An Experimental Study on the Temperature Distribution and Steam Condensation in IRWST

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1. Introduction

The In-Containment Refueling Water Storage Tank (IRWST) has a function to condense the high enthalpy fluid discharged from the Reactor Cooling System (RCS). The condensation of discharge fluid makes the tank temperature high and oscillation. Also if cooling water temperature in the tank approaches 93.3℃, the steam bubble may escape form the tank. As a result, tank structure would receive undue load due to the oscillation by uncondensed fluid.

Therefore, an experimental work (1:400 volume scale) on the temperature distribution and steam condensation characteristic in IRWST has performed.

2. Design of Experimental System

Experimental system consists of an annular water tank, a steam generator, two spargers, and some instruments (such as thermocouple, a flow meter, a data acquisition system, etc.). The water tank is manufactured by 1:400 volume scale (R_{in}=80.8cm, R_{out}=109.5cm) in comparison with the IRWST of APR1400. And the submerged is determined 1:1 (3.66m) by the Grashof number which is the most important dimensionless parameter that governs the thermal stratification and natural circulation.

Two spargers are installed on the tank at intervals of 90°. The sparger is arranged with 3x4 upper holes (R=0.6cm) and one lower hole (R=4.33cm). Also, steam flow rate is decided on 200kg/hr, which is concerned with decay power when 10^5sec after TLOFW.

The temperature was measured by K-type thermocouples, and the signal is acquired by 5 SCXI-1303 modules (total 100 signals.).

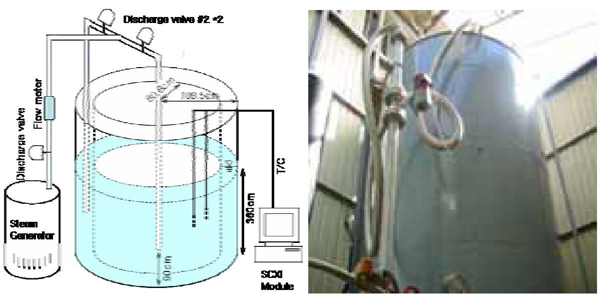

Figure 1. Schematic diagram and picture of the experimental facility

3. Experimental Works

The experiments were performed as following conditions.

① The steam condition : 120℃, sat. steam
② Initial Pool Temperature : 15℃
③ Flow rate : 200kg/hr
④ The temperature were measured real time.

The focus of the experiment aimed as following.

① Global tank distribution – vertical, azimuthal
② Condensing shape, steam jet length

As shown fig. 2, thermocouples are basically set on 10 vertical fixed points per one horizontal section. Also, 5 additional thermocouple tips are set on a buoy to measure the temperature of the water surface, and the interval between the tips is 0.5mm.

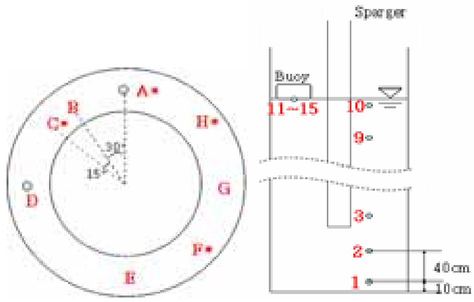

Figure 2. Positions of thermocouples

4. Results

The temperature distributions are horizontally stratified. Particularly, the condensed fluid around sparger hole goes up straight like a thermal plume, therefore, the temperature of upper plan is higher than other points. Otherwise, the temperature gradient of lower plan is slower than other plans and finally the temperature of lower part is stagnated.

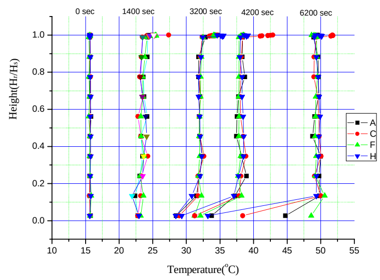

Figure 3. Vertical temperature distribution (where H_r is height of thermocouple, H_s is height of water level)

And then the horizontal temperature distribution of upper plan is equilibrium, but lower plan is non-equilibrium, as shown fig 4, 5. It shows that natural circulation effect on the lower part is slighter than other places, and local forced circulation as the steam condensation dominates in where.

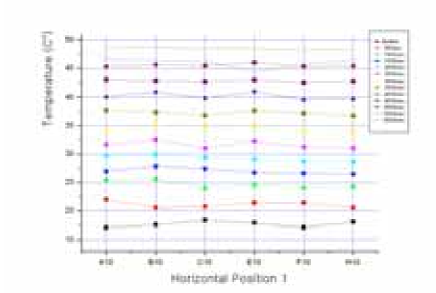

Figure 4. Horizontal temperature distribution (Upper plan)

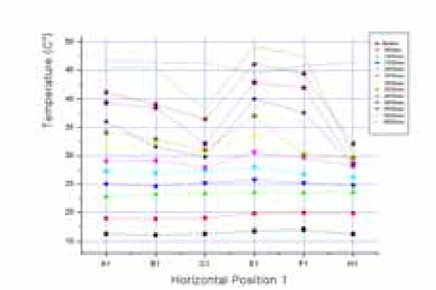

Figure 5. Horizontal temperature distribution (Lower plan)

Lastly, the most of discharged steam is condensed around sparger hole, and some steam goes up to the upper part with non-condensable gas. The steam jet length is short in compare with the tank scale.

Figure 6. Steam condensation around sparger hole.

5. Conclusion

This experimental results show that the temperature distributions are horizontally stratified. Particularly, the hot liquid produced by the condensation around the sparger holes goes up straight like a thermal plume. And then, the momentum of the discharged fluid is not so strong to interrupt this horizontal thermal stratification significantly. As a result, the temperature of the free surface on C section where is located between two spargers has highest temperature and this temperature may be set as the limit temperature below which the tank temperature should be kept since the temperature is the highest in the tank except around the sparger hole.

Also, the layout and shape of sparger is not so important as long as the location of the sparger hole is sufficiently close to the bottom of the tank.

Finally, for the effective tank cooling it is recommended that the locations of the discharge and intake lines of the cooling system be cautiously selected considering the temperature distribution, the water level change, and the cooling effectiveness.

REFERENCES

[1] Kyungho Nam, Hejeon Ko, Jaeyoung Lim, "IRWST System Design in KNGR", Power Engineering, Vol. 7, No. 2, KOPEC, July 1996

[2] KOPEC, "IRWST T/H Load Analysis" KOPEC, Korea, Dec. 1996

[3] Korea Atomic Energy Research Institute, "Joint Passive Safety Evaluation Program for System 80+", Aug. 1994

[4] KEPCO, "Elementary Requirement in KNGR", Dec. 1994

[5] Korean Next Generation Reactor, Center for Advanced Reactor Research, "Design Concept-The Total Plant Design(IV)", Dec. 1994

[6] Combustion Engineering "System 80+ Standard Safety Analysis Report - Design Certification", Amendment W, June 1994

[7] Heyjung Kim, "Safety Requirement in KNGR", KINS, Dec. 1996

[8] B.T. Lubin, "Evaluation of the System 80+ Steam Relief System and IRWST Design", Oct. 1991

[9] Snagdeuk Park, "Design Requirements and Features of Korean Next Generation Reactor, Center for Advanced Reactor Research of KEPRI", Korea, Dec. 1996