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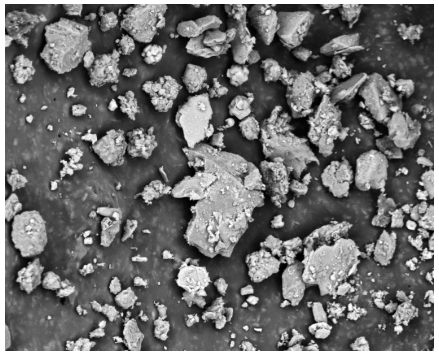

Key Data Gaps in Assessing the Chloride Induced Stress Corrosion Cracking of Interim Storage Containers for Spent Nuclear Fuel

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U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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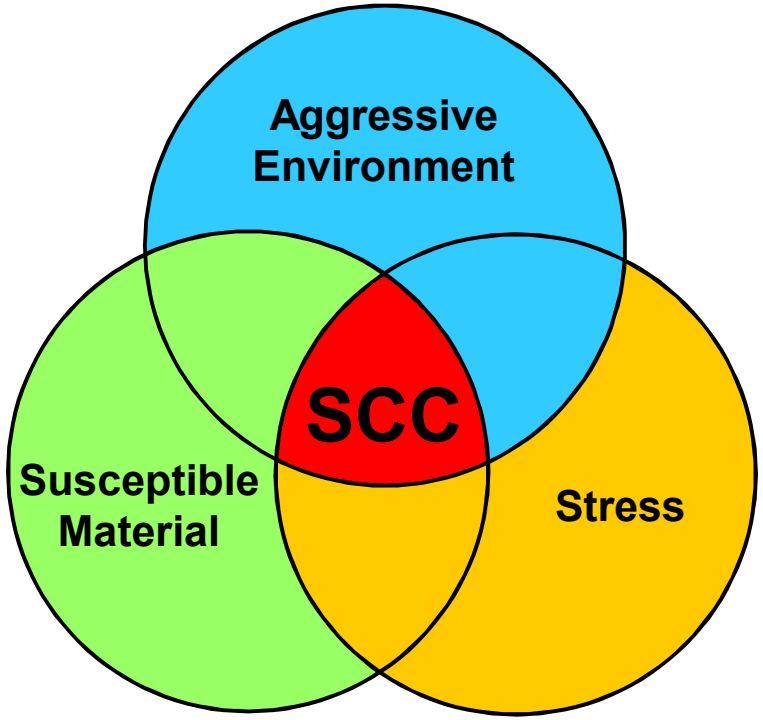
Degradation Mechanism of Concern: Stress Corrosion Cracking (SCC)



Issue: State of understanding of effectively all aspects of the crack initiation and growth process poorly understood. Lack of realistic data leads to highly conservative predictions.

Panel Members and Rationale

- Assemble panel of individuals whom are well known and respected researchers in the area of localized corrosion and stress corrosion cracking of stainless steels.

- Dr. Peter Andresen (GE Global Research Center)

- Dr. Robert Kelly (University of Virginia)

- Dr. John Scully (University of Virginia)

- Dr. Alan Turnbull (National Physical Laboratory)

