U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

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Collaborators: **None**

Title: **An Investigation of the Mechanism of IGA/SCC of Alloy 600 in Corrosion Accelerating Heated Crevice Environments**

The crevice formed by the tube/tube support plate (tube/TSP) intersection in a pressurized water reactor (PWR) steam generator is a concentration site for nonvolatile impurities (referred to as hideout) in the steam generator water. The restricted mass transport in the small crevice volume prevents the species, which concentrate during the generation of steam, from quickly dispersing into the bulk water. The concentrated solutions in crevices have been a contributing cause of several forms of corrosion of steam generator tubes including intergranular attack/stress corrosion cracking (IGA/SCC), pitting, and wastage. Today, IGAISCC of alloy 600 steam generator tubes in tube/TSP crevices is the most pervasive form of corrosion in nuclear power plants even though plants have been markedly successful in limiting the ingress of impurities and oxidants.

The present strategy for mitigating IGA/SCC aims at controlling the crevice chemistry. This is based on the assumption that crack initiation and propagation rates depend on pH and the electrochemical potential (ECP). Laboratory data show that IGA/SCC crack growth rates reach a minimum at pH's between 5 and 9 under reducing conditions. Some plants are injecting Na and CI ions into the feedwater to adjust the crevice pH. However, there are plants experiencing IGA/SCC, which are believed to have continuously operated in the pH 5 to 9 range. The reasons for these discrepancies are not clear. There are several uncertainties. Since measurements of crevice chemistry and ECP cannot be made in an operating steam generator, estimates are made using computer codes based on hypothesized processes believed to occur in crevices. Moreover, laboratory IGA/SCC data were obtained in static autoclaves using what are believed to be simulated crevice solutions. The IGA/SCC mechanism may be different under heat flux conditions. Crevice chemistries are complex and pH may not be the only important factor.

The objective of this program is to develop the mechanistic understanding needed too enable control of corrosion processes in steam generator crevices by control of crevice chemistry . This includes the capability of predicting crevice chemistry and IGNSCC susceptibility from feedwater chemistry.

The program will use an instrumented heated crevice, which is a replica of a steam generator tube/TSP crevice. The system was designed in an EPRI funded program and has been built as an in-plant monitoring system. With the system operating at simulated steam generator thermal conditions, measurements can be made of the free span ECP, the ECP in the crevice, the Raman spectra from the species in the crevice, and

the temperature in the tube wall at different elevations in the crevice.

The temperature at a location indicates whether it is wetted or dry. In addition, solutions can be extracted from the crevice and bulk water in the autoclave through capillary tubes while the system is fully operational. An analysis of the extracted solutions permits the chemical composition of the crevice solution and the pH in the crevice to be determined. In this program a system will be built having a pressurized tube to provide the stress needed to initiate IGA/SCC with the additional capability of measuring electrochemical noise during IGA/SCC and during other corrosion processes.

The approach will first establish reference IGA/SCC and electrochemical noise results. This will be done using feedwater with NaOH in sufficiently high concentrations to produce through-wall cracks in a few days of run time, using reported results from model boiler tests as a guide. This feedwater chemistry was selected since caustic crevices are believed to be responsible for IGA/SCC in several plants. Measurements will be made using aerated, deaerated, and deaerated with hydrazine additions feedwater chemistries to assess the effect of ECP .

The next task will examine the effects of pH on IGA/SCC by varying the Na/CI ion ratio in the feedwater. Measurements will be made using aerated and deaerated feedwater as with the reference conditions. Potential dynamic polarization curves will be obtained in static autoclaves using simulated crevice solutions. The chemistries of these solutions will be determined from the solutions extracted from the crevice. This task will be followed by one, in which complex feedwater chemistries containing multiple species in proportions typical of those found in steam generators will be used. Tube analysis will provide the distributions of cracks and passive film compositions on the fracture face and OD.

The experimental data will be compared with models predicting crevice chemistry and IGNSCC initiation and propagation. One model starts from basic conservation laws and predicts the spatial changes in composition and wetting in the crevice from feedwater composition. A second model predicts the ECP and coupling currents between the anodic processes in the crevice and the external cathodic processes during corrosion. Finally , a methodology for electrochemical noise analysis models crack initiation and propagation.