U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING

SUBJECT: WASTE PACKAGE DEGRADATION MODELING AND ABSTRACTION FOR TSPA-1995

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ARLINGTON, VIRGINIA
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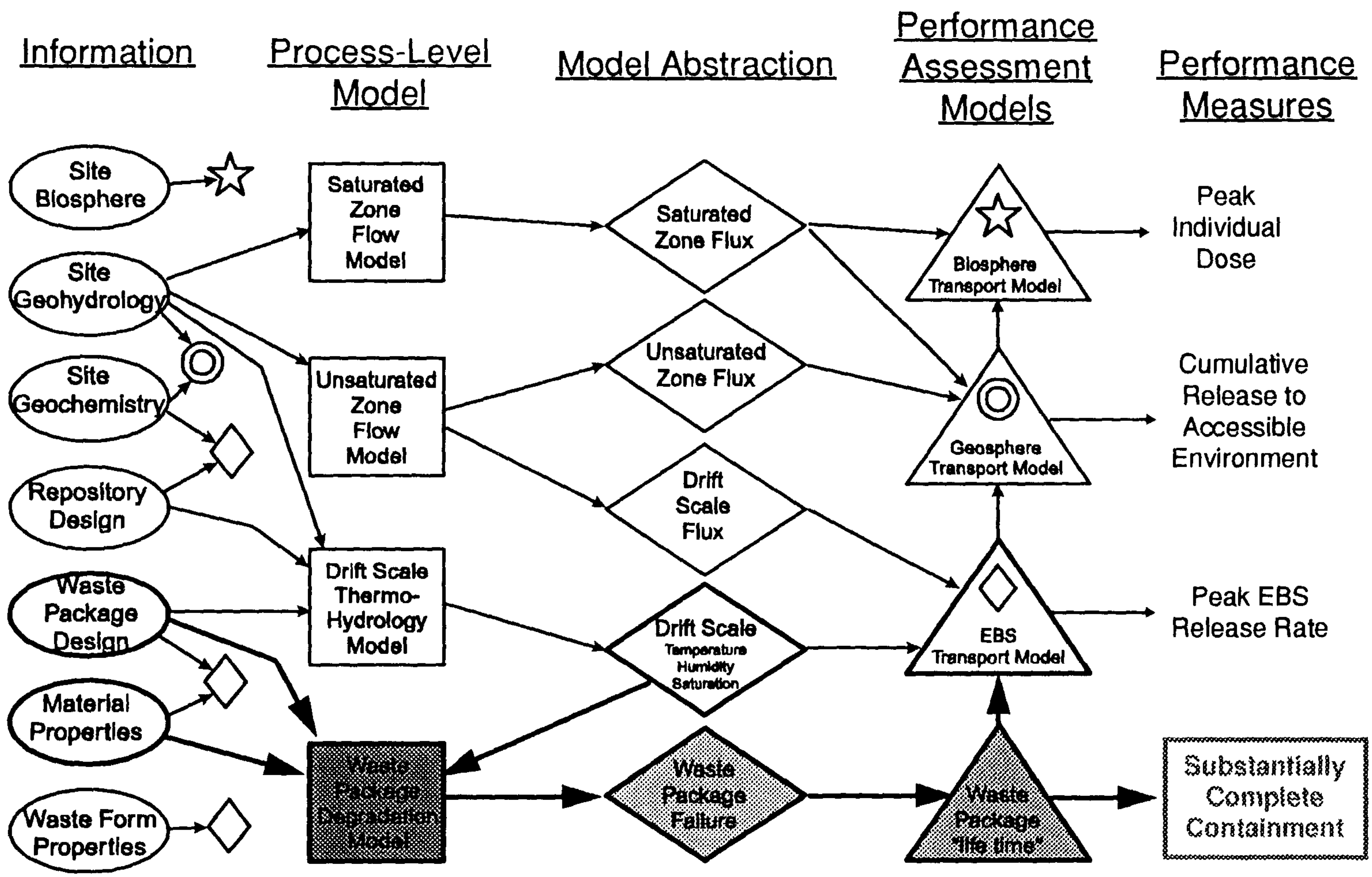
TSPA-1995 Information Flow Diagram
(Waste Package Degradation Modeling)



