Understanding the Risk of Chloride Induced Stress Corrosion Cracking

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Understanding and Addressing Data Gaps for Chloride Induced Stress Corrosion Cracking (CISCC)

- What is the environment on the surface of dry storage canisters and how does it evolve with time?
- Is there sufficient stress to support through-wall stress corrosion cracks, and if so, what is the magnitude?
- Generically, what are the crack growth kinetics given the known physical and environmental conditions of dry storage casks?
Samples acquired from three different nuclear power stations were provided by EPRI for analysis.

Dust and salt loads were high on canister upper surfaces, but low on vertical surfaces.

Near-marine site 1 (approximately 0.5 miles from brackish water)
- Soluble components largely calcium and sulfate with little chloride

Near-marine site 2 (approximately 0.25 miles from brackish water)
- Soluble components largely calcium, sulfate, and nitrate with little chloride

Marine site (approximately 0.35 miles from the ocean)
- Sea-salt aerosols, occurring as aggregates of NaCl and Mg-sulfate with trace amounts of K and Ca, were a major component of the dust samples.
Once deposited on the surface of a storage container, there are numerous processes that will affect the composition of the species that remain

- Gas to particle conversion reactions
- Acid degassing
- Ammonium mineral decomposition and brine degassing

On a hot canister, prior to deliquescence, NH$_4$NO$_3$ and NH$_4$Cl will not persist. If deposited, other chloride salts will accumulate, and (NH$_4$)$_2$SO$_4$ may accumulate.

However, upon deliquescence, brines containing NH$_4^+$ and NO$_3^-$ or Cl$^-$ will rapidly degas until either NH$_4^+$ or (NO$_3^-$ + Cl$^-$) are consumed.

Consider a deliquesced (NH$_4$)$_2$SO$_4$ brine:

$$(\text{NH}_4\text{)}_2\text{SO}_4 + \text{NaCl} \rightarrow \frac{1}{2}\text{Na}_2\text{SO}_4 + \frac{1}{2}(\text{NH}_4\text{)}_2\text{SO}_4 + \text{NH}_3(\text{g}) + \text{HCl}(\text{g})$$
Understanding the Residual Stress State in Fielded Dry Storage Containers

- Propagation of a stress corrosion crack requires the presence of a sufficiently large stress
  - Residual stresses associated with welds
  - Residual stresses associated with forming process
- Stresses will vary based upon the type of weld
  - Longitudinal vs. Circumferential
  - Weld repairs

Mock container assembled and being evaluated
- Deep hole drilling
- Contour measurement + x-ray diffraction
- Electrochemical properties

Once analyzed, container will be sectioned and used as samples for the UFD and NEUP programs

- Wall material: 304 SS (dual certified 304/304L) welded with 308 SS
- Geometry mimics NUHOMS 24P container
- Welds are Full penetration and inspected per ASME B&PVC Section III, Division 1, Subsection NB (full radiographic inspection)
Development of a Probabilistic Stress Corrosion Cracking Model for SNF Interim Storage Canisters

- Goal—identify most important parameters for evaluating canister SCC performance (penetration times). Used to prioritize research needs.

- Current model is simplified—not intended to accurately predict canister performance, but only to develop the functional form and data needs for the model.

- SCC model based on approach by Turnbull et al. (2006a, b)
  - Assumes SCC initiates from localized corrosion pre-cursors (corrosion pits)

- Submodels
  - Pitting initiation model
  - Pitting growth model
  - Model for pit-crack transition
  - Model for crack growth
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