Some Key Corrosion Issues Identified in the 1997 Waste Package Degradation Expert Elicitation Project

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United States Nuclear Waste Technical Review Board Meeting
October 23, 1997

Overview

- A plausible set of "corrosion scenarios" have been defined for the current waste package design (WP):
  - corrosion phenomena governing WP damage evolution have been identified.
  - a flow chart (logic tree) defining conditions that make certain corrosion scenarios more likely has been developed.
- A lack of accurate definition of near field and local (WP) environment composition, its evolution with time, water drip rate and spatial distribution of drips is the <u>greatest overall shortcoming</u> to accurate WP degradation performance assessment
  - an accurate definition must define water hydrology as well as effects of concrete, wet/dry cycling, corrosion products, etc.

Overview - continued

❑ Steel CAM oxidation rates, humid air corrosion rates, and aqueous corrosion rates are well-defined in TSPA-95. Threshold %RH's are reasonably defined. Localized corrosion processes are not well-defined in TSPA-95.

❑ Uncertainties in the nature of various probabilistic and deterministic localized corrosion damage functions do not present intractable scientific issues for the "corrosion community" to address. *(e.g. the field of localized corrosion doesn't have to be invented before localized corrosion damage functions can be defined).*

- ❍ Localized corrosion probabilistic (PDF's, CPD's) and deterministic functions (growth laws) could be defined after a 1-4 year period of study.

- ❍ A few unresolved scientific corrosion issues do require a 3-6 year period of study.

Comments on TSPA-95 approach and current on-going research efforts

Modeling approach in TSPA 95

❑ Accurate definition of near field and local (WP) environment and its evolution with time is the greatest overall shortcoming to accurate WP degradation performance assessment.

❑ CAM dry oxidation, humid air, and aqueous corrosion rates under drips, hygroscopic salts, thin aqueous films seem reasonable

- a ~4x pitting factor applied to uniform penetration is not reasonable; technical justification for leveling exists

❑ A more conservative estimate of local WP electrolyte composition is a saturated salt solution from evaporated drips; this differs from utilization of the composition of J-13 well water x100, x1000, etc.

❑ Galvanic suppression of CRM corrosion depends critically on thickness of electrolyte layer, drip frequency, CAM corrosion front morphology, etc., but appears to be too short to significantly impact waste package degradation.

❑ The TSPA-95 assumption of localized corrosion penetration rate, pit area densities, and diameters for CRM inner barrier lack strong technical justification.

Comments on TSPA-95 approach and current on-going research efforts

On-going research and testing presented

- ❑ Current research efforts would benefit from modification of objectives and outputs to yield data that can better contribute to a probabilistic corrosion degradation model incorporating corrosion damage evolution based on CPD's, etc.

  - Localized corrosion studies best provide relative rankings of candidate CRM materials. This data is not readily "abstracted" to a probabilistic model of localized corrosion damage evolution.

  - Galvanic corrosion studies do not address galvanic interaction in a thin aqueous film, under dripping, nor with episodic wetting/drying. Full immersion data is not readily "abstracted" to a probabilistic model of corrosion damage evolution that seeks to take credit for galvanic suppression under drips.

  - Current MIC studies emphasize role of MIC on uniform corrosion of CAM (acknowledging that the passive dissolution rate of CRM is not affected by MIC). However, should consider refocus to understanding the effects of MIC on localized corrosion initiation (e.g. biofilm-induced potential ennoblement).

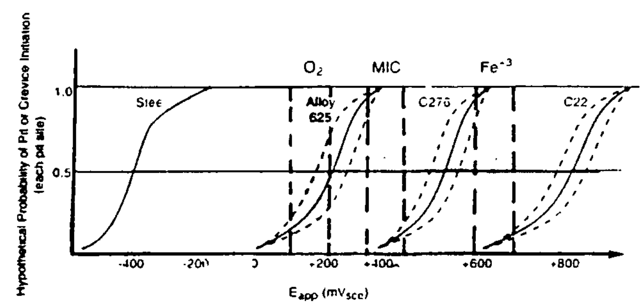
Corrosion phenomena with the greatest current uncertainties that may have the most significant impact on performance assessment

- ❑ Probabilistic and deterministic aspects of CRM localized corrosion (i.e. pitting and crevice corrosion initiation probabilities and growth rates) must be better defined.

  - establish localized corrosion site initiation probabilities, pit or crevice site densities, growth rates, and repassivation criteria (stifling criteria) for CRM materials.

- ❑ Establish a rational technical basis and conditions for crevice, pitting, and stress corrosion repassivation (i.e. stifling criteria for propagating sites).

- ❑ Determine the impact of microbial activity at drip sites (e.g. electrochem. potential ennoblement, other effects) on localized corrosion processes (if any).



Corrosion phenomena with the greatest current uncertainties that may have significant impact on performance assessment

- Probabilistic and deterministic aspects of localized corrosion processes on the steel CAM in alkaline environments (i.e. pitting and crevice corrosion initiation probabilities and growth rates) must be defined.

  -Establish pit densities, growth rates, and repassivation criteria (stifling) for high aspect ratio pits, if high pH drip scenario is validated.

  - Determine passive dissolution rates as a function of pH, electrolyte composition.

$$d = At + B\,t_e^{\,n+1}$$

- Scientific issues that have impact on spatial distributions of damage should be addressed:

  1. Do localized corrosion sites interact positively or negatively (if at all)?

  2. What are the rules for coalescence of localized corrosion sites?

  3. How many monolayers of water are required for the humid air (99-100% RH) corrosion rate of the CAM to equal that observed in bulk water under drips?

Corrosion phenomena with the greatest current uncertainties that may have some impact on performance assessment

- 100-200°C oxidation behavior of the CAM steel; establish whether growth laws are logarithmic or parabolic and the oxide growth, epitaxy, and thickness conditions that promote spalling.

  - Spalling affects dry oxidation rate, but humid air, aqueous uniform, and/or pitting corrosion are likely the rate determining stages for steel CAM penetration.

  - Spalling only marginally effects pitting initiation probabilities. Compact oxide barriers do not radically improve pit initiation probabilities and may actually promote pit stabilization.

- Determine whether high rate corrosion processes can occur over sustained periods in thin electrolyte films with voluminous corrosion product development.

  - how many monolayers of water are required to support "bulk" aqueous corrosion processes on steel?

  - what is the distance of galvanic interaction as a function of electrolyte film thickness and composition?

  - Do galvanic interactions apply only to drip sites? If so, the period of galvanic suppression might be 10^3 years of *"actual time"* for 10^2 years of *"drip time."*

Comments regarding the Waste Package Degradation Expert Elicitation Project

- ❑ Time frame for WPDEE was too compressed for optimal input from experts.

- ❑ Corrosion scenario development, research studies, probabilistic model development, and, ultimately, performance assessment would benefit from multiple research efforts in industry, national labs and universities: Examples:

  Aging aircraft
  Government agencies: Airforce, Navy, FAA, NASA
  Industry: Alcoa, Boeing, Coating Companies
  University: UVa, OSU, Lehigh, SUNY, etc.
  Government Labs: NASA-Langley, Wright-Patterson, BNL, Sandia, etc.

  Joint Industry Program: Steel pressure vessels in hydrogen service in the petrochemical industry
  Industry: 10 oil co., 4 steel co., 2-3 pressure vessel co.
  Labs: 3 labs in 2 countries performing hydrogen embrittlement studies

- ❑ Technical society symposia and refereed journal articles are providing a valuable external audit in these cases