Objectives

- Assimilate relevant corrosion degradation data for similar containment barrier materials in similar environments
- Develop corrosion models for the containment barrier materials
- Implement the corrosion models and their uncertainties to develop detailed waste package degradation simulation model
- Develop abstractions for waste package degradation for TSPA model
  - Use drift-scale thermal-hydrology results
  - Determine distribution of initial pit penetrating waste container
  - Determine distribution of pits penetrating waste container

Objectives

(continued)

- Investigate the sensitivity of waste package performance to different conceptual models
  - Cathodic protection
    - » Delay the inner barrier pitting until the corrosion-allowance outer barrier thickness reduced by 75 %
  - Alternative thermal-hydrologic models
    - » This study vs Buscheck's model (LLNL)
  - Thermal load
  - Corrosion initiation
  - Infiltration rate
  - Backfill

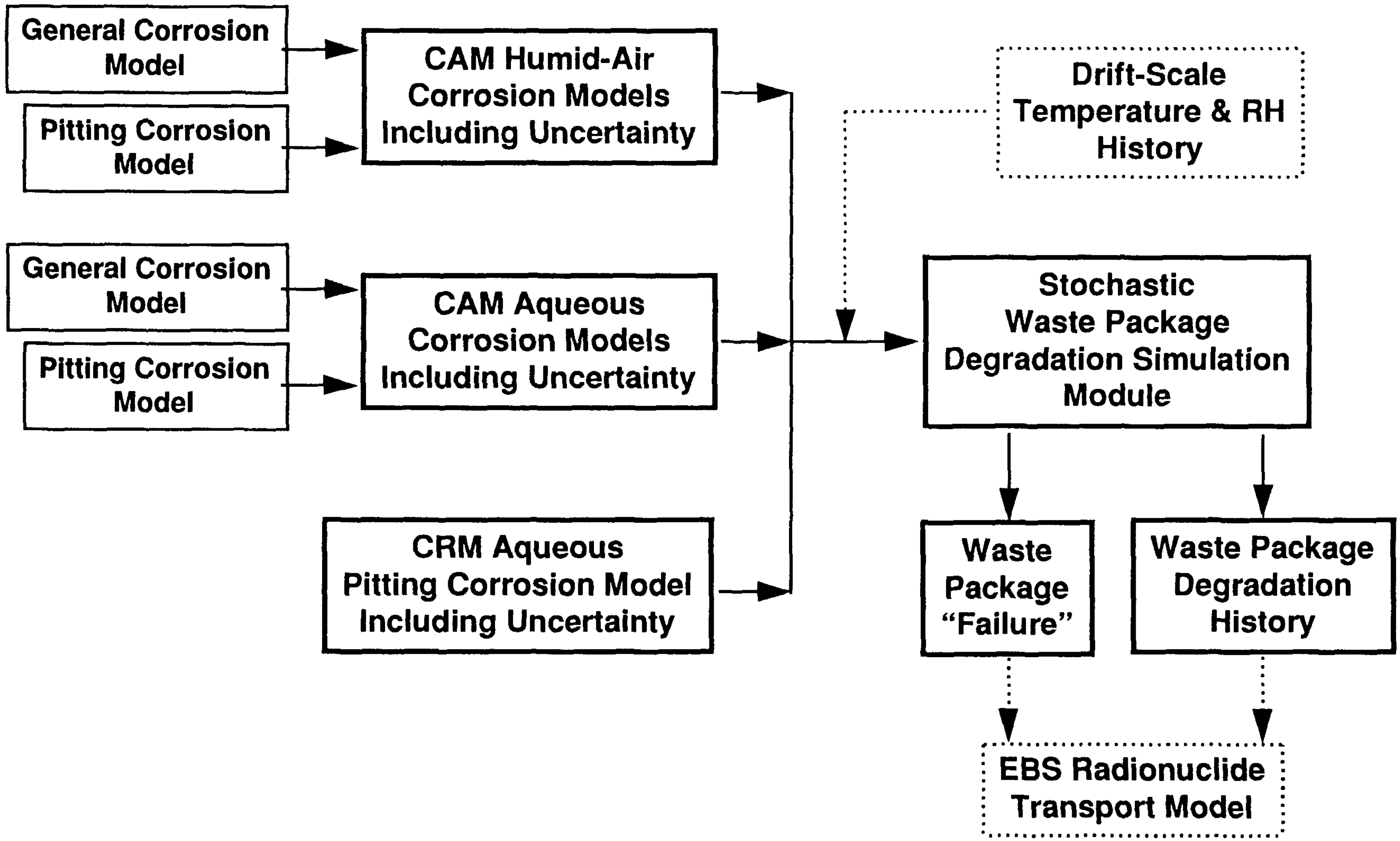
Waste Disposal Container Design

	Large MPC	HLW Glass
Capacity	21 PWR or 40 BWR Spent Fuel Assemblies	4 Pour Canisters
	High-Thermal Load	
Inner Barrier	Alloy 825 (20 mm)	Alloy 825 (20 mm)
Outer Barrier	Carbon Steel (100 mm)	70/30 Cu-Ni Alloy (50 mm)
	Low-Thermal Load	
Inner Barrier	Alloy 825 (20 mm)	Alloy 825 (20 mm)
Middle Barrier	Carbon Steel (100 mm)	70/30 Cu-Ni Alloy (50 mm)
Outer Barrier	Monel 400 [(1)]	Monel 400 [(1)]

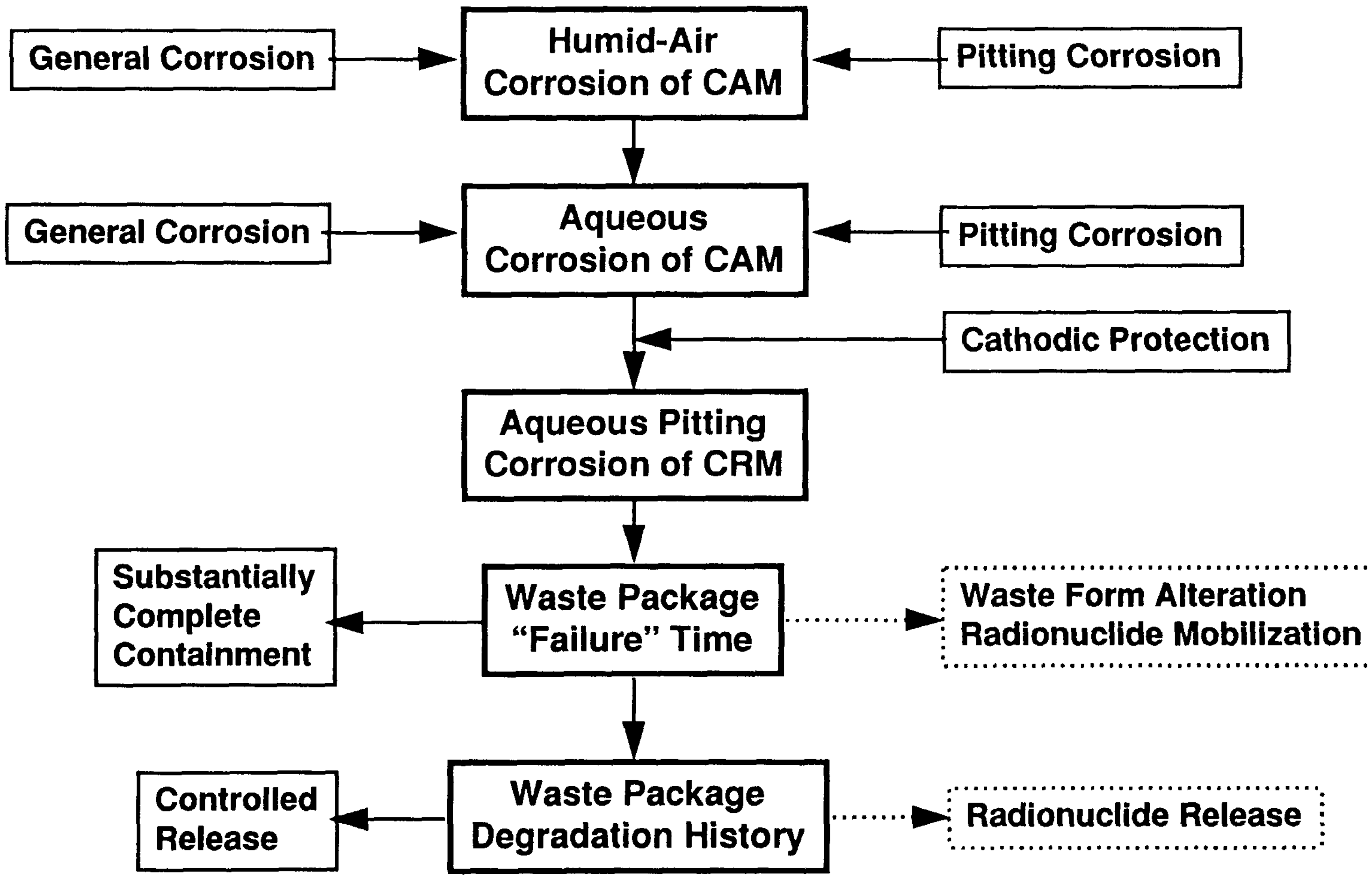
Alloy 825: Corrosion Resistant Material (CRM)
Carbon Steel: Corrosion Allowance Material (CAM)
Monel 400 and 70/30 Cu-Ni Alloy: Moderately Corrosion Resistant Materials (MCRM)
Sources: Controlled Design Assumption Document, Rev. 1 (M&O, 1995)
Doering (M&O IOC LV.WP.TWD.5/95.182, 1995)

