Risk Assessment of Uniform Corrosion and Localized Corrosion of Alloy 22

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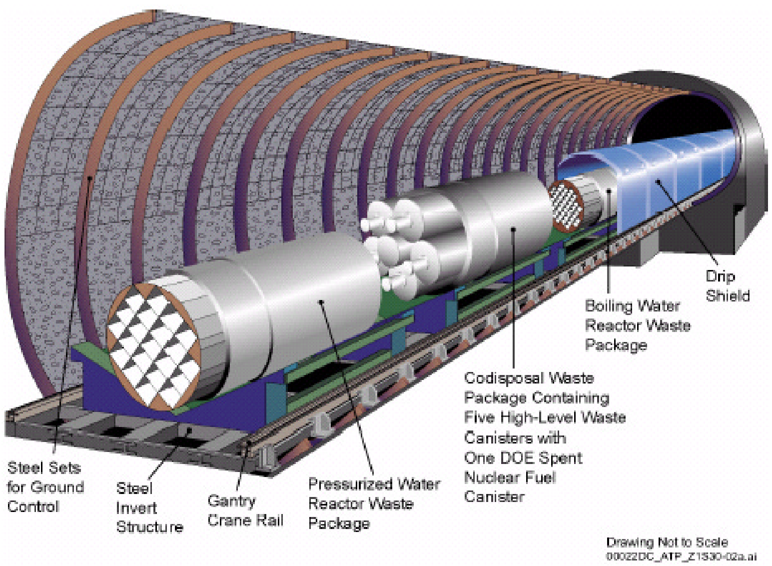
OBJECTIVES

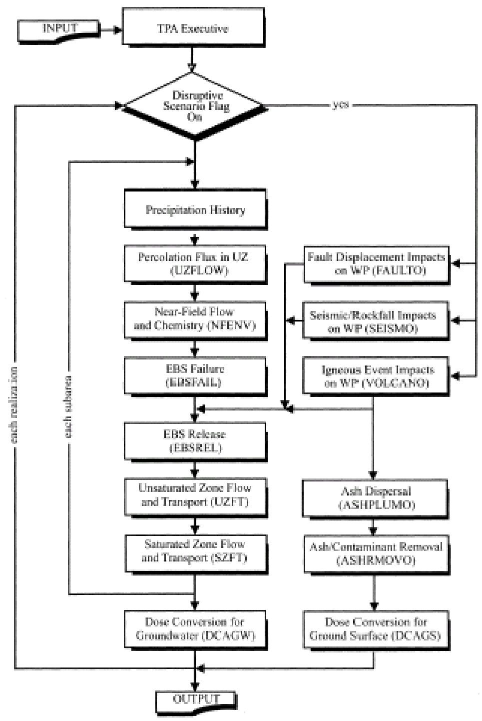
Conduct Sensitivity Studies of Localized Corrosion and Non-passive Uniform Corrosion of Alloy 22 with Nuclear Regulatory Commission (NRC)'s Total-system Performance Assessment (TPA) Code

- **severe chloride solution**
- **high temperature deliquescence point of salts**
- **fabrication-induced microstructural alteration**
- **inhibitor effects**
- **controlled release through pits**
- **anodic sulphur segregation and long-term development of surface roughness**

REPOSITORY AND ENGINEERED SYSTEM NRC'S TOTAL-SYSTEM PERFORMANCE ASSESSMENT (TPA) CODE



Schematic Illustration of the Emplacement Drift with Cutaway Views of Different Waste Packages (DOE, 2002)



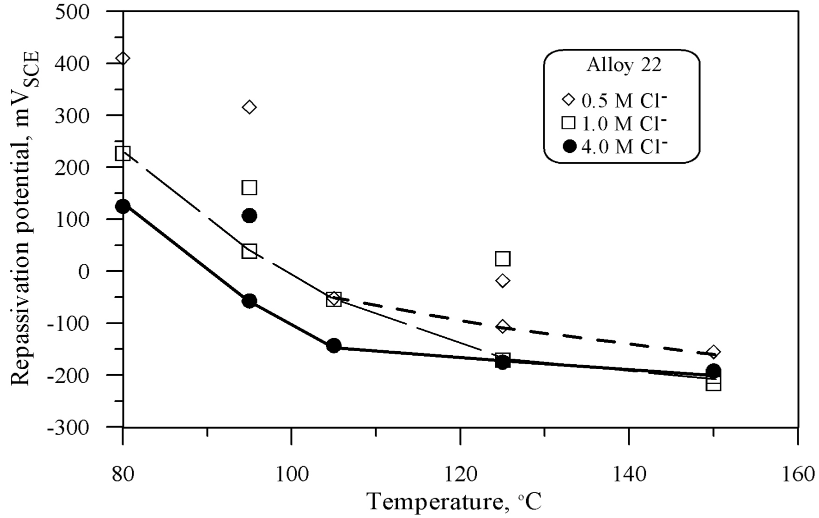
Flow Diagram for TPA Version 4.0 Code (Mohanty et al., 2002)

