Preliminary Assessment of Post-Accident Chemical Effects in Containment Sump

Yu Jung CHOI [a*], Sang Won LEE[a], Hyeong Taek KIM [a]
[a]*Korea Hydro & Nuclear Power Co., LTD.*
25-1 Jang-dong, Yusung-gu, Daejon, 305-343 KoreEa
[*]*Corresponding author: yujungchoi@khnp.co.kr*

1. Introduction

In order to respond to issues of GSI-191 and GL 2004-02, an evaluation of the Emergency Core Cooling System (ECCS) recirculation sump performance has been carried out in Nuclear Power Plants (NPPs). This work includes an evaluation of chemical effects to confirm their impact on sump screen additional head loss. After a survey on the containment materials in the NPPs, the chemical effects were evaluated analytically in the containment sump as a preliminary study for subsequent chemical effects experiments. To identify sensitivity to a containment material ratio, pH change, and temperature change for amounts of chemical precipitation, the WCAP-16530 methodology, which has obtained Nuclear Regulatory Commission (NRC) acceptance, and the WCAP-16785 methodology modified the WCAP-16530 methodology were used.

2. Methods and Results

2.1 WCAP-16530-NP Methodology

To evaluate the chemical effects that may occur post-accident in containment sump fluids, WCAP-16530-NP was performed a series of tests and found predominant chemical precipitates. They are aluminum oxyhydroxide, sodium aluminum silicate, and calcium phosphate (for plants using trisodium phosphate for pH control). The results of this evaluation are based on plant specific data about containment materials. On this basis, the chemical model considers only the release rates of aluminum, calcium and silicate. For each chemical species, WCAP-16530-NP developed release rate equations as a function of temperature, pH, and the concentration of the given species. The release rate equation is shown below.

$$RR = 10[A+B(pHa)+C(1000/T)+D(pHa)^2 +E(pHa)(T)/1000] \quad \text{(eqn.1)}$$

where, A, B, C, D and E are constants obtained by tests.

RR = release rate [$mg/(m^2 min)$]
pHa = initial pH corrected to 25℃
T = temperature[K]

After the quantity of the elements for the key precipitates is determined by eqn.1, using the stoichiometry of the precipitates, the quantities may be calculated directly.

2.2 WCAP-16785-NP Methodology

WCAP-16530-NP's conservatisms were identified in the chemical model. Conservatisms were taken to estimate the amount of insulation debris that might be available to react post-accident inside a reactor containment building. They also include the assumption that 100 percent of the aluminum and calcium (in the presence of phosphate) form. Hence, additional inputs are considered in the chemical model to reduce the precipitate generation. WCAP-16785-NP performed some tests and concluded the aluminum release rate equations have been provided for reduction of the aluminum metal release due to either the presence of silicate or phosphate in the sump solution.

2.3 Sensitivity to calcium silicate ratio

Containment materials were surveyed in domestic Westinghouse type plants. According to this survey, except aluminum, Nukon(insulation) was generally found in NPPs, and calcium silicate was found in one NPP. Based on the results of our survey, the effect of calcium silicate mass ratio was predicted using the WCAP-16530-NP and WCAP-16785-NP approaches respectively. The results are shown in Figure 1.

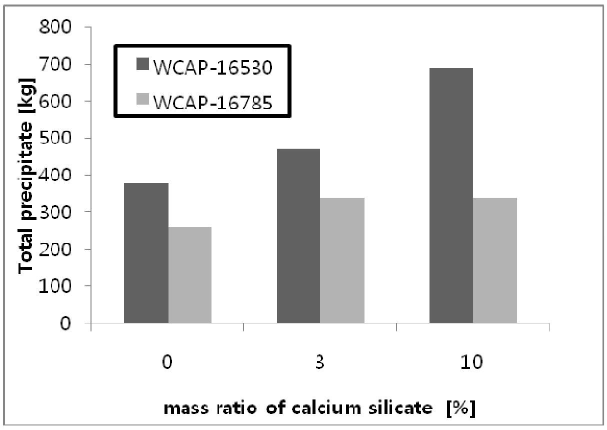

Figure 1. Sensitivity to calcium silicate mass ratio

Total precipitate means the sum of three predominant chemical precipitate - aluminum oxyhydroxide, sodium aluminum silicate, and calcium phosphate.