[(1)] Recommended that the third barrier not be included in waste package performance analysis (Doering, 1995).

Stochastic Waste Package Performance Simulation Model



Approach to Waste Package Degradation Simulation



Development of Humid-Air Corrosion Models for Corrosion-Allowance Barrier Material

- Develop general corrosion model as a function of time, humidity, and temperature

  $$\ln D_g = a_0 + a_1 \ln t + a_2/RH + a_3/T + a_4[SO_2]$$

  - A total of 166 atmospheric corrosion data points (up to 16 years) from 10 sources
  - Included data from tropical, rural, urban, and industrial test locations
  - Data from marine test locations not included
  - Data reduced to define "active" corrosion time and the relative humidity and temperature during which RH $\geq$ 70 %

Development of <u>Humid-Air</u> Corrosion Models for Corrosion-Allowance Barrier Material

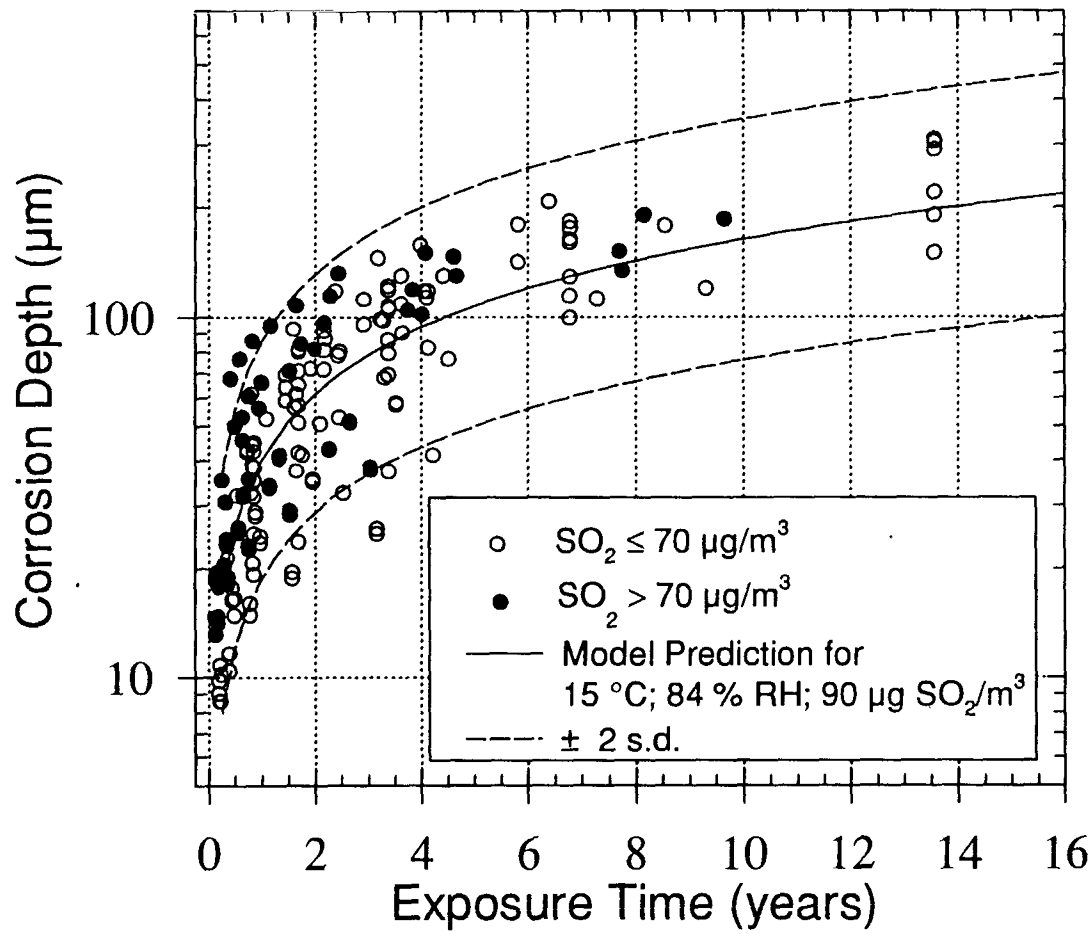
(Continued)

