AN INVESTIGATION OF THE MECHANISM OF IGA/SCC OF ALLOY 600 IN CORROSION ACCELERATING HEATED CREVICE ENVIRONMENTS

NUCLEAR ENERGY RESEARCH INITIATIVE (NERI) PROGRAM
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TECHNICAL PROGRESS REPORT

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This program focuses on understanding the mechanisms causing corrosion damage to steam generator tubes in a pressurized water reactor (PWR) and the effects of the proposed remedial measures. The crevice formed by the tube/tube support plate (T/TSP) intersection in a 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.

Damage to Alloy 600 steam generator tubes by IGA/SCC continues despite rigorous water chemistry controls during power operation. The continued degradation has resulted in operational leakage, extensive tube inspections and repair. Eventually, replacement of steam generators or plant decommissioning must be considered. Many remedial actions against IGA/SCC have been taken, which include: increases in secondary water purity, reductions in oxygen ingress, use of buffers such as boric acid, injecting of hydrazine to maintain reducing conditions, and control of molar ratios of cations and anions. These measures have been

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useful in reducing the rate of increase in tubes affected by IGA/SCC in some plants; however, other plants using the same measures have continued to experience IGA/SCC.

The present strategy for mitigating IGA/SCC is based on the assumption that crack initiation and propagation rates depend on pH and the electrochemical potential (ECP). Laboratory data, using static autoclaves, show that IGA/SCC crack growth rates reach a minimum at pH's between 5 and 9 under electrochemically reducing conditions. Some plants are injecting Na and Cl ions into the feedwater to adjust the crevice pH. There are several uncertainties in this approach. Since measurements of crevice chemistry and electrochemical potential (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 simulated crevice solutions. The IGA/SCC mechanism may be different under heat flux conditions, during which steam is being generated. Crevice chemistries are complex and pH may not be the important factor or the only important factor.

The objective of this program is to develop an understanding of the corrosion accelerating mechanisms, particularly IGA/SCC, in steam generator crevices. The important variables will be identified, including the relationship between bulk water chemistry and corrosion accelerating chemistries in a crevice. The approach will use an instrumented heated crevice, which is a replica of a PWR steam generator tube/TSP crevice. With the system operating at simulated steam generator thermal conditions, measurements can be made of the chemical, electrochemical, and thermal conditions in the crevice. Damage to the tube due to IGA/SCC and other corrosion processes will be monitored using electrochemical noise.

Task 1: Modification of Heated Crevice for SCC and Electrochemical Noise Measurements.

1. Task Status.

The construction of the heated crevice with the capabilities of performing SCC measurements and measuring electrochemical noise has been completed. A schematic of the apparatus is shown in

Figure 1. The crevice is formed by a section of Alloy 600 steam generator tubing inserted into an alloy 600 ring. The dimensions of the crevice are typical of a tube/tube support plate crevice in a nuclear steam generator. A cartridge heater inside the tube maintains a molten salt mixture inside the tube at primary water temperature. The tube assembly is contained in an Alloy 718 autoclave, which has external heaters to supply sufficient heat flux to heat the water to the steam generator secondary water temperature, 280°C. The tube, autoclave, and ring are electrically isolated from each other and are mechanically independent. This allows electrochemical measurements to be made and the easy removal of the tube for analysis and for replacement after a test. The tube can be pressurized to 2700 psi.

