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Life Prediction of Spent Fuel Storage Canister Material

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ABSTRACT

With the elimination of Yucca Mountain as the long term storage facility for spent nuclear fuel a number of other options are being explored. In the interim it is likely that spent fuel will be stored times that have been suggested will be 100 years. While the storage casks are “dry” this is not the case on the external surfaces including, due to the venting of the outer canister which is fabricated from stainless steel and welded.. Storage casks will be stored mostly in coastal or lake-side regions where a salt air environment exists. Thus, it is likely that the storage casks will be exposed to a salt-containing environment for the entire storage period. Austenitic stainless steels are susceptible to stress corrosion cracking (SCC) in chloride-containing environments if a continuous aqueous film can be maintained on the surface. Types 304 and 304L are especially susceptible. The key variables in the process include: (1) tensile stress, (2) an aqueous environment containing chloride and oxygen, temperature, and (4) microstructural variables including the degree of sensitization. Sensitization often occurs in the heat effected zone of welds. High stresses are often present as a result of welding. In the case of a salt air environment the possibility of chloride salt buildup due to deliquescence is a strong possibility. Under these conditions the temperature will be a key variable in the determination of eventual susceptibility. One remaining phenomena can have a strong influence as well-pitting. If pitting occurs then a stress concentrator will be created that can move the stress level from benign to the danger zone.

There is now a large body of evidence that shows that for very high concentrations of chloride, as may exist in deliquesced conditions containing Na, Ca and Mg chloride salts, the temperature limit for “immunity” is well below 50°C-most likely as low as 30°C if enough time is involved. Maximum SCC susceptibility occurs in a saturated condition-the point of deliquescence. Cracking has been observed in all of the solutions at temperatures 30°C and above with the exception of FeCl₃. Since many of the cask storage facilities are on seacoast sites it is likely that the salt containing environment will contain a combination of Na, Ca, and Mg based salts. Pitting can further aggravate the situation. A number of power plants, nuclear included, have experienced chloride stress corrosion cracking of austenitic stainless steel piping that has been exposed to a salt air atmosphere where concentration can occur after a period of 30 years or less. This is well short of the anticipated 100 year storage requirements that have now been placed on spent fuel storage casks.

The purpose of this project will be to develop a probabilistic model for the prediction of failure of canisters by stress corrosion cracking for periods up to and exceeding 100 years when exposed to saltcontaining environments in the temperature range 30-70°C.