LOCALIZED CORROSION

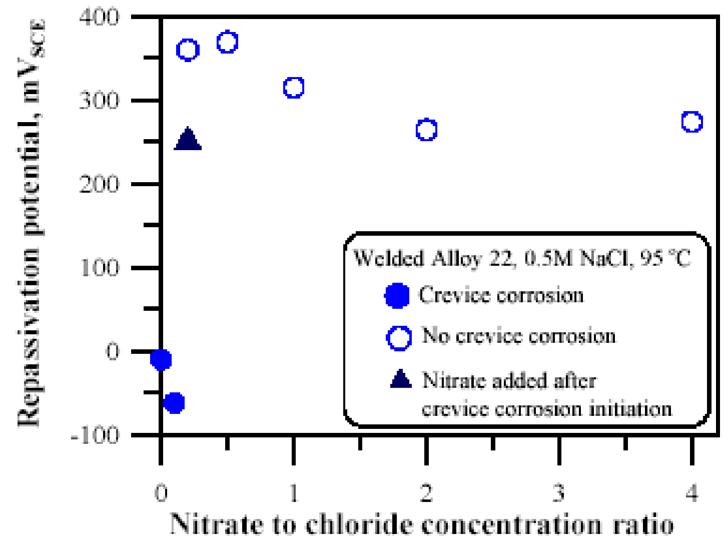
- Sensitivity study of the effect of critical relative humidity – Some salts deliquesce at a low RH.
- If $RH_{environment} > RH_{lowerCriticalAqueousCorr}$ localized corrosion occurs.

	Range of Critical RH for Aqueous Corrosion
Base (Drip Shield Included)	0.60 – 0.65
Modified (High Temperature Deliquescence of Salts	0.35 – 0.60

LOCALIZED CORROSION (Repassivation Potential)



(Brossia et al., 2001)



(Dunn et al., 2002)

Temp effect on the repassivation potential crevice corrosion of Alloy 22 in Cl^- solutions data was integrated into modified corrosion potential equation parameter set in TPA.

Data from $[NO^3]/[Cl^-]$ experiment was used to empirically determine new values for the repassivation potential equation (the inhibitor effect)

LOCALIZED CORROSION

(Modified Criteria)