Outline

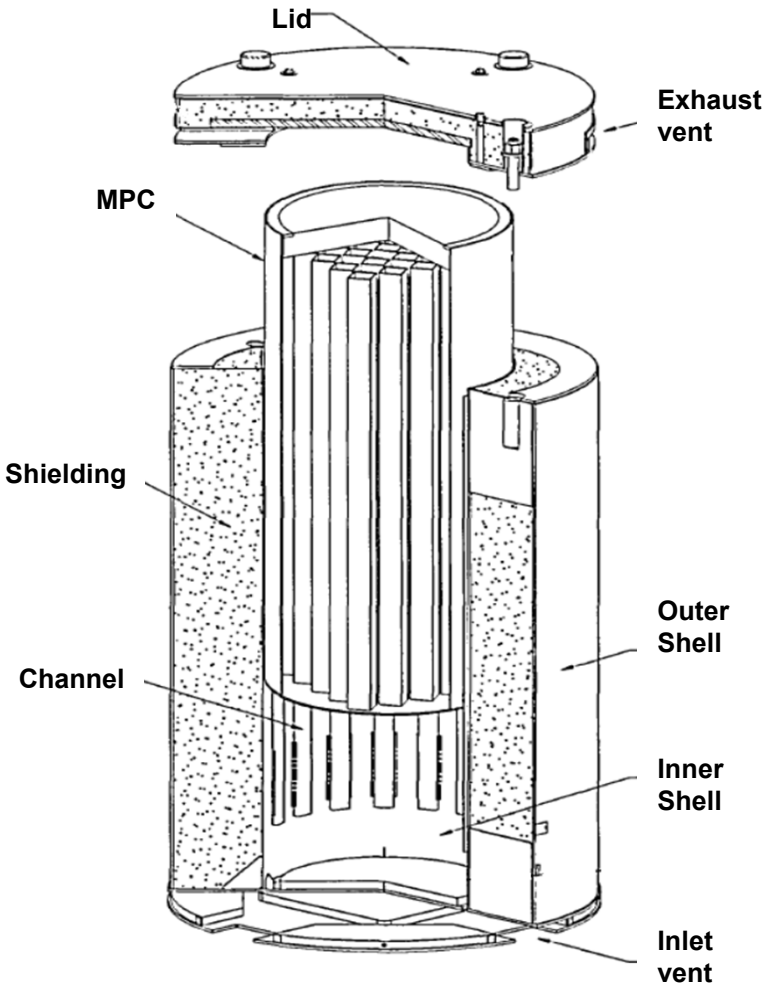
- Discussion of the guidance currently being provided to ISFSIs as they approach license renewal

- Broke topic down into 4 areas
  - Environmental conditions
  - Localized corrosion
  - Pit to crack transition
  - Crack growth rate

