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An Experimental Study on the Temperature Distribution in IRWST

Ki-Hoon Yoon, Sang-Nyung Kim, Hyun-Chul Joeng
Department of Nuclear Engineering Kyunghee University
kihoon98@gmail.com

1. Introduction

The IRWST (The In-Containment Refueling Water Storage Tank), which is an advanced design concept adopted for APR-1400, has a function to condense the high enthalpy fluid discharged from the Reactor Cooling System (RCS) during a reactor transient. Steam condensation increases the temperature of the coolant in the IRWST, and if the temperature of the water storage tank exceeds 93.3℃, bubble escape temperature, serious oscillation will happen. This phenomenon would apply mechanical load to the structure of IRWST.

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

2. Experimental Facility

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 holes are arranged by 3x4 upper holes (R=0.6cm) and one lower hole (R=4.33cm). Also, steam flow rate was decided on 140kg/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.

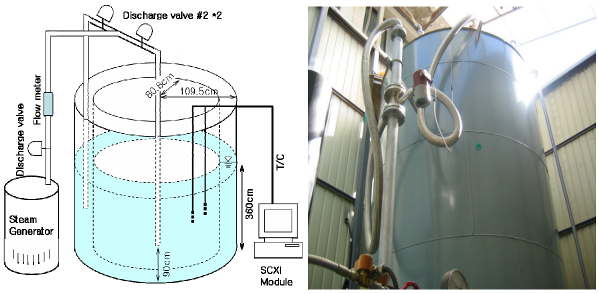

Figure 1. Schematic diagram and picture of the experimental facility

3. Experimental Works

As a result of the earlier experimental works, which was performed for the general temperature distribution of the water storage tank, the temperature of water surface was highest why the condensed water goes up almost straight around the sparger, and the temperature of the lower part of the water storage tank stagnated.

On this experimental works, more thermocouples were installed on the lower part of water storage tank to find out why the temperature of the lower part of one stagnates. Also the temperature distribution according to initial coolant capacity of the tank was measured and the condensation shape of the steam on bubble escape temperature was observed.

Table 1 and figure 2 show the experimental matrix and the location where thermocouples are installed.

	Part 1	Part 2
Discharge time	30,000sec	20,000sec
Initial water level	3.6m	2.0m
T/C Array	- 6×13 (submerged) - 2×5 (water surface)	
Interest Region	Lower part of the tank	

Table 1. Experimental Matrix

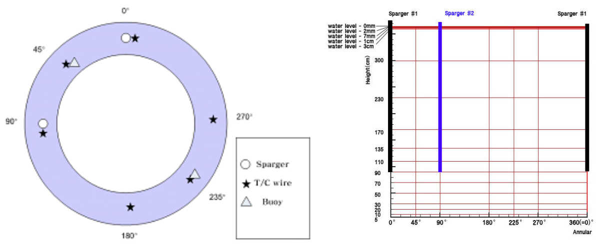

Figure 2. Location of Thermocouples

4. Results

As the result of the experimental works(both Part 1 and Part 2), the water in the water storage tank up to 50cm from the ground of tank did not contribute to the cooling of the condensed water when the temperature exceeded the bubble escape temperature(93.3℃). Like earlier experimental works, the water surface has highest temperature and temperature distribution of the middle and upper part of the tank is uniform

In the lower part of tank, temperature of near 225°, where the two spargers were the farthest form each other, was the highest

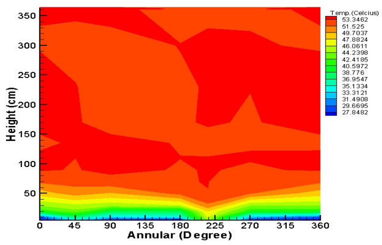

Figure 3. Temperature distribution
(Initial water level : 3.6m, Steam discharged : 10000sec)

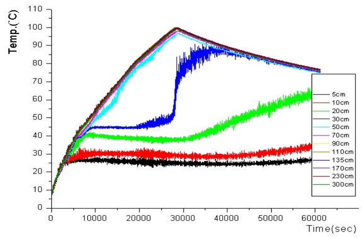

Figure 4. Temperature transient (Initial water level : 3.6m, place : 0°)

Also as shown figure 4, even though the temperature in the middle and upper part of the tank approaches the saturated temperature, the temperature in the lower part of the tank stagnated at a certain point, and then did not increase any further. But after steam discharge stopped(after 30,000sec), there was heat exchange between the lower part and the other part, thereby raising the temperature of the lower part of the tank. And in the lower part of the tank where the temperature stagnates, the temperature oscillated severely, the temperature change exceeded 15℃ for 30 seconds.

When the initial water level was 2.0m, the overall temperature distribution was similar to that when it was 3.6m. And when the temperature of the water storage tank exceeded the bubble escape temperature, the discharge steam was discharged without getting condensed far to the Sparger Hole (7~10cm), and the one becomes buoyant and rose to the upper part of the tank with severe oscillation and a noise. Also there was chugging when steam discharges on low temperature of the coolant.

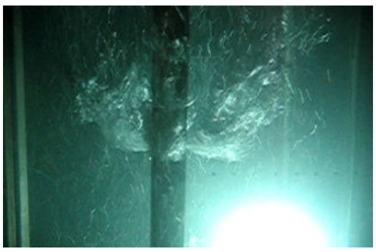

Figure 5. Steam condensation (Temp. 95℃)

5. Conclusion

This experimental results show that the temperature distributions are horizontally stratified. Especially the temperature of the water surface is highest because the hot liquid produced by the condensation around the sparger holes goes up straight. But the temperature of the lower part of tank stagnates when the temperature of the coolant reaches certain temperature. This phenomenon is happened by change of natural convection, which is generated by a rise of the water temperature.

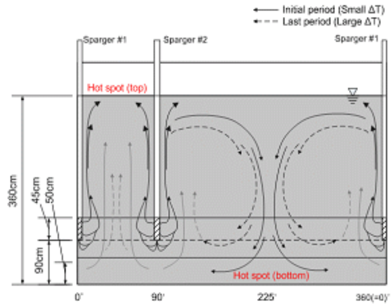

Figure 6. Assumption of natural convection pattern in IRWST

Also, where temperature was stagnant in lower part of the tank, temperature variations over time were more severe than in the other part of the tank. This indicates that the thermal boundary layer oscillated severely in the lower part of the tank.

And, when the steam discharge was stopped, a heat exchange between the lower part and middle part of the tank was generated. Therefore, the momentum by the steam condensation takes negative effect on the heat exchange.

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