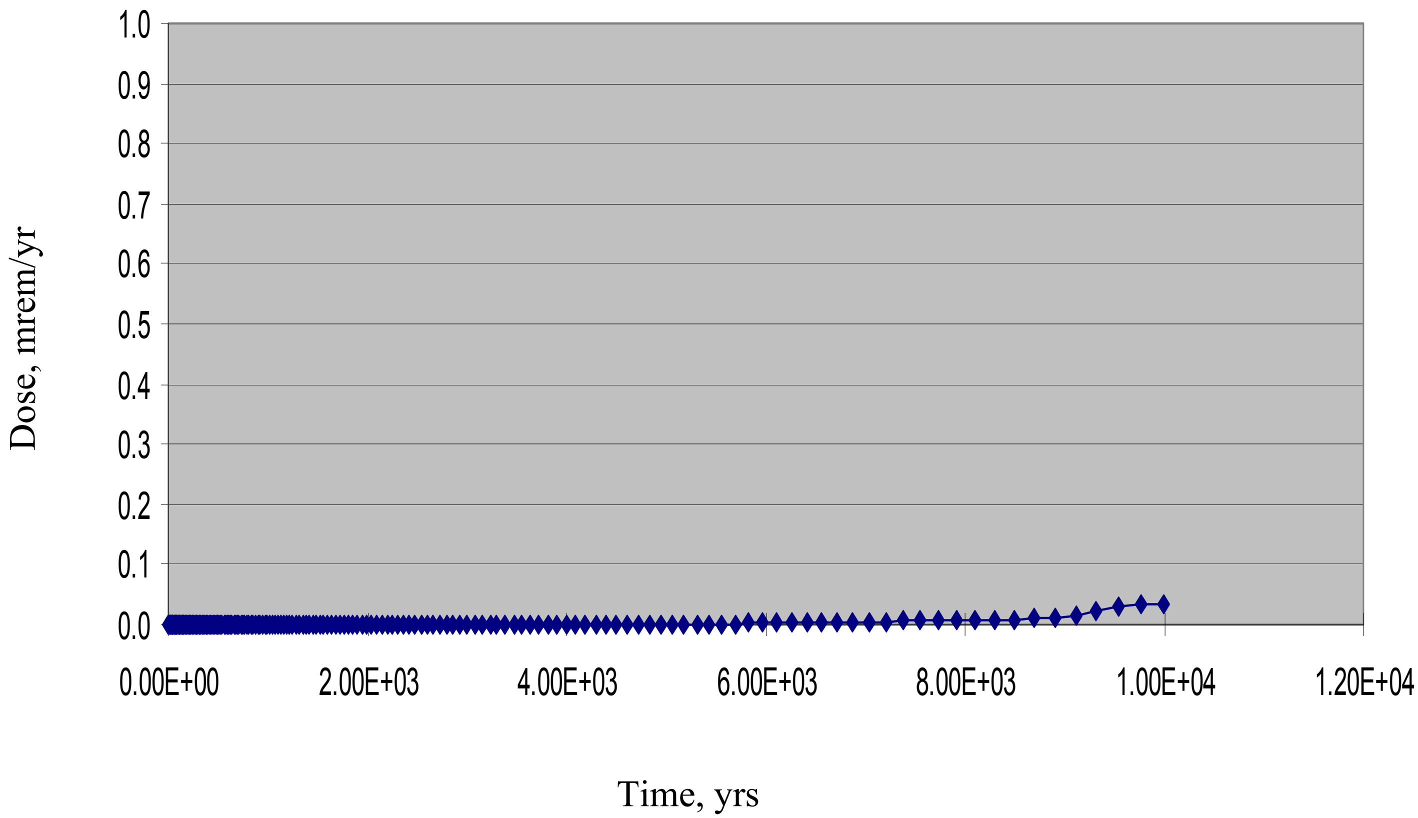
- $E_{repass} = E_o crit\ (T) + B(T) \log[Cl^-]$
  - $E_o crit\ (T) = A_1 + A_2 T$
    - OuteroverpackErpIntercept, A_1 (mV_{SHE})
    - TempCoefOfOuterPackErpIntercept, A_2, ($mV/^oC$)
  - $B(T) = B_1 + B_2 T$
    - OuterOverpackErpSlope, B_1 (mV)
    - TempCoefOfOuterPackErpSlope, B_2 ($mV/^oC$)

    Critical Corrosion Equation Values
- Nearly constant with sufficient concentration of inhibitors are present

