Effects of Sea Salt Solution on Reflood Heat Transfer in a Long Vertical Tube

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1. Introduction

The Tohoku earthquake, which occurred at 2:46 p.m. (Japan time) on Friday, March 11, 2011, on the east coast of northern Japan, is believed to be one of the largest earthquakes in recorded history. Following the earthquake on Friday afternoon, the nuclear power plants at the Fukushima Daiichi, Fukushima Daini, Higashidori, Onagawa, and Tokai Daini nuclear power stations (NPSs) were affected, and emergency systems were activated. The earthquake caused a tsunami, which hit the east coast of Japan and caused a loss of all on-site and off-site power at the Fukushima Daiichi NPS, leaving it without any emergency power. The resultant damage to fuel, reactor, and containment caused a release of radioactive materials to the region surrounding the NPS [1]. The water circulation systems were severely damaged, and radionuclides were released to the environment, especially for days in the middle of March. Concentrations of the radionuclides released was not clearly known at the time these early releases [2]. In this situation, several different schemes were used to add water in order to remove heat. For example, freshwater and seawater were used by helicopter, fire truck, and concrete pump truck [1].

In this work, we have observed a quenching phenomenon of a long vertical tube during a reflood using sea salt solution as a coolant, instead of water in order to investigate the effect of seawater.

2. Experiment

2.1 Preparation of the sea salt solution

Table 1 shows the component ratio of sea salts. The component ratio of NaCl is 80 ~ 85 wt % and that of Mg is 0.5 ~ 1.0 wt %.

Table 1. The component ration of sea salts

Component	Component Ratio
NaCl	80 ~ 85
Ca	0.2
Mg	0.5 ~ 1.0
SO4--	1.0 ~ 1.5
K	0.1 ~ 0.17
Vapour	8 ~ 12

Generally, the concentration of sea salt solution was fabricated to 35 ‰, because the salt concentration of seawater is 35 ‰.

The process of preparation of sea salt solution is as follows: (1) weigh the mass of sea salts by a digital electronic balance; (2) put sea salts into the weighed deionized and prepare the sea salt solution (Fig. 1).

Fig. 1. Sea salt solution fabricated in 35 ‰.

2.2 Reflood Test

Fig. 2 shows the reflood test apparatus. The test section are made of SS 316 tube (the inner diameter : 10.206 mm and the heating length : 1,600 mm), and are directly heated by a DC passing through the tube wall. In order to measure the tube wall temperature, the nine K-type ungrounded thermocouples (TCs) with a sheath outer diameter of 0.5 mm are attached to the outer wall surface at intervals of 145 mm.

The experimental procedure is as follows. The heated section was heated up to 620 ℃ ~ 720 ℃ (The standard TC is second TC from below and this was heated up to almost 720 ℃), and then the cold working fluids of the temperature of 20 ℃ in the coolant reservoir was injected into the test section by the pump. Just before the working fluids reached the first TC, the dc power supplied to the tube was switched off. The injection flow rate (3 cm/s) was controlled by pump and the needle valve in the upstream of the test section. The total amount of each fluid was 2 liters. Three runs of the experiment were performed for each condition (water and sea salt solution).

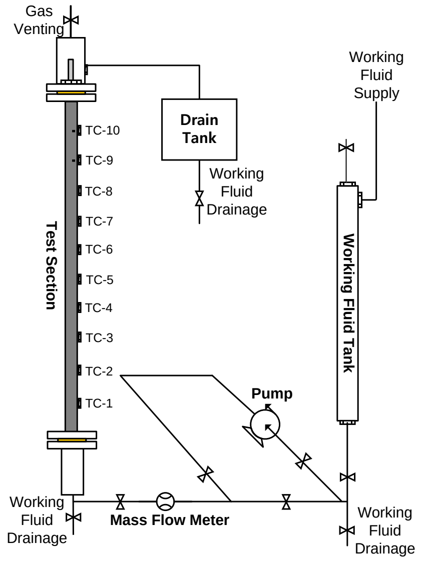

Fig. 2. Schematic diagram of the reflood test apparatus.

3. Results and Discussion

The wall temperature behavior for sea salt solution refloods was compared with those for the water refloods.

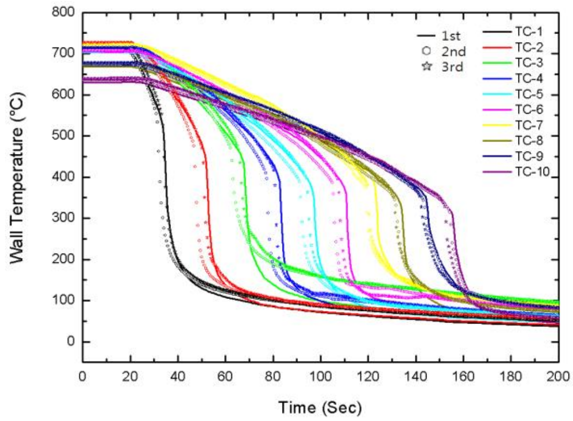

Fig. 3. Wall temperature variations for repetitive runs during water reflood (injection flow rate : 3 cm/s).

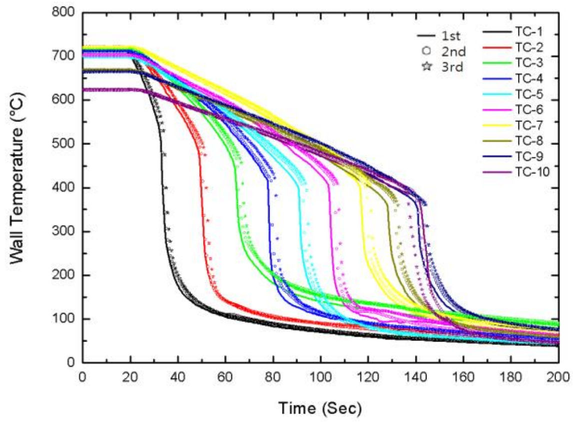

Fig. 4. Wall temperature variations for repetitive runs during sea salt solution water reflood (injection flow rate : 3 cm/s).

Fig. 3 and Fig. 4 show the wall temperature variations for repetitive runs during water and sea salt solution reflood when the injection flow rate is 3 cm/s. As shown in Fig. 3 and Fig. 4, the wall temperature with three runs of the experiment was nearly same. Table 2 shows the comparison of quenching velocity about water and sea salt solution. As shown in Table 2. The quenching time was faster in 10 seconds for sea salt solution compared with water.

Table 2. The comparison of quenching velocity about water and sea salt solution

	Injection Velocity (cm/s)	Quenching Time (seconds)		Quenching Distance (cm)	Quenching Velocity (cm/s)	
Water	3	120.17	116.76	130.5	1.09	1.12
		115.95			1.13	
		114.15			1.14	
Sea Salt Solution	3	110.54	106.96	130.5	1.18	1.22
		107.63			1.21	
		102.70			1.27	

4. Conclusions

The present works were conducted to investigate the effect of sea salt solution on reflood heat transfer in a long vertical tube. When the potential application of sea salt solution comes to Emergency Core Cooling System (ECCS), the situation of interest is quenching phenomena of fuel rods during reflood of emergency coolants.

The following results are obtained.

(1) The reflood tests have been performed using sea salt solution as a coolant, instead of water. We have observed a more enhanced cooling performance in the case of sea salt solution reflood.

(2) A more enhanced cooling performance is attributed to a high wettability of a thin layer formed on a heating surface by a deposition of sea salts and foaming in the liquid film generated by the dissolved sea salts [3].

REFERENCES

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