- Assembled recommendations of the panel to help define a path forward

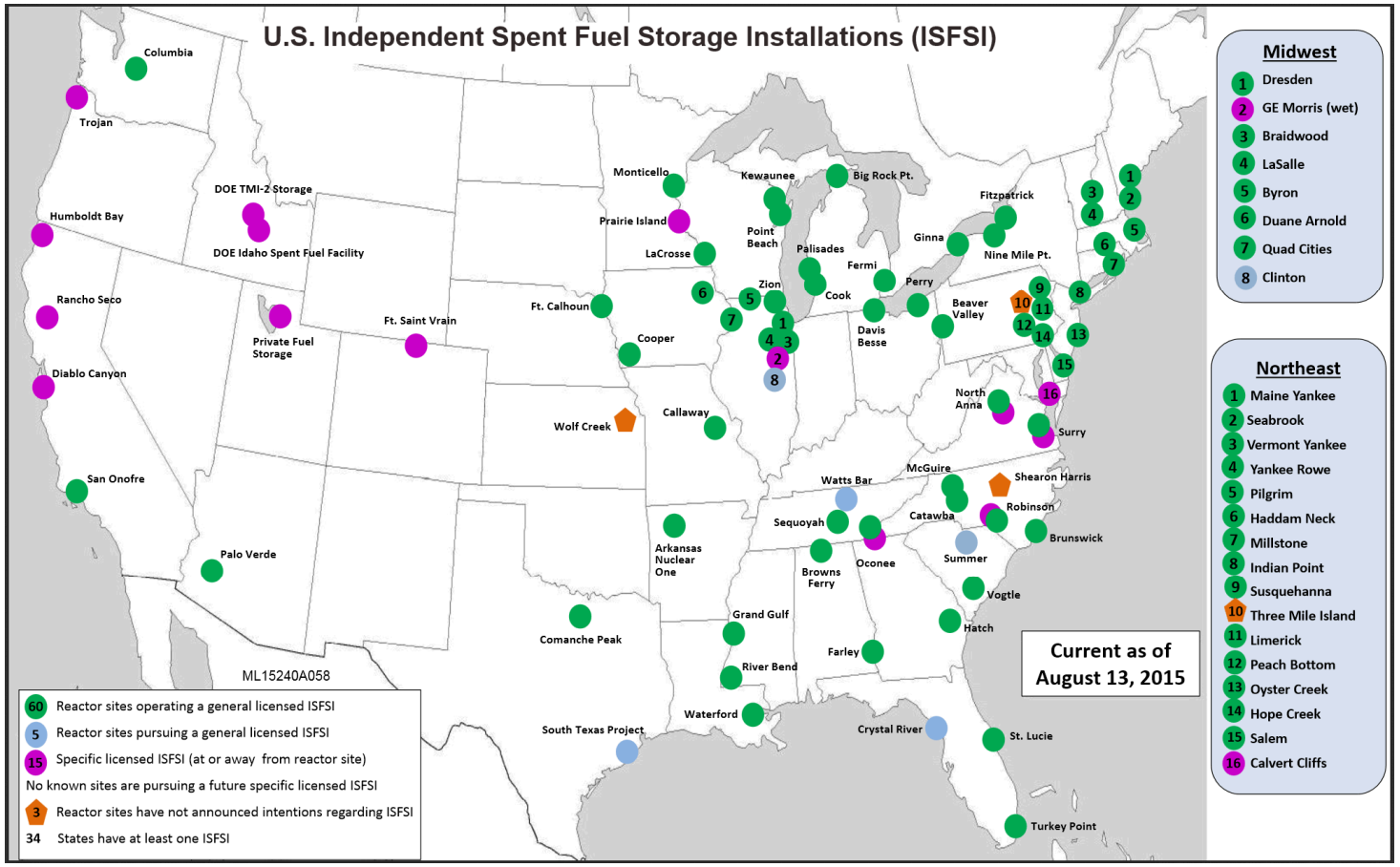
Inspection

- First dry storage fielded in 1986 at the Surry reactor
- Licenses initially approved for 20 year periods
- As the fuel sits, deposits build up and temperatures go down – SCC may become viable degradation mode
- License renewal requires inspection of at least one system (lead system)
- License extension requires an aging management program (AMP)
  - Inspections at least once every 5 years
  - Regions of most interest are welds



Environment

- ISFSI sites in variety of locations, yielding a range of weather conditions and potential salt deposition chemistries.

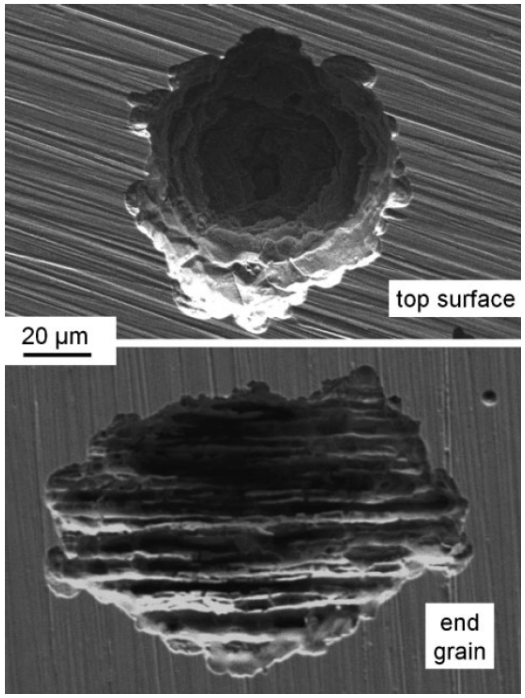


- Environment must be understood such that SCC behavior is assessed under relevant conditions, rather than unreasonable extremes

Localized Corrosion

- ***Understanding window of conditions where stable localized corrosion can initiate is critical in predicting performance***

- Crack initiation under conditions relevant to dry storage requires the presence of an active localized corrosion site.
- For fielded structures, pits appear to have a limiting size.
  - Pit density may increase with time, but maximum depth appears to plateau.
  - Function of exposure conditions and alloy composition.