LOCALIZED CORROSION

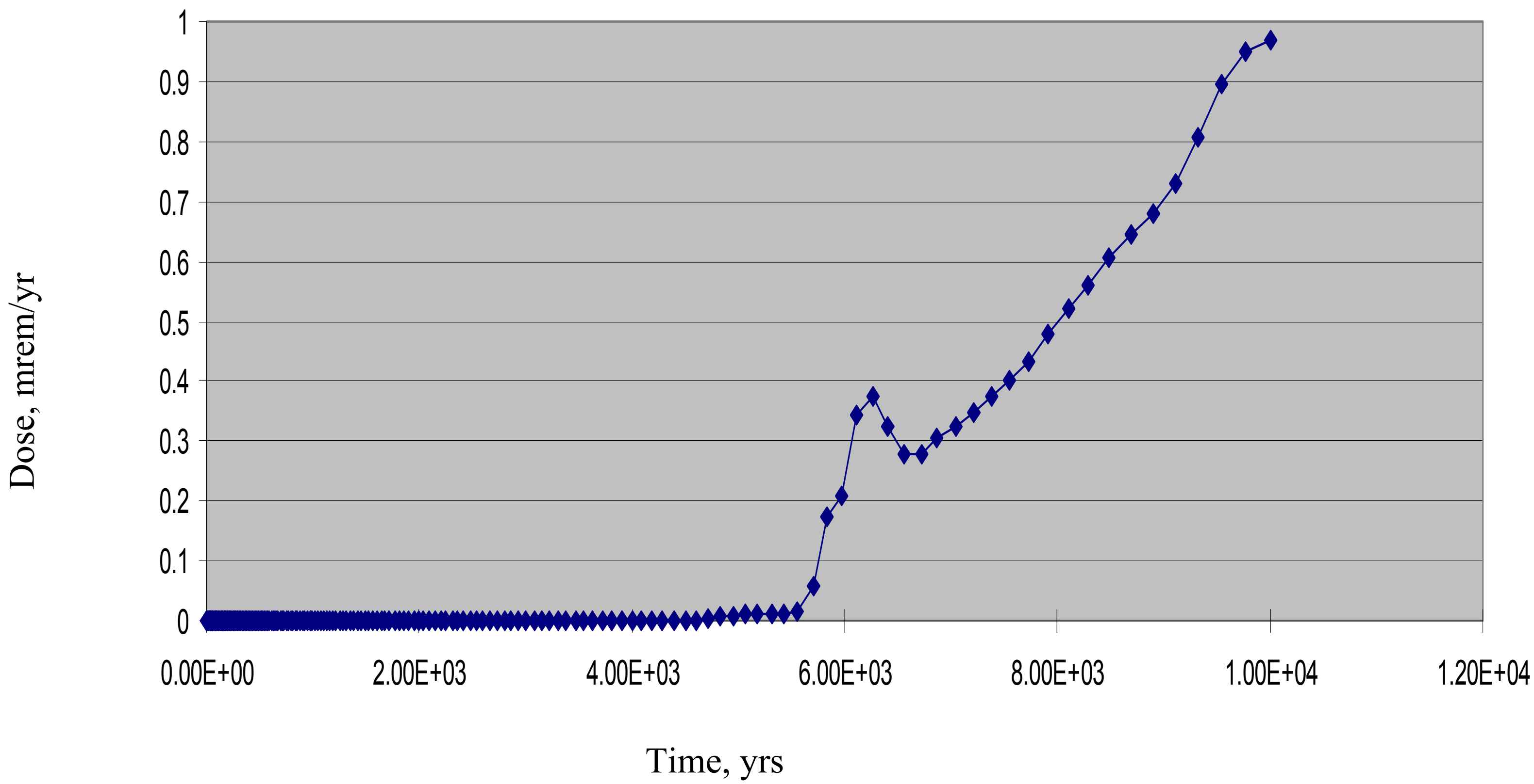
	Repassivation Potential Parameters			
	A_1 (mV_{SHE})	A_2 ($mV/^oC$)	B_1 (mV)	B_2 ($mV/^oC$)
BASE	2006.0	-15.2	-590.7	4.3
MODIFIED (more data added and fitting refined)	1541.0	-13.1	-362.7	2.3