- Develop pitting corrosion model

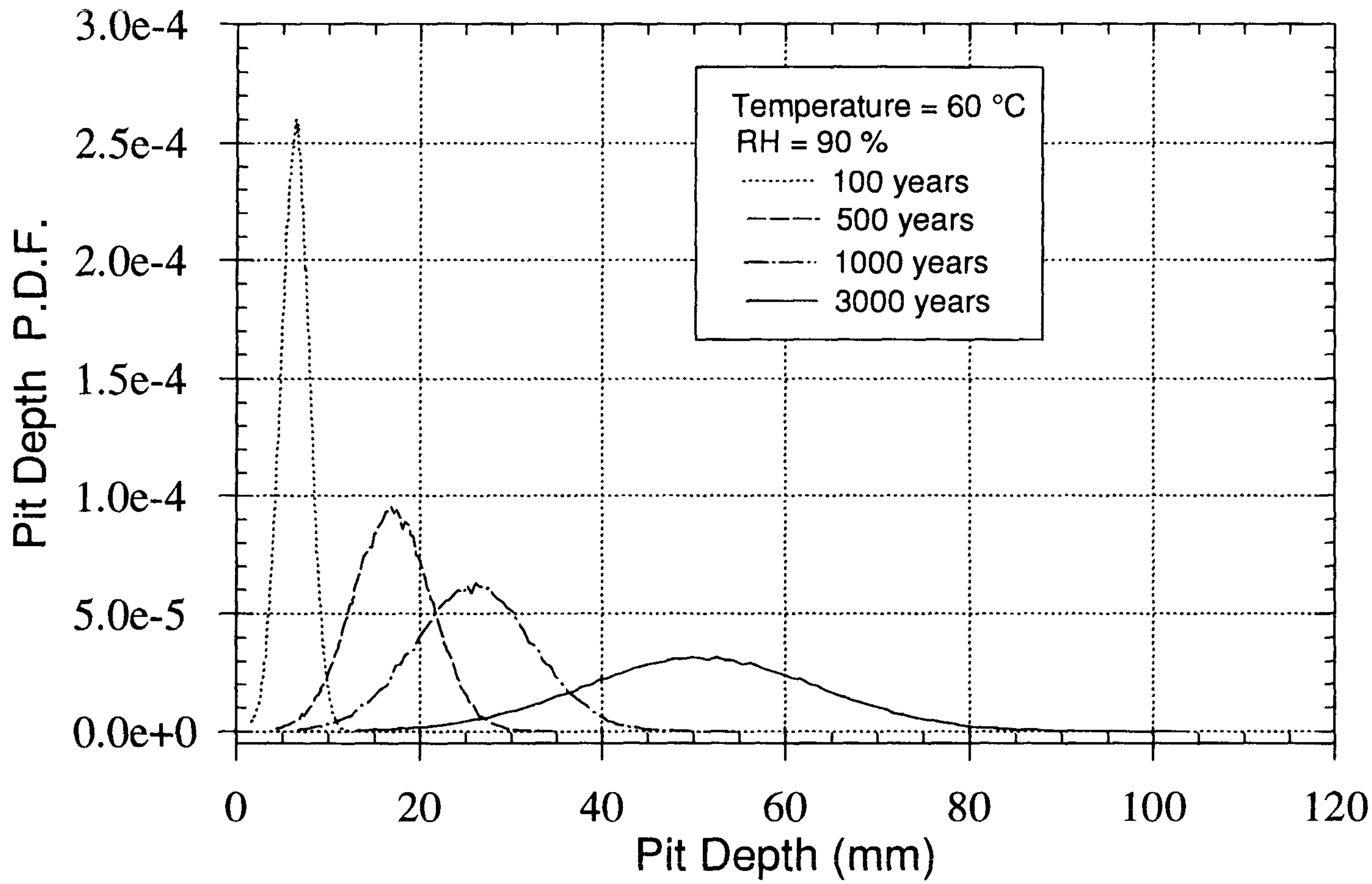
  $D_p = f_p \cdot D_g = \text{normal}(4,1) \cdot D_g$

