Effect of Containment Spray on Chemical Effect during Long-Term Cooling after Loss of Coolant Accident

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1. Introduction

During long-term cooling after Loss of Coolant Accident (LOCA), a variety of materials present in a reactor building may dissolve or corrode when exposed to reactor coolant and spray water solutions, forming oxide particulate corrosion products and precipitates through chemical reactions with other dissolved materials. These chemical products produce much larger head loss through the emergency core cooling system filter screen and thus should be quantitatively estimated to secure long-term cooling of a reactor core.

Therefore, the present study is performed to investigate the effect of containment spray on the chemical effect, which determines the amounts of materials exposed to the test solution, during long-term cooling. The investigation is performed by measuring of the emergency core cooling system filtration head loss for thirty (30) days under plant specific LOCA conditions.

2. Experimental Methods

2.1 Chemical Effect Test Apparatus

Figure 1 shows a schematic diagram of the chemical effect test apparatus. The apparatus consists of five chambers with individual loops. Each test loop is equipped with a test chamber, recirculation pump, heater, water chemistry measurement box, piping, and valves with sampling tabs. A circular screen with diameter of 10 cm and 2.38 mm holes is installed at the bottom of each chamber.

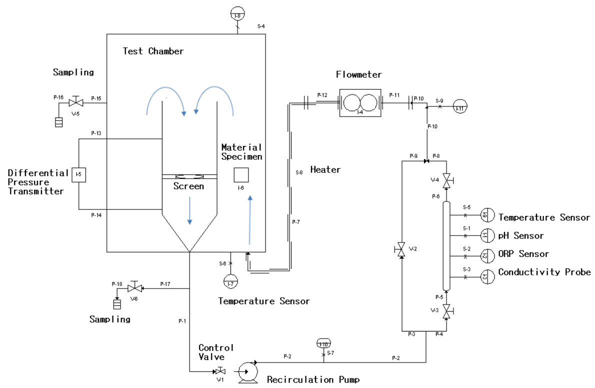

Fig. 1 Schematic Diagram of the Test Apparatus.

The head loss across the screen, flow rate, temperature, pH, oxidation-reduction potential (ORP), and water conductivity are measured online through a data acquisition system. The water is sampled periodically from both upstream and downstream of the screen during the test and its composition is analyzed with Inductively Coupled Plasma using Atomic Emission Spectroscopy (ICP-AES).

2.2 Scaling Method

The head loss across the screen can be measured by maintaining the water velocity of a specific plant. Two scaling factors are used in the present tests; one is a water volume ratio for scaling the materials that affect chemical effect and the other is a screen area ratio for the physical materials that do not affect the chemical effect. The present tests are performed for the plant specific conditions of Kori unit 1 with an estimated screen area of 2,200 ft^2.

2.3 Test Conditions

Table 1. Test conditions

Test ID.	Test #1	Test #2	Test #3
Remarks	Short Spray	Long Spray	Non-Chemical
Materials	NUKON Coating (surrogates) Latent Materials	NUKON Coating (surrogates) Latent Materials	NUKON Coating (surrogates) Latent Materials
Materials induce Chemical Bed	Aluminum Zinc Concrete	Aluminum Zinc Concrete	N.A.
Spray Buffer	TSP	TSP	N.A.
Additives to Solution	H_3BO_3, LiOH, HCl,	H_3BO_3, LiOH, HCl,	N.A.
Temperature	90~40°C	90~50°C	90~45°C
Water Volume	41.24 L	41.24 L	41.24 L
Flow rate	1.06 Lpm	1.06 Lpm	1.06 Lpm
Effective Spray Duration	3600 sec	30 days	0

The test conditions are summarized in Table 1. For the containment spray duration effect, two different times are considered. Test #1 is a short spray condition where the operator switches off spray operation at 3,600 seconds after starting recirculation. Test #2 is a long spray condition where spraying is maintained for 30 days. Test #3 is performed to obtain a pure pressure drop across the screen by a test material bed that produces negligible chemical effect. For this test, chemicals additives are not added to the test solution.

The duration with water temperature greater than 115 °C after LOCA in the said plant is about 36.5 minutes. However, the present test apparatus does not accommodate temperatures greater than 100 °C. Thus using the law of chemical reaction rate we obtained 61 minutes as an equivalent under 90 °C. Before starting each test temperature is maintained at 90 °C for 61 minutes and thereafter it is controlled to simulate plant behavior to about 40~50 °C at the end of the tests.

