Panel Discussion Implications of Dry Storage Canister Degradation

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Background

- Chloride Induced Stress Corrosion Cracking (CISCC) of stainless steels has occurred in applications other than dry cask storage with:
  - Surface contamination by atmospheric chlorides
  - Sufficient humidity
  - Elevated stress
- EPRI has inspected stainless steel dry storage canisters at three coastal sites
  - No evidence of gross degradation was observed
  - Inspection techniques not sufficiently advanced to rule out potential CISCC
- EPRI has a multi-year project to
  - Evaluate susceptibility to CISCC for welded stainless steel used fuel canisters
  - Develop related aging management guidelines
  - Scope of project is limited to extended storage, does NOT include transportation

Progression of Modeling

- Failure Modes and Effects Analysis
  - Qualitative judgments of degradation frequency/probability, detectability, and severity over time based on literature and limited calculations
  - Define boundaries of the degradation problem; guide approach to subsequent assessments
- Canister Flaw Growth and Flaw Tolerance
  - Model flaw growth to through-wall
  - Determine consequential flaw sizes
- Susceptibility Assessment Criteria
  - Identify the critical parameters affecting canister degradation based on the pathways identified in the FMEA
- Canister Confinement Integrity Assessment
  - Probabilistic analysis to determine the benefit of various monitoring, mitigation, and inspection regimes

Failure Modes and Effects Analysis

- FMEA confirms that CISCC leading to a through-wall crack should be the focus of aging degradation consideration
- Chlorides are most credible atmospheric species to cause degradation of austenitic stainless steels
- Investigation of consequences of confinement penetration
  - Crack releases helium and any fission gasses in the canister cavity; allows air to enter
  - Cracks are concerns for through-wall penetration and leakage but not concerns for rupture

Canister Flaw Growth and Flaw Tolerance

- Crack growth was modeled independent of crack initiation
- Crack growth model based on most relevant data
  - Substantial statistical conservatism applied to data in consideration of limited data set
  - Available data does not support crack growth rate dependence on SS material alloy, degree of salt loading, or stress intensity factor
    - Model assumes initiation has occurred due to the presence of these factors
- Crack growth rate equation models dependence on temperature and humidity
- Canisters are highly flaw tolerant under typical loads and under accident pressure
  - Critical flaw sizes are longer than one meter (for hypothetical through-wall flaws) or deeper than 80% (for hypothetical full circumferential flaws)
- Depressurization (loss of helium down to atmospheric pressure) will be relatively rapid compared to the time for air ingress (it will likely take years to replace helium with air)

Susceptibility Assessment Criteria

- ISFSI Susceptibility Ranking (Z_{ISFSI})
  - Direct resources to locations where CISCC is more likely to occur
  - Results from sites identified as more susceptible may help to refine aging management recommendations (improve technical basis, identify bounding locations)
  - Proximity to chloride source and local absolute humidity are key variables
- Canister susceptibility ranking (H_{CAN} and V_{CAN}) intended to identify canister(s) to be inspected at a given site and to guide scope expansion if needed
  - Geometry (horizontal or vertical) affects locations of maximum chloride deposition and locations of minimum temperature
  - Canister material, storage duration, and fuel load power are key variables

Publicly Available EPRI Reports

- December 2013
  - *Failure Modes and Effects Analysis (FMEA) of Welded Stainless Steel Canisters for Dry Cask Storage Systems*. 3002000815.
- May 2014
  - *Literature Review of Environmental Conditions and Chloride-Induced Degradation Relevant to Stainless Steel Canisters in Dry Cask Storage Systems*. 3002002528.
- October 2014
  - *Flaw Growth and Flaw Tolerance Assessment for Dry Cask Storage Canisters*. 3002002785.
- Coming in 2015
  - *CISCC Susceptibility Assessment Criteria*
  - *Canister Confinement Integrity Assessment*

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