  - Assume the pitting factor normally distributed with a mean of 4 and a standard deviation of 1

General Corrosion Depth vs Time of Corrosion-Allowance Material in Humid-Air and the Model Fit



Predicted Pit Depth Distribution of Corrosion-Allowance Material in Constant Humid-Air Condition Using Expected Values of Model Parameters



Development of Aqueous Corrosion Models for Corrosion-Allowance Barrier Material

- Develop general corrosion model as a function of time and temperature

  $$\ln D_g = a_0 + a_1 \ln t + a_2/T + a_3 T^2$$

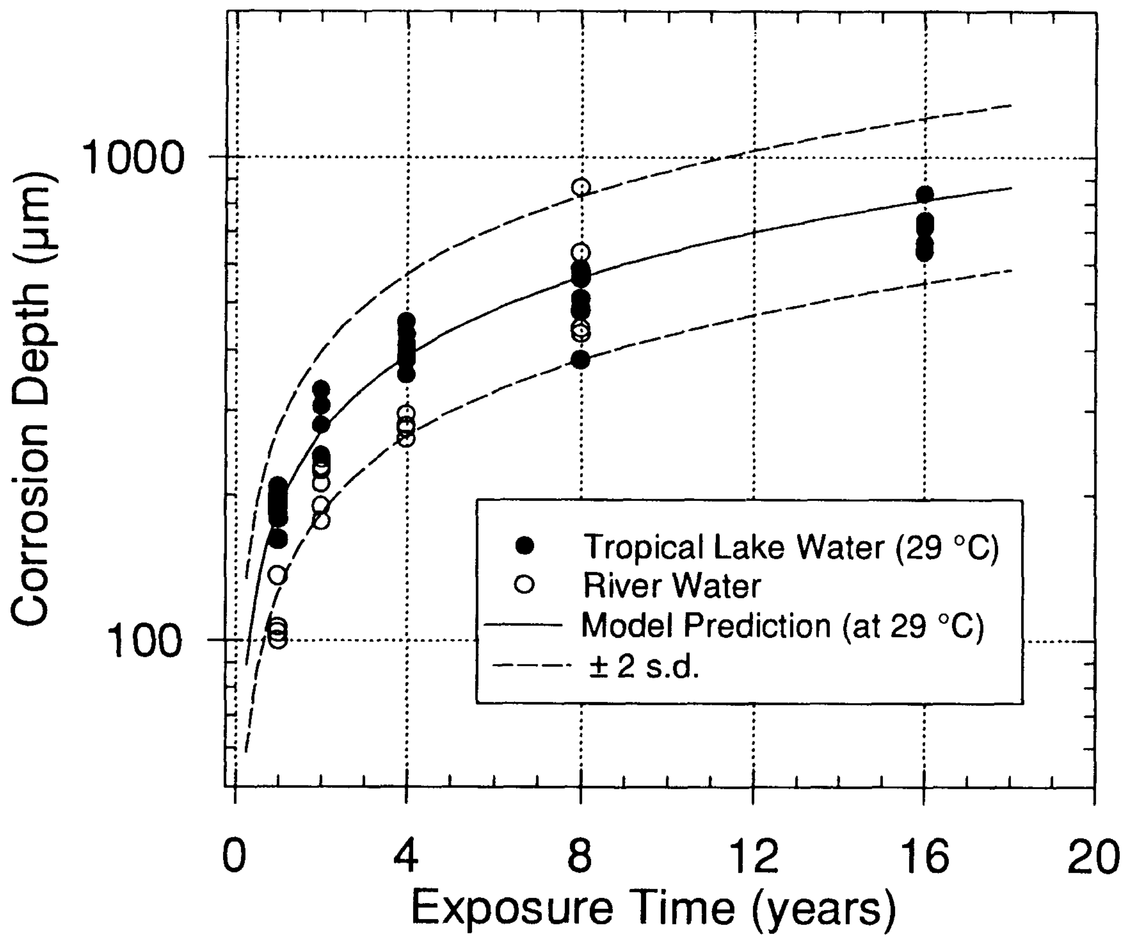
  - Included data from tropical lake water and polluted river water (up to 16 years)
  - Included short-term laboratory data in distilled ("clean") water for temperature-dependency