Base Case



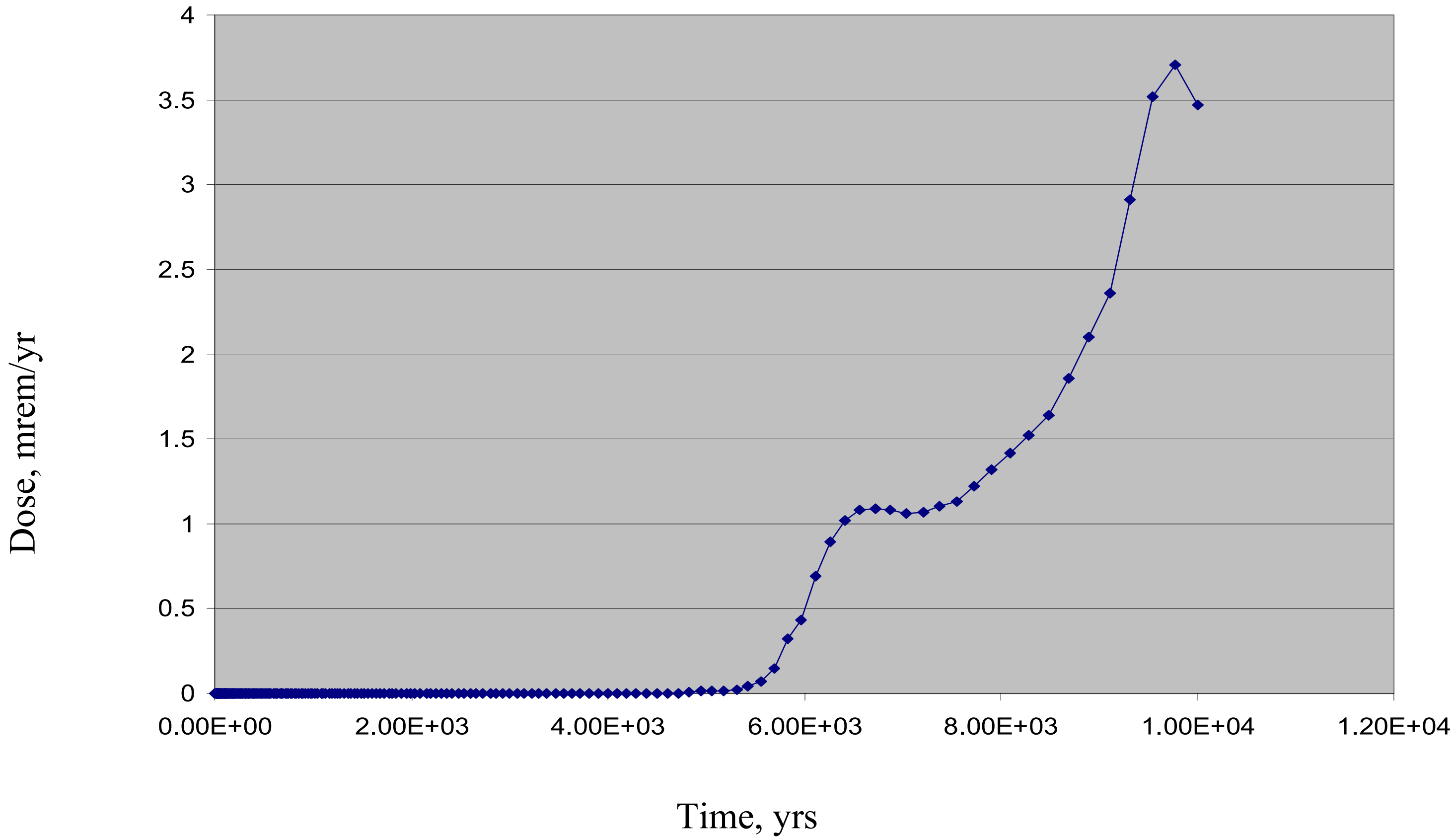
Dose from corrosion/juvenile failure – manufacturing defects, human error, etc.

Base Case, Lowered Critical RH (High