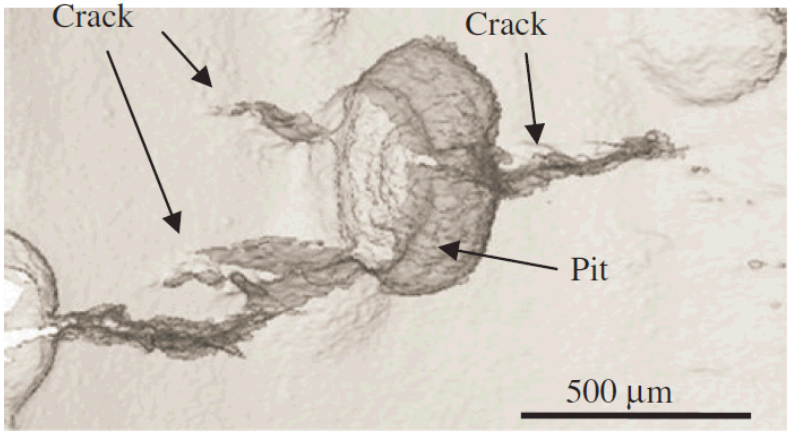


Davenport, et al, Corrosion Engineering, Science and Technology, Vol 49, no. 6 (2014), 514-520

- Pits expected to nucleate, grow, and repassivate.
  - Repassivated pits unlikely to reinitiate.
  - Repassivated pits behave differently than the surrounding surface.

Pit to Crack Transition

- ***Critical conditions under which SCC can take place are poorly defined and difficult to establish***
- Localized corrosion sites play key role in crack initiation
  - While likely to be key nucleation sites, not necessarily only nucleation site

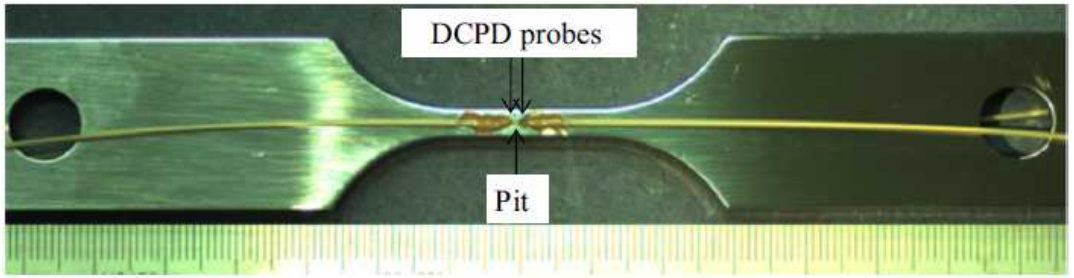


Horner, et al, Corrosion Science 53 (2011) 3466-3485

- Concept of a critical temperature below which cracking does not occur has been demonstrated to be incorrect
  - Other mechanisms may become dominant at lower temperatures (e.g., hydrogen embrittlement)
- Crack initiation is not a fast process
  - Crack embryo forms, but is slow to reach critical size and may be overcome by localized corrosion or run out of mechanical driving force

Crack Growth Rate Measurement

- SCC processes are complex
  - Experimental studies often flawed.
  - Hinders the ability to identify interdependencies
  - Flawed approaches can generally not be overcome by statistics
- Large number of variables and extended time periods over which LC and SCC take place, hinders use of a traditional DOE.
  - Don't get too greedy in terms of test to test variations or in efforts to simulate all the complexities of the system
- Inundated experiments using traditional fracture mechanics approaches invaluable in understanding key parameters
- Non-traditional samples often fail to deliver high fidelity CGR data.



Zhou, et al. Corrosion Science,97 (2015), 25-37.

Recommendations from the Panel

- Consider what a model needs to tell you, as that dictates its structure. (Turnbull)
- Accurate kinetic data that must be acquired under representative environmental conditions needed to predict LC behavior. (Kelly)
- Proof of principle tests critical in establishing experimental capabilities. (Andresen)
- Don’t get greedy in defining experimental test matrix – keep it simple. (Andresen)
- Non-standard test specimens need to be modeled and understood. (Andresen)
- Divide and conquer - Formation of a series of small working groups should be considered. (Andresen)