With presence of more calcium silicate, greater amounts of precipitate were formed in both of models.

2.4 Sensitivity to pH change

Prior to this work, the base case was calculated by both models based on the results of survey. The effect of pH change on precipitate mass was evaluated using the WCAP-16530-NP and WCAP-16785-NP model. To identify effect on pH, the maximum pH was changed to calculate the amount of precipitate. The results are shown in Figure 2.

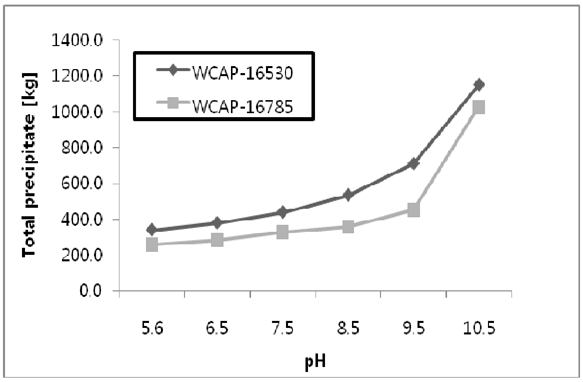

Figure 2. Effect of pH change on total precipitate

The amount of precipitate was increased slowly between pH 5.6 and 8.5. At the pH 8.5 above, total precipitate is generated rapidly compared with the results under pH 8.5. In the WCAP-16785-NP chemical model, the results are shown similar trend like the WCAP-16530-NP model. The corrosion of aluminum was the key contributor to precipitate increase at high pH values.

2.5 Sensitivity to temperature change

The effect of temperature variation on total precipitate was developed in the similar manner like the approach of sensitivity to pH change using both models. To identify effect on temperature, maximum temperature of containment sump fluid was changed. The results of the temperature sensitivity are shown in Figure 3.

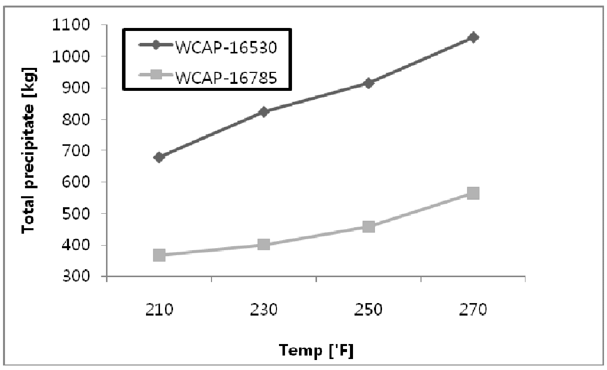

Figure 3. Effect of Temperature variation on total precipitate

The Increase of total precipitate is commensurate with temperature. The effect was mainly due to the increase of aluminum corrosion with temperature.

3. Conclusions

To evaluate the chemical effects in containment sump under post-accident sump conditions, the amounts of precipitates that may lead to sump blockage are determined by using the analytical models in WCAP-16530-NP and WCAP-16785-NP.

With presence of more calcium silicate, greater amounts of precipitate are formed. Effect of pH and temperature change on total precipitate was identified. The conservatism of WCAP-16530-NP was confirmed compared with WCAP-16785-NP from all of the analytical results.

Nevertheless many chemical effects that have yet to be identified may occur under post-accident conditions in the sump, and thus further review and evaluation are needed. Based on the present results, we are planning to carry out further study and experiments on chemical effects in the sump.

REFERENCES

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[4] WCAP-16785-NP, Rev.0, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model", May 2007