Temperature Deliquescence of Salts), No Nitrates



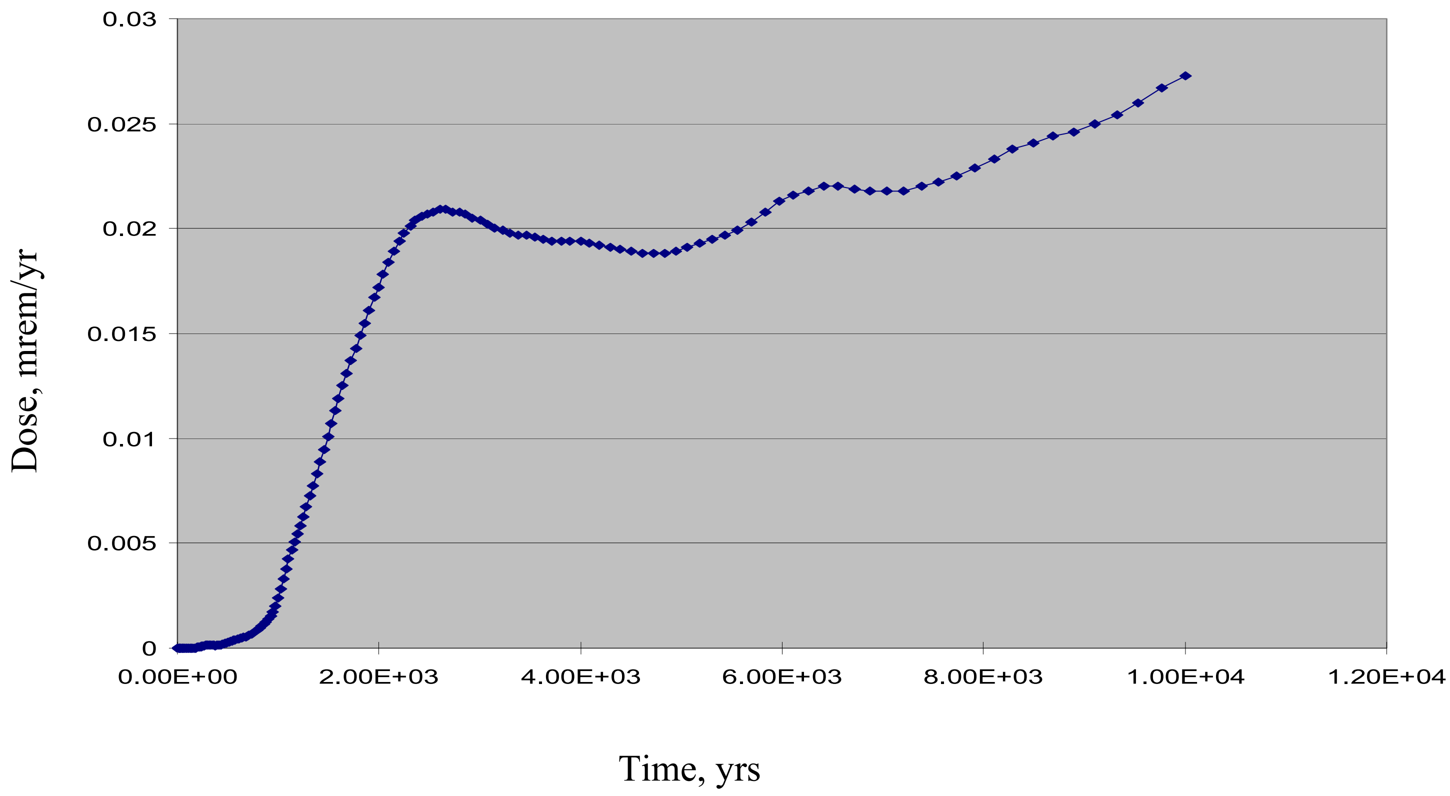
Dose from corrosion/juvenile failure – manufacturing defects, human error, etc.

