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Investigation on Chemical Effects in Post-LOCA for OPR1000 Plant

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1. INTRODUCTION

During a loss-of-coolant accident (LOCA), the chemical environment generated by the injection of chemical agents into the Emergency Core Cooling System (ECCS) may create a chemical environment that facilitates the corrosion of metals and generation of precipitate. This corrosion may exacerbate the sump-screen head loss in a Pressurized Water Reactor (PWR) containment sump pool. The chemical effects tests demonstrated that the interaction of sodium hydroxide with exposed surfaces of the wall structures and pipes that may be present in PWR containment may release substantial quantities of coating and metal materials into solution via corrosion. Consequently, in this study the behavior of coating and metal materials following a LOCA were investigated. In this regard, the bench-scale testing (BST), in which coating and metal materials were artificially generated in solution by introducing dissolution and precipitation, indicated that these chemical products may exacerbate sump-screen clogging and consequently lead to an unacceptable Net Positive Suction Head (NPSH) margin. Therefore, the objective of this study, BST, demonstrated the feasibility of generating substantial quantities of dissolution and precipitation in solution, which on cooling could lead to the formation of gelatinous material. In addition, a detailed mechanism to form the gelatinous material, including the conditions necessary for its production, was also introduced. .

2. BENCH-SCALE TESTING (BST)

2.1 Dissolution Test

The tests have been performed to investigate the solubility limit of the coating materials (N-102, N-108) and the metal materials (Nukon, CLP, SSLP)..

Table 1: Testing Materials of Dissolution

Sample	Sample weight	Water volume
N-108	76.65g	300mL
N-102	20.43g	300mL
Nukon	11.28g	300mL
CLP	150.68g	300mL
SSLP	150.68g	300mL

In the method, the five materials (small pieces) initially were introduced at ambient temperature of containment in post-LOCA into the solution, followed by storage in an oven, where the temperature was maintained at 88C and 130C for 30 minutes, 60 minutes, and 90 minutes, respectively. Following the dissolution process, the solution concentration was analyzed using ICP-AES (Atomic Emission Spectrometer)

2.2 Precipitation Test

To assess whether precipitate was being formed, both turbidity measurements and suspended solids were measured at test conditions. Consequently, since the bulk dissolved solution of coating and metal material using at the plant may not appear at the ambient temperature, the visual examination of the precipitation would not be detectable via a turbidity measurement. Instead, in the pre-test for $CaCl_2 \cdot 2H_2O$ dissolution testing, it is recognized that dissolution of Ca material is more detectable rather than that of Al. Hence, the $CaCl_2 \cdot 2H_2O$ samples (3.23wt%, 6.25wt%, 9.09wt%, 11.76wt%) that contained TSP and DI water with pH 8.5 was applied to the turbidity measurements and was identified colloids.

2.3 Gap Measurement of Nukon Particle

To identify a detailed mechanism to form the gelatinous material and to clog the sump screen, the measurement of the particle size distributions of Nukon that may be encountered following a LOCA. Such an analysis may be used to allow for the detailed mechanism of gelatinous formation at the sump screen. As for testing, Nukon samples (small pieces) contained solids were mixed with water and measured via filtration using SEM (scanning electron microscope).

Table 2: Testing Materials

	Nukon
①	0.2040g
②	0.3148g
③	0.4001g

3. RESULTS AND DISCUSSION

3.1 Dissolution Test Results

The total quantity of dissolution formed at 88C was measure by ICP-AES is shown in Fig. 2.

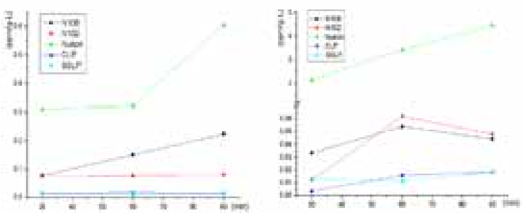


Fig. 2 Dissolution Test Results (at 88C)

The dissolution formed at 130C is shown in Table 3. As shown the results, the reaction indicates that the dissolution rate depends on the concentrations and temperature at the solid/liquid interface. Thus, the the dissolution rate at 130C is higher than that at 88C.

