Role of Hydrazine Control in a Steam Generator Management Program and Basis for Revising EPRI Chemistry Guidelines

Jeoh Han [a*], Kuk-Hee Lee [a], Seung-Jae Kim [a]
[a]*Central Research Insistute of Korea Hydro & Nuclear Power Co., Ltd, Mechanical Engineering Laboratory*
[*]*Corresponding author: johan2965@khnp.co.kr*

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1. Introduction

According to the water chemistry guidelines [1], feedwater (FW) chemistry control parameters are related to the deterioration of the steam generator (SG) performance and include pH, dissolved oxygen concentration, total iron and copper concentrations, and hydrazine (N_2H_4) concentration.

Among these parameters, elevated dissolved oxygen concentration can lead to corrosion-related degradation of SG tubes, such as intergranular attack (IGA), stress corrosion cracking (SCC). Therefore, to establish reducing conditions of SGs, hydrazine is injected, typically in the condensate to pressurized water reactors (PWRs) and pressurized heavy water reactors (PHWRs) to react with dissolved oxygen along the FW train.

Under normal operating conditions, hydrazine is maintained at a concentration of at least eight-times the feed source oxygen concentration or 20 ppb, whichever is greater. When the hydrazine concentration falls below this threshold, the system enters Action Level 1. These criteria were originally established to mitigate SCC in Alloy 600 SG tubes.

However, recent discussions at an Electric Power Research Institute (EPRI) meeting proposed alleviating the hydrazine control criteria to a minimum of three-times the feed source oxygen concentration or 20 ppb, whichever is greater. Accordingly, this study describes the technical basis for alleviating the hydrazine concentration limits in the secondary-side chemistry control.

2. Methods and Results

According to the EPRI report [2], an assessment of approximately 650 operating cycles over the past 20 years showed that most plants complied with EPRI guidelines on a cycle-average basis, with a median feedwater hydrazine to CPD oxygen ratio of 21 and only 58 cycles below the guideline value of 8. The reviewed operating experience among multiple plants without a deaerator and with varying degrees of operating data is consistent with no significant impact on SG degradation from a cycle average FW hydrazine to CPD oxygen ratio less than eight, with a median value among all considered plants of 5.0. The integrated exposures of sodium, chloride, sulfate were not observed to be related to oxygen control.

The EPRI report also presents both industrial and laboratory data. Cracking of Alloy 600 was found to be most severe and rapid at approximately 150 mV above the Ni/NiO equilibrium line, while cracking was negligible at potentials less than 100 mV or greater than 200 mV from the line. Cracking susceptibility was therefore limited when operating within 0–100 mV above the potential calculated using Eq. (1).

$$E(V) = 0.110 - 1.98 \times 10^{-4} \times pH \times T \qquad (1)$$

Laboratory data further indicate that the measured electrochemical potential of Alloy 600 is significantly reduced at a hydrazine to oxygen molar ratio of approximately three, and remains relatively stable even at ratios up to about 30.

A feedwater hydrazine–to–condensate oxygen ratio of three provides three times the hydrazine required to react stoichiometrically with the oxygen present in the condensate. Nevertheless, an absolute lower limit of 20 ppb hydrazine was retained to account for the transport of reducible metal oxides to the SGs.

3. Conclusions

Long-term operating experience and electrochemical data indicate that the existing hydrazine control criteria in secondary-side water chemistry are conservative. Operation with a cycle-average feedwater hydrazine to CPD oxygen ratio below eight did not result in a significant impact on steam generator degradation. Electrochemical evaluations further demonstrate that cracking susceptibility of Alloy 600 is minimized when operating within 0–100 mV above the Ni/NiO equilibrium line, a condition that can be achieved at a hydrazine to oxygen ratio of approximately three. Accordingly, maintaining this ratio with a minimum hydrazine concentration of 20 ppb provides sufficient electrochemical margin while preserving steam generator tube integrity.

REFERENCES

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