Modified Equation, Base Case, No Nitrates



Dose from corrosion/juvenile failure – manufacturing defects, human error, etc.

Modified Equation, Base Case, No Drip Shield, With Nitrates



Dose from corrosion/juvenile failure – manufacturing defects, human error, etc.

LOCALIZED CORROSION CONTROLLED RELEASE THROUGH PITS

- **Overall Factor = 10^{-9}, 1" log uniform distribution**

(Pits)

- **Size: (10^{-4} – 10^{-1}) cm^2**
- **Density: (0.1 – 100)/cm^2**
- **Fraction:**

$$(10^{-4}\ cm)^2 \times 0.1/cm^2 = 10^{-9}$$

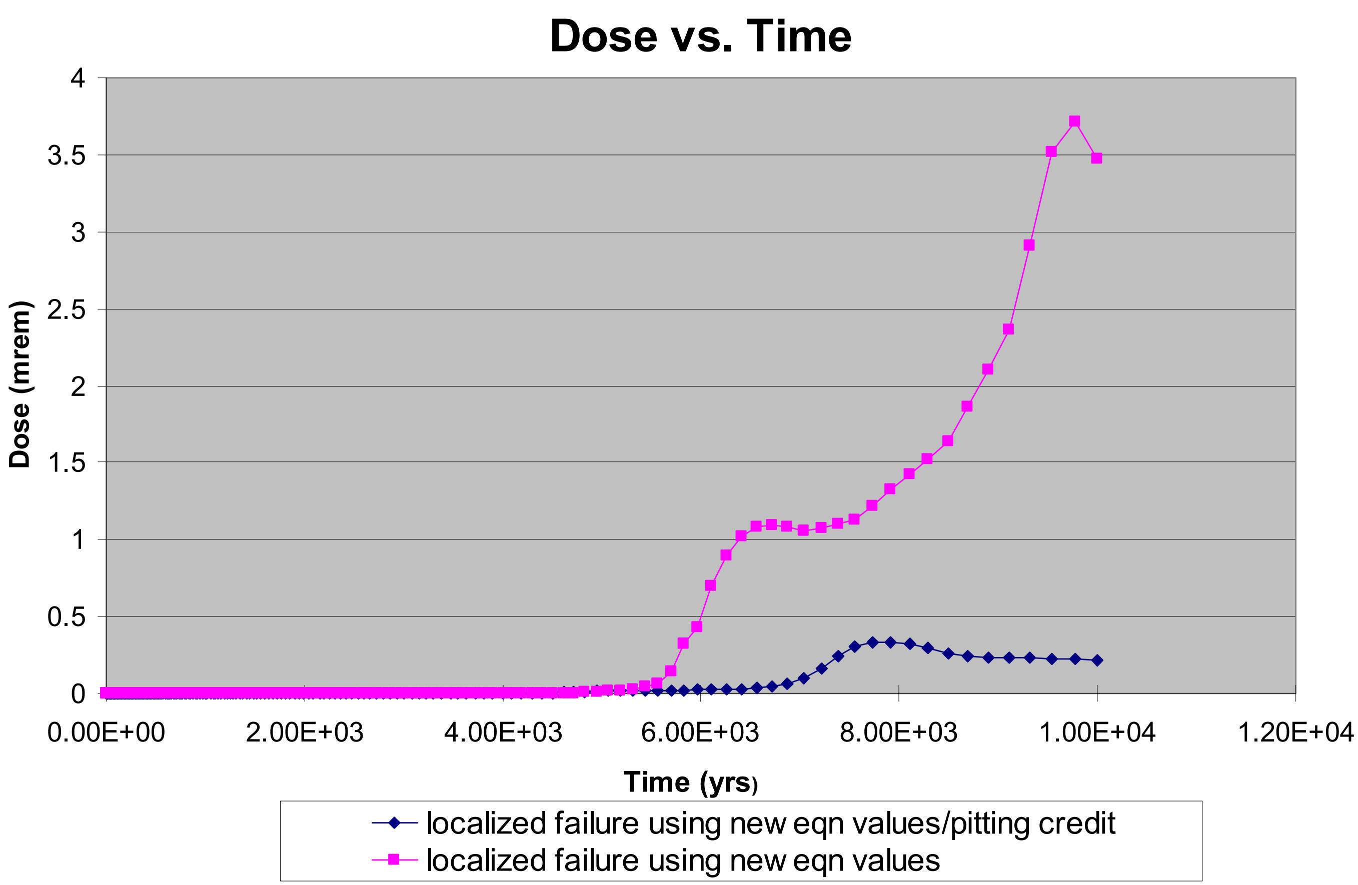
$$(10^{-1}\ cm)^2 \times 100/cm^2 = 1$$

(Stress Corrosion Cracks)

- **Size: (25 x 1.02) cm^2 = 25.5cm^2**
- **Fraction: 25.5cm^2/WP / WP surface area 2.3×10^5 cm^2 = 1.1×10^{-4}**

From Ahn (1994), Esh (2002)

LOCALIZED CORROSION CONTROLLED RELEASE THROUGH PITS



DEVELOPMENT OF LONG-TERM STATISTICAL SURFACE ROUGHNESS AND SULFUR SEGREGATION

- Cyclical process of degradation
- Periods of slow (passive) corrosion due to passive layer formation are followed by anodic sulfur segregation and sloughing of the passive layer
- Then fast (non-passive) corrosion occurs in those areas before they repassivate.