Table 3: Dissolution Test Results (at 130C)

	Al	Ca	Fe	Si
N-108 30min	0.0038	0.3673	N.D	1.5656
N-108 60min	0.0129	0.3944	N.D	0.8484
N-108 90min	0.0174	0.3880	N.D	0.8593
Nukon 30min	0.0490	3.2092	N.D	33.5133
Nukon 60min	0.0954	3.1206	N.D	29.2671
Nukon 90min	0.0198	2.8978	N.D	34.4007

3.2 Precipitation Test Results

At the solution phase, Ca is a formation of ionic Ca state. But the increase in the pH is the result of the formation of carbon hydroxide bridges. Hence, a formation of Ca precipitation is introduced into a large excess of Ca; therefore, poly-nuclear species probably will be generated as an increase of concentration with time as shown in following Table 4.

Table 4: Precipitation Test Results

	30min	60min	90min
Ca 3.23wt%	1245.3	1308.7	1689.4
Ca 6.25wt%	1188.8	1731.6	2885.2
Ca 9.09wt%	1675.0	2182.1	4941.7
Ca 11.76%	1719.2	3032.1	5174.9

3.3 Gap Measurement of Nukon Particle

As increase of Nukon concentration, the measured results via filtration using SEM (scanning electron microscope) are shown in Figs. 3-3.

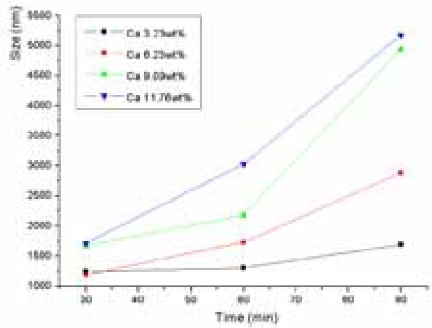
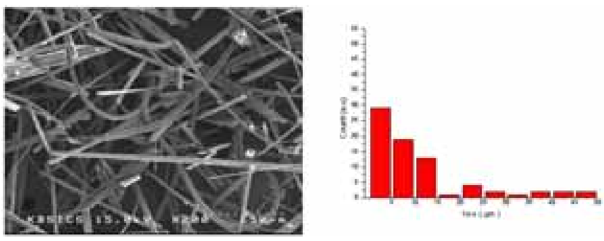
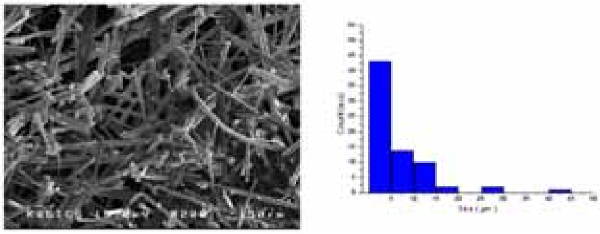


Fig. 3 Results of Gap Measurement of Nukon Particle





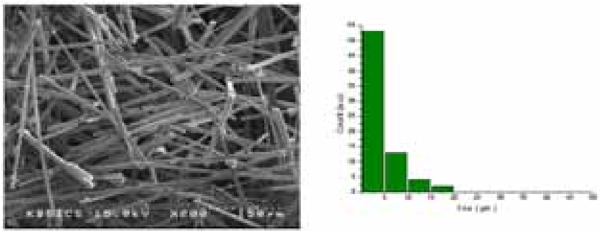


Fig. 3 Results of Gap Measurement of Nukon Particle

Table 4: Averaged Gap Measurement of Nukon Particle

Nukon 로딩량	Nukon 입자 간격의 평균 사이즈
① 0.2040g	7.17㎛
② 0.3148g	4.51㎛
③ 0.4001g	3.44㎛

4. CONCLUSIONS

To investigate the behavior of coating and metal materials following a LOCA, the bench-scale testing (BST) was conducted. As the result, the BST demonstrated the feasibility of generating substantial quantities of dissolution and precipitation in solution, which on cooling could lead to the formation of gelatinous material. Besides, to identify a detailed mechanism to form the gelatinous material and to clog the sump screen, the measurement of the particle size distributions of Nukon was also carried.

REFERENCES

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