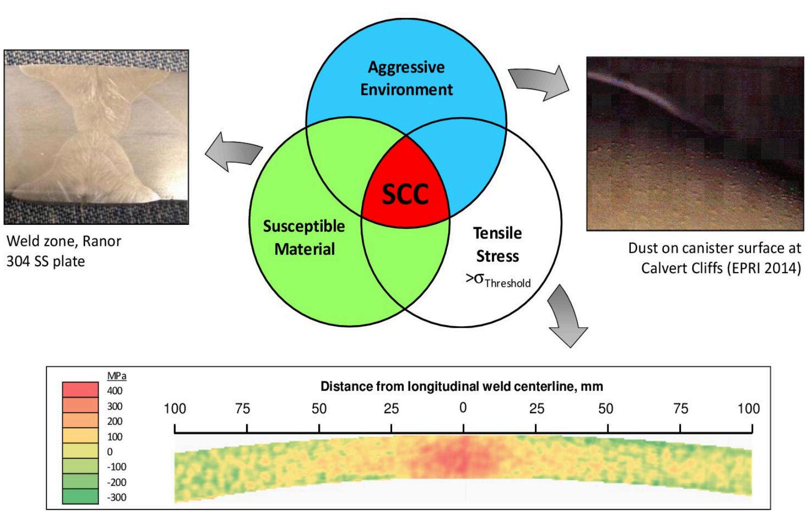
EVALUATING STRESS CORROSION CRACKING OF SPENT NUCLEAR FUEL STORAGE CANISTERS

Criteria for Stress Corrosion Cracking



Measured weld residual stresses (SNL 2016)

In the U.S., spent nuclear fuel (SNF) is stored in dry storage cask systems for long-term interim storage. The systems commonly consist of welded stainless steel canisters enclosed in ventilated cement or steel overpacks. These canisters may be required to perform their waste isolation function for many decades, and failure by chloride-induced stress corrosion cracking (SCC) due to deliquescence of deposited salt aerosols is a major concern. Stress corrosion cracking requires that three conditions be met—the material be susceptible to SCC, high tensile stresses be present, and a corrosive environment be present. SNF interim storage canisters are made of 304SS, which is known to susceptible to SCC. Moreover, recent work has verified that high tensile stresses are present in canister weld and heat-affected zones, and field sampling has confirmed that chloride-rich salt aerosols are present on canister surfaces at some near-marine sites. Once aqueous conditions develop through deliquescent of salt aerosols, localized corrosion can occur and SCC cracks may initiate, eventually penetrating the canister wall. To asses the time-dependent risk of canister failure by SCC, we have developed a probabilistic model that evaluates the evolution of the canister surface environment after placement into storage. The model first utilizes canister thermal models and ambient weather data to determine the timing of salt deliquescence and corrosion initiation. Following deliquescence, maximum pit sizes as a function of time are estimated from deliquescent brine film properties, which are in turn based on salt load, salt composition, and canister surface environment (T and RH). Maximum pit sizes and data for weld residual stress profiles are then used to determine timing of SCC crack initiation. Once initiated, crack growth rates are sampled from literature data as a function of temperature and through-wall tensile stress profiles, and are implemented using a time-of-wetness approach. Currently, available data do not allow accurate prediction of timing of canister failure; instead, the model is used to identify assumptions and parameter values that have the greatest impact on predicted storage canister performance, and to provide guidance for further research to reduce uncertainties.

Dr. Bryan is a geochemist and a Principal Member of the Technical Staff at Sandia National Laboratories. His expertise is in thermodynamic/geochemical modeling of aqueous systems, including concentrated brines formed by evaporation and deliquescence; geochemical modeling and experimental investigation of contaminant transport phenomena; and experimental characterization of geomaterials. He has over 20 years experience in the fields of nuclear waste storage and disposal, working on both the Waste Isolation Pilot Plant and Yucca Mountain repository programs. He developed the model used to predict the composition of seepage into emplacement drifts for the Yucca Mountain project. Dr. Bryan is currently studying the evolution of the chemical and physical environment on the surface of spent nuclear fuel dry storage canisters, and working to develop predictive models for the formation and growth of stress corrosion cracks (SCC) that could ultimately lead to canister failure. He is a member of the ASME task group currently developing a code standard for evaluation of SCC on in-service interim storage canisters.

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