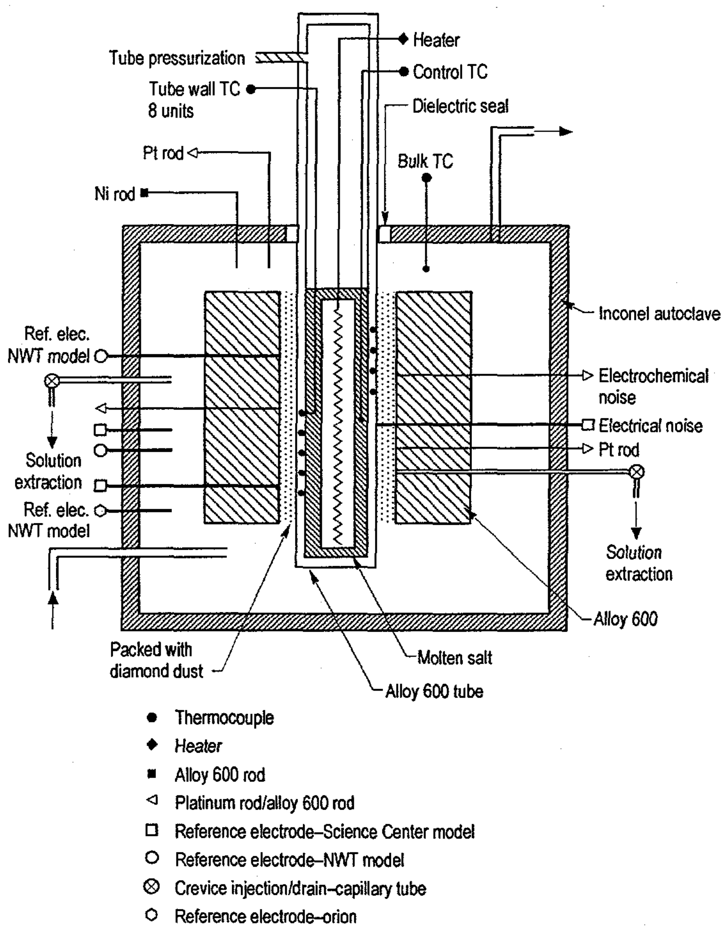

Figure 1. Schematic of the heated crevice.

The system is instrumented to monitor the chemistry in the crevice and the IGA/SCC processes in the tube. Probes are inserted through ports in the side of the autoclave into the crevice to evaluate the chemistry. A Ag/AgCl reference electrode monitors the electrochemical potential in the crevice. One port contains a Pt reference electrode, which extend into the crevice. A third port has a capillary for extracting the crevice solution for chemical analysis. There are several vacant ports for other sensors as they are developed. A Ag/AgCl and a Pt reference electrode are also inserted into the bulk solution for monitoring the freespan electrochemical potential. The bulk solution can also be extracted through a capillary for chemical analysis. Electrochemical noise produced by IGA/SCC is monitored by a Gamary ESA 400.

A photograph of the interior of the autoclave with the bottom removed is shown in Figure 2. The six holes visible in the top are for the input and output of the water circuit and for the insertion of sensors into the bulk water. The connectors attached to the seventeen ports for inserting probes into the crevice can be seen surrounding the outside of the autoclave.

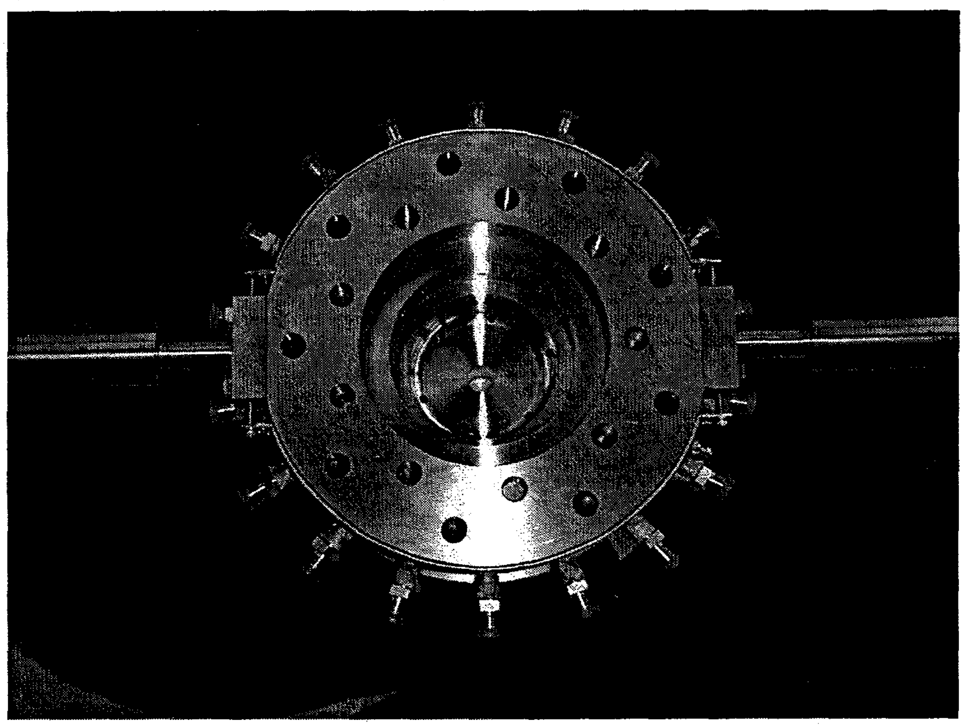

Figure 2. Photograph of the interior of the autoclave with the bottom removed.

