Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steel for Dry Storage of Spent Nuclear Fuel

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Under current practices, spent nuclear fuel (SNF) assemblies are taken out of SNF pools at nuclear power plants after an initial decay period and packaged in dry casks for storage at Independent Spent Fuel Storage Installations (ISFSIs). Some dry storage cask designs utilize austenitic stainless steel canisters surrounded by concrete shielding structures. The concrete structures have vents open to the outside atmosphere for cooling. Should the ISFSI be located where chlorides may be deposited on the austenitic stainless steel canisters, then under certain conditions, the potential may exist for initiating chloride-induced stress corrosion cracking (SCC).[(1) – (3)] Susceptibility to chloride-induced SCC depends on the environmental conditions at the canister surface, including the following key parameters: temperature, relative humidity (RH), and amount, composition and aqueous concentration of deposited salts, as well as the stress state of the canister particularly at the weld and in the weld heat affected zone (HAZ).

Due to decay heat from the SNF, the canister temperature is an important parameter for assessing the susceptibility to SCC. The canister surface will likely be at high temperature and the local RH will be relatively low when first loaded, making deliquescence of salts on the canister surface unlikely. Over time, the canister temperature is expected to decrease, driving a corresponding increase in local RH, as the radioactive material decays. At lower temperature and higher RH, salts that deposit on the canister may deliquesce, forming chloride-rich corrosive brine on the canister surface. For SCC to initiate, the amount of salts deposited needs to be large enough to provide the sufficiently concentrated chloride solution. National and international literature was reviewed on threshold values of temperature, RH, the amount of salts deposited, and stress induced by welding for SCC initiation. The review showed a wide range of conditions for SCC initiation.

For dry storage systems, key parameter values are not definitely known, so uncertainties should be considered when assessing the susceptibility of the canister to chloride-induced SCC. The time to reach the required temperature for salt deliquescence is a function of the initial thermal loading and radioactive constituents in the cask. Local spatial or temporal variations of atmospheric temperature and humidity also affect the tendency for salt deliquescence. Other parameters include salt composition, water volume on the canister surface, and salt deposition rate. Gamma radiolysis may also affect the solution chemistry with radiolysis species present. Lastly, there are uncertainties associated with weld stress during initiation and propagation of SCC and with temperature of the canister that is emitting heat.

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References

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