Development and Experimental Validation of Pitting and SCC Models for Welded Stainless Steel Dry Storage Containers Exposed to Atmospheric Environments

PI: Robert G. Kelly,
University of Virginia

Collaborators: James T. Burns (UVA), Eric Schindelholz, (Sandia National Laboratories), Robert Tryon (VEXTEC)

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ABSTRACT:

Used Nuclear Fuel (UNF) is currently stored in welded stainless steel (SS) dry storage canisters (DSC) at independent spent fuel storage installations (ISFSI). At near-marine ISFSI, the cooling air drawn from the outside leads to ingress of aerosols into the concrete overpack that will deposit on the steel. These aerosols will contain aggressive ions, including chloride ions, as well as oxidizing species. They can also develop very low surface pH values. Such aerosols can be transported hundreds of miles inland with decreasing deposition rates with increasing distance from the coast.

Initially after emplacement of the DSC into the concrete overpack, the DSC surfaces will be at a high enough temperature (T) that any aerosols deposited will be dry. Under these conditions no aqueous corrosion can occur. Eventually, the canister will cool sufficiently, and the deposited salts will deliquescence. The corrosivity of the solution formed will be dependent on the chemical constitution of the deposits, the concentration of the resulting solution (which depends on the T/RH), the solution volume, and the extent of oxidizing gases (*e.g.*, oxygen, ozone). SS exposed to brine environments are susceptible to pitting, crevice corrosion, and stress-corrosion cracking (SCC) at sufficiently high stresses. Each of these damage modes is potentially serious, but the coupling of localized corrosion to SCC is considered the most likely failure mode for DSC given the high stresses that can exist near welds.

Some studies have characterized the effect of important parameters (*e.g.*, [Cl-], sensitization level, T, RH, deposit/droplet type, etc.) on these degradation processes for materials fully immersed in bulk aqueous solutions, characterization and understanding of the coupled processes under the more relevant thin electrolyte film conditions is lacking. To fully evaluate the impact of the electrochemically induced degradation on the structural integrity of DSC, several stages must be addressed: localized corrosion initiation, localized corrosion growth, SCC initiation, and SCC growth. The proposed effort will use cutting-edge techniques to measure/model these processes, enhancing the mechanistic understanding of pitting and SCC. The overarching goal is to develop validated, mechanism-based models to inform risk-based ranking of ISFSI sites as well as proposed mitigation and repair strategies. The specific goals of this work are to: (a) validate the maximum pit size model for DSC-relevant corrosion conditions as well as quantifying the effects of limited cathodic current on SCC kinetics, (b) demonstrate a means to quantitatively rank the risk of SCC based on measurable parameters by coupling the limiting pit size/Kondo approaches, (c) generate da/dt vs. K data and perform probabilistic FM predictions of SCC growth, and (d) validate the model predictions.