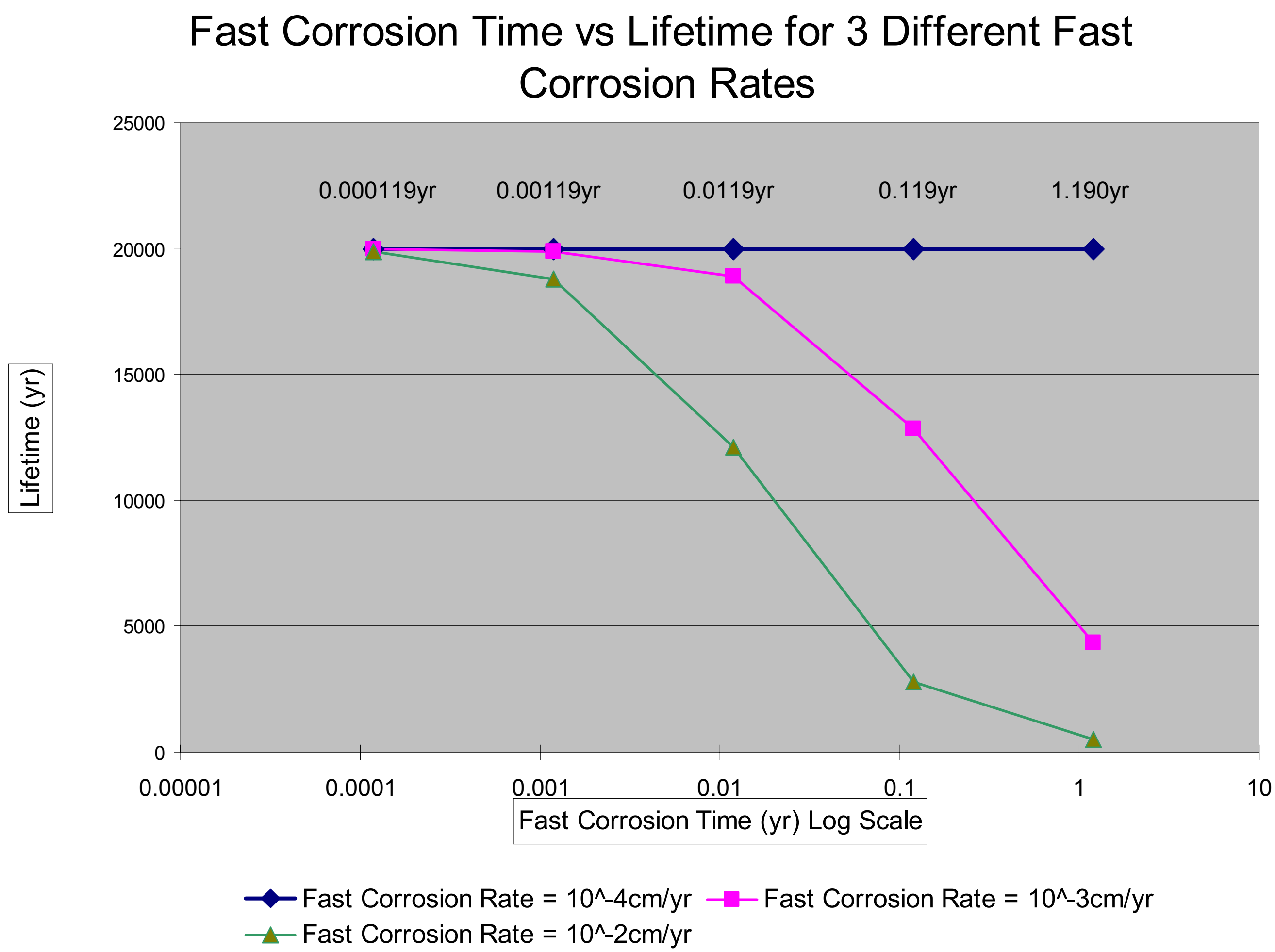
DEVELOPMENT OF LONG-TERM STATISTICAL SURFACE ROUGHNESS AND SULFUR SEGREGATION

- Penetration Depth = $\Sigma[CR_f * Ct_f + CR_p * Ct_p]$
- CR_f = fast corrosion rate
  Varied ~ $10^{-4} – 10^{-2}$ cm/yr
- Ct_f = fast corrosion time (1)
  Varied ~ 0.000119 – 1.19 yr
- CR_p = passive corrosion rate (1)
  10^{-4} cm/yr
- Ct_p = passive corrosion time (2)
  1.8 yr
- Process repeated until 2cm of container thickness corroded.

(1) From *Repassivation Kinetics*, Brossia et al., 2001

(2) From *Sulfur Segregation Time*, Jones, 2002

DEVELOPMENT OF LONG-TERM STATISTICAL SURFACE ROUGHNESS AND SULFUR SEGREGATION



CONCLUSIONS

- Lowering the critical RH for the Base Case (no nitrates) and Modified case for the repassivation potentials resulted in an increase in dose.

- The modified repassivation equation with nitrates incorporated resulted in a lower dose.

- WP failure by sulfur segregation is not expected based on the unrealistic combination of fast corrosion rates and recurrence frequencies necessary to breach the outer container.

References

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- S. Mohanty, T. McCartin, and D. W. Esh, Total-System Performance Assessment (TPA), Version 4.0 Code: Module Descriptions and User's Guide, Center for Nuclear Waste Regulatory Analyses, San Antonio, Texas, 2002
- U.S. Department of Energy, Yucca Mountain Science and Engineering Report, DOE/RW-0539, 2001

NOTE: The NRC staff views expressed herein are preliminary and do not constitute a final judgment or determination of the matters addressed or of the acceptability of a license application for a geologic repository at Yucca Mountain. This presentation is also an independent product of the Center for Nuclear Regulatory Analyses and does not necessarily reflect the view or regulatory position of the NRC**.**