3. Results and Discussion

The measured head loss across the screen is shown in Fig. 2. As shown in the figure, head loss induced by chemical effects with long spray operation (test #2) is twelve (12) times greater than that in the test with a short spray condition (test #1). This indicates spray duration has a significant effect on head loss across the screen.

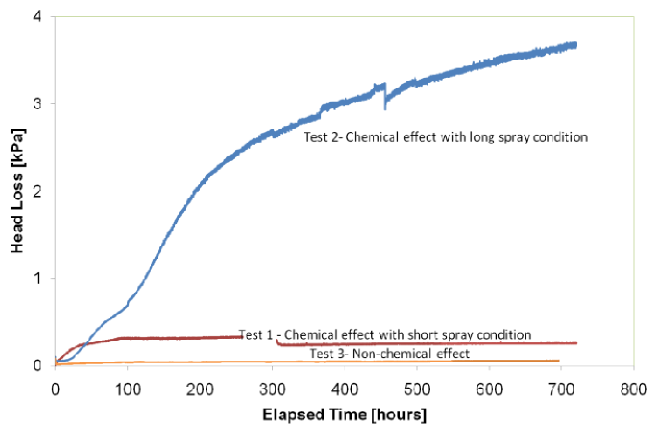

Fig.2 Head loss Behavior across the screen during the entire test period.

A result different from the existing literature [1] can be drawn from test #2: reference 1 states that when TSP is used as the reactor building spray buffer agent, corrosion to aluminum is markedly lower because it reduces aluminum precipitates of $AlPO_4$ and AlH_3 like protective coating on the metal surfaces. However, test #2 in this work shows that such precipitates to form protective coating on the metal surface and alleviate aluminum leaching is not effective for conditions with a large amount of aluminum and a long spray.

As shown in Fig. 3, the conductivities of the test solutions for test #1 and test #2 initially decreased and then increased from 100 hours and 160 hours for test #1 and test #2, respectively. Initial decreases in conductivity are due to a decrease in the solution temperature. Conductivities later increase as a result of dissolved ions generated from chemical reactions such as corrosion and leaching. Test #3 exhibited a different trend. Initially, for about 120 hours, the conductivity of the test #3 solution was much smaller than that of the other tests because chemicals such as boric acid, lithium hydroxide, or TSP were not added. However, the conductivity gradually increased from 20 μS/cm to 40 μS/cm. This trend indicates that dissolved ions increased due to a continuous leaching reaction from the fiberglass insulation NUKON™. Therefore, head loss due to non-chemical materials is also affected by the leaching reaction, although the incremental head loss of test #3 by leaching is very small compared with that of the other tests, as shown in Fig. 2. When the conductivity decreases, the head loss by chemical effects sharply increases. The decrease in conductivity can be explained by the reduction of the mobility of the dissolved ions due to the decrease of temperature and increase of precipitation.

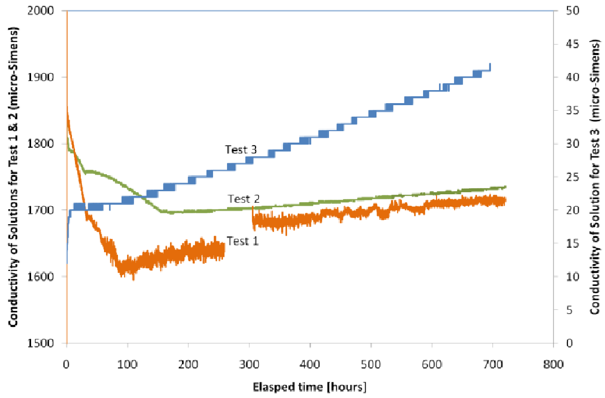

Fig.3 Conductivities of the solutions in the tests.

3. Conclusions

An integral test method is developed to investigate the effects of chemical products on head loss across an emergency core cooling filter screen for 30 days under a loss of coolant accident environment.

Three different tests show that the head loss across the screen is strongly affected by spray duration. A long spray condition generates a twelve-fold larger head loss than the short spray condition. This finding should be taken into account in the design of a new filter screen for the plant, since the required area of the filter for the long spray condition is too large. The most plausible option is to ensure that the technical specifications reflect early termination of the spray around the recirculation time.

Also, it is found that aluminum precipitates which form a protective coating on the metal surface and reduce aluminum leaching is not effective for conditions with a large amount of aluminum and a long spray. This is another important factor that should be considered in the design of new filters for plants with such operating conditions.

REFERENCES

[1]WCAP-16596-P, Evaluation of Alternative Emergency Core Cooling System Buffering Agents, June 2006.