig. 6. Comparison of Test Results with CFD Prediction by Volume and Time Average (JC2002)
(Volume average means the average of 3 thermocouples in the middle of the sensor pole, and time average is for30 sec)

5. Conclusions

In-plant test in SKN3 on the thermal mixing was successfully conducted and it shows the more activated mixing compared with CFD analysis.

REFERENCES

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