Figure 3 is a photograph of the assembled heated crevice apparatus. Ports, which contain the probes, surrounding the center of the autoclave are clearly visible. The tubing emerging from the top of the autoclave connect to the water circuit, which is shown in the background. Also visible in the background is the stainless steel feedwater tank. Both once through and circulating modes of operation are possible.

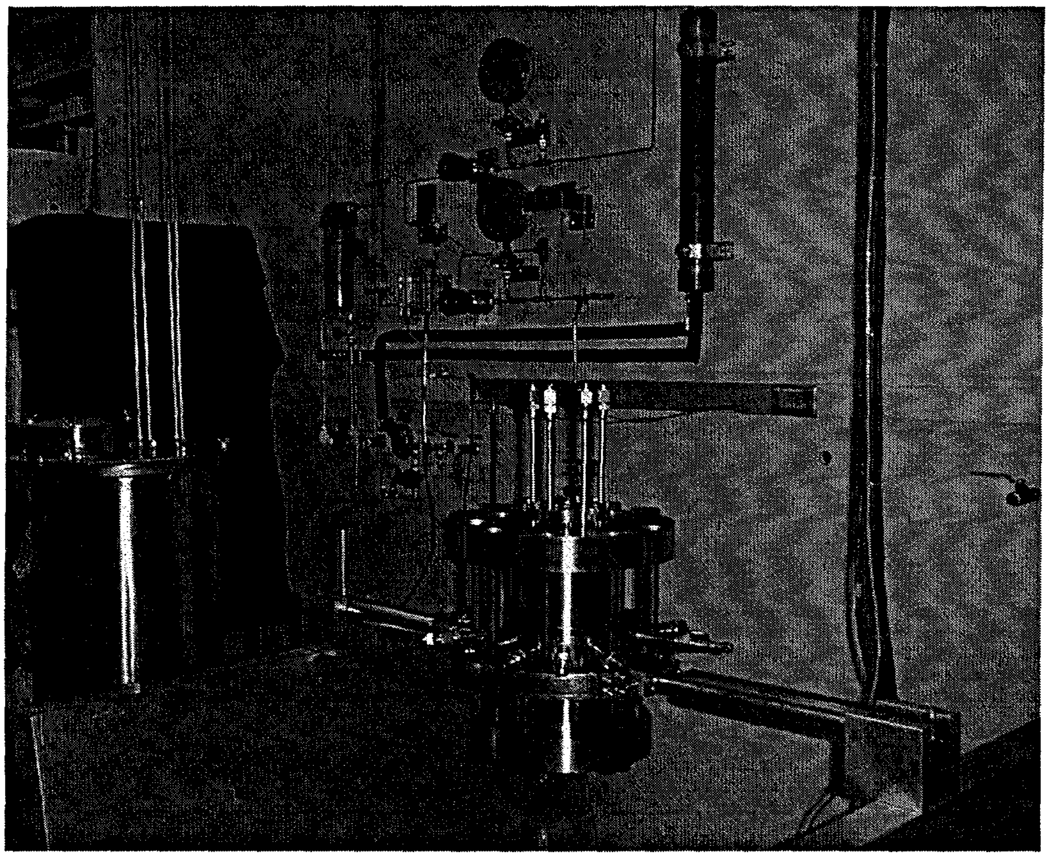

Figure 3. Photograph of the assembled heated crevice with the cater circuit in the background.

The system is currently is being “burned in”. The plan is to make it operational within two weeks.

2. Issues/Concerns.
None

Task 2: Evaluation of Electrochemical Noise

1. Task Status.

The hardware and software for electrochemical noise analysis (ENA) have been tested successfully for a simple corroding system at room temperature. The current and potential noise have been collected and analyzed using the ENA statistical parameters. This has provided a system validation of the instrumentation and methodology to be used in the heated crevice work.

We are continuing to take baseline measurements using a static autoclave system. These investigations are being performed in a caustic environment using C-rings cut from Alloy 600 steam generator tubing. Our work on EPRI programs has shown that the conditions which we are using will produce rapid SCC crack growth rates in the C-rings. This type of analysis has the advantage that SCC can be turned off or on by changing the electrochemical potential.

Our initial work using the heated crevice will use feedwater having NaOH. Under heat flux conditions, this feedwater chemistry will produce a concentrated caustic solution in the crevice like that in the static autocalve. The structure and intensity of the noise spectra from the static autoclave measurements will provide a reference for determining the time of initiation of SCC and for determining the crack propagation rate in the heated crevice work.

2. Issues/concerns

None