

## Irradiation-Assisted Stress Corrosion Cracking Testing Laboratory at INL

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### INTRODUCTION

Irradiation-assisted stress corrosion cracking (IASCC) is a known issue in current nuclear reactors. During a 60-year lifetime, reactor core internals may experience fluence levels up to 15 dpa for boiling water reactors (BWRs) and 100+ dpa for pressurized water reactors (PWRs). To support safe operation of the current fleet of reactors and maintain their economic viability, it is important to be able to predict any evolution of material behavior as reactors age and as fluence accumulated by reactor core components increases. Although there are attempts to understand IASCC with materials that were irradiated with alternative techniques (e.g., proton irradiation or self-ion irradiations), generation of IASCC crack growth rate data and fracture toughness data required the use of a bulk specimen irradiated with neutrons. This need calls for specific testing capabilities supported by an adequate infrastructure. This type of capability, which is operational at Idaho National Laboratory (INL), is presented in this paper.

### LABORATORY LAYOUT

The laboratory is composed of a transfer cell, used for specimen transfers, and contains a test cell that hosts two test rigs. The test environment (i.e., water for BWRs and PWRs) is prepared and controlled outside the hot cell in specially designed water boards. The laboratory's electrical power distribution includes a flywheel backed up by a diesel generator that assures continuous operation of the facility in the event of a loss of main power. An overview of the hot cells is presented Figure 1.

### TRANSFER CELL

Specimen transfer, decontamination, and post-test microscopy are performed in the transfer cell. The transfer cell's walls are made of 6.5 in. of lead for shielding. It is equipped with a set of master slave manipulators, two hermetically closed doors to access to the test cells that are located on each side of the transfer cell (only one test cell has been built at the time of writing of the paper), and a transfer port on the cell's floor. A shielded storage compartment, a benchtop scanning electron microscope, and equipment for specimen decontamination are inside the transfer cell. The scanning electron microscope is a NEOSCOPE Model JMC-5000, with most of its electronic equipment located outside the cell.



Figure 1. Overview of the test cells for IASCC testing and scanning electron microscope characterization at INL.

### SPECIMENS TRANSPORTATION AND TRANSFER

The specimens are transported from the storage area to the test facility using a modified GE Model 100 shipping cask. A new lid that incorporates a permanent bagging ring to prevent the spread of contamination during specimen loading/unloading operations was machined. The lid includes a removable tapered plug with an integral hook that allows placement of the specimens in the shipping cask. The transfer cask mates to the transfer cell from the floor of the cell. The cask is placed on a scissor lift installed on rails. The cask is rolled underneath the transfer cell and lifted to mate to the transfer cell. A contamination bag is installed and connects the top of the cask and the transfer port. A shielding ring for minimizing radiation shine during specimen transfer is installed. The in-cell hoist is used to lift the cask plug and retrieve the specimens. After transfer is complete, the contamination bag is heat sealed and cut before being removed.

### IASCC TEST CELL

The test cell hosts the two autoclaves and their respective heat exchangers. The 9-in. thick lead walls provide enough shielding for 40,000-R/hour sources. Three master slave manipulators cover the entire area, permitting loading of specimens and operation of the autoclaves. High visibility of the working area is assured by a large 47-in. x 24-in. window. A camera is used in cell to facilitate operations.

The 4-L CRAIGLOC stainless steel autoclaves were designed to 3,250 psi at 750°F. Their sealing is ensured by a clamp actuated by a single drive screw that allows easy operation with the manipulators. Each autoclave hosts the reaction cage where the compact tension specimen is located. The system was designed for IASCC and fracture toughness tests up to 1T-CT specimen sizes. Servo hydraulic 100 KN test frames are used for load control. The actuators are located underneath the hot cell, where they are protected from radiation damage by 7-in. of lead and are accessible for calibration and maintenance. A view of inside a test cell is presented in Figure 2.



Figure 2. View of the test cell showing the two autoclaves used for IASCC testing at INL.

Inside each autoclave, a Cu-CuO reference electrode allows the in-line measurement of specimen corrosion potential. Platinum leads are connected to the specimen to permit crack growth measurements for real-time crack growth monitoring, using reverse current with the direct current potential drop technique.

The autoclaves are part of two testing loops. In each loop, water is continuously refreshed with a flow rate of about 200 mL/minute and water chemistry is continuously monitored and controlled in independent water boards located outside the hot cell (Figure 3). Dissolved gas concentration is controlled by applying an overpressure of mixed gas at room temperature before the water flows in the high-pressure, high-temperature part of the loop. The ion content in the water is controlled by flowing water through an ion exchanger to remove corrosion products and by adding a controlled amount of sulfate or other solution when desired.

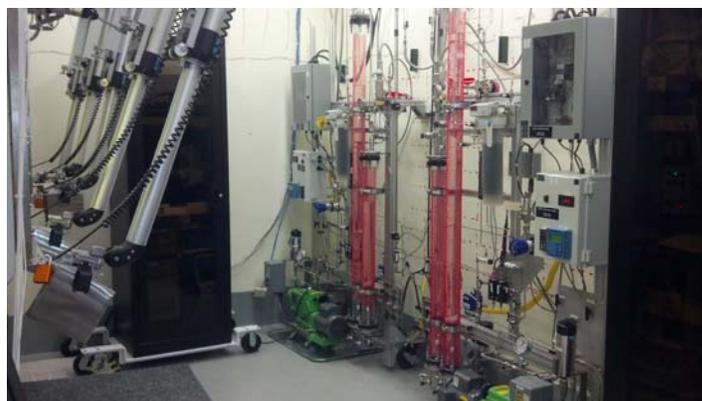


Figure 3. View of the waterboards where water chemistry is controlled.

## SUMMARY

Two shielded test systems for IASCC crack growth rate and fracture toughness measurements on irradiated materials in PWR and BWR environments were commissioned for use with high dose-rate radioactive materials in 2014.

These systems are capable of constant K (i.e., IASCC CGR) tests and fracture toughness tests of up to 1T-CT sample sizes. For crack growth measurements, reversing the current direct current potential drop measurements is used for real-time crack growth monitoring.