- Develop pitting corrosion model

  $$D_p = f_p \cdot D_g = \text{normal}(4,1) \cdot D_g$$

  - Assume the pitting factor normally distributed with a mean of 4 and a standard deviation of 1

General Corrosion Depth vs Time of Corrosion-Allowance Material in Water and the Model Fit



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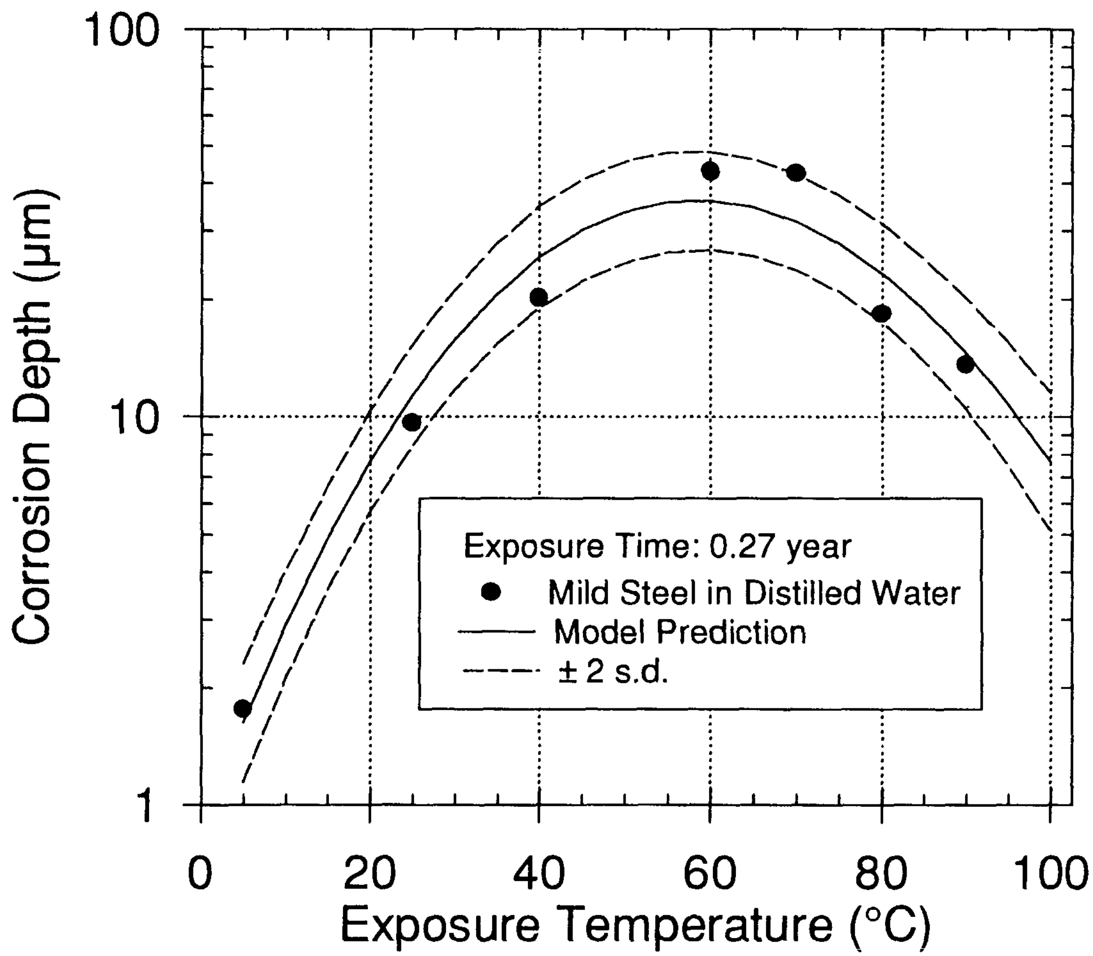
General Corrosion Depth vs Temperature of Corrosion-Allowance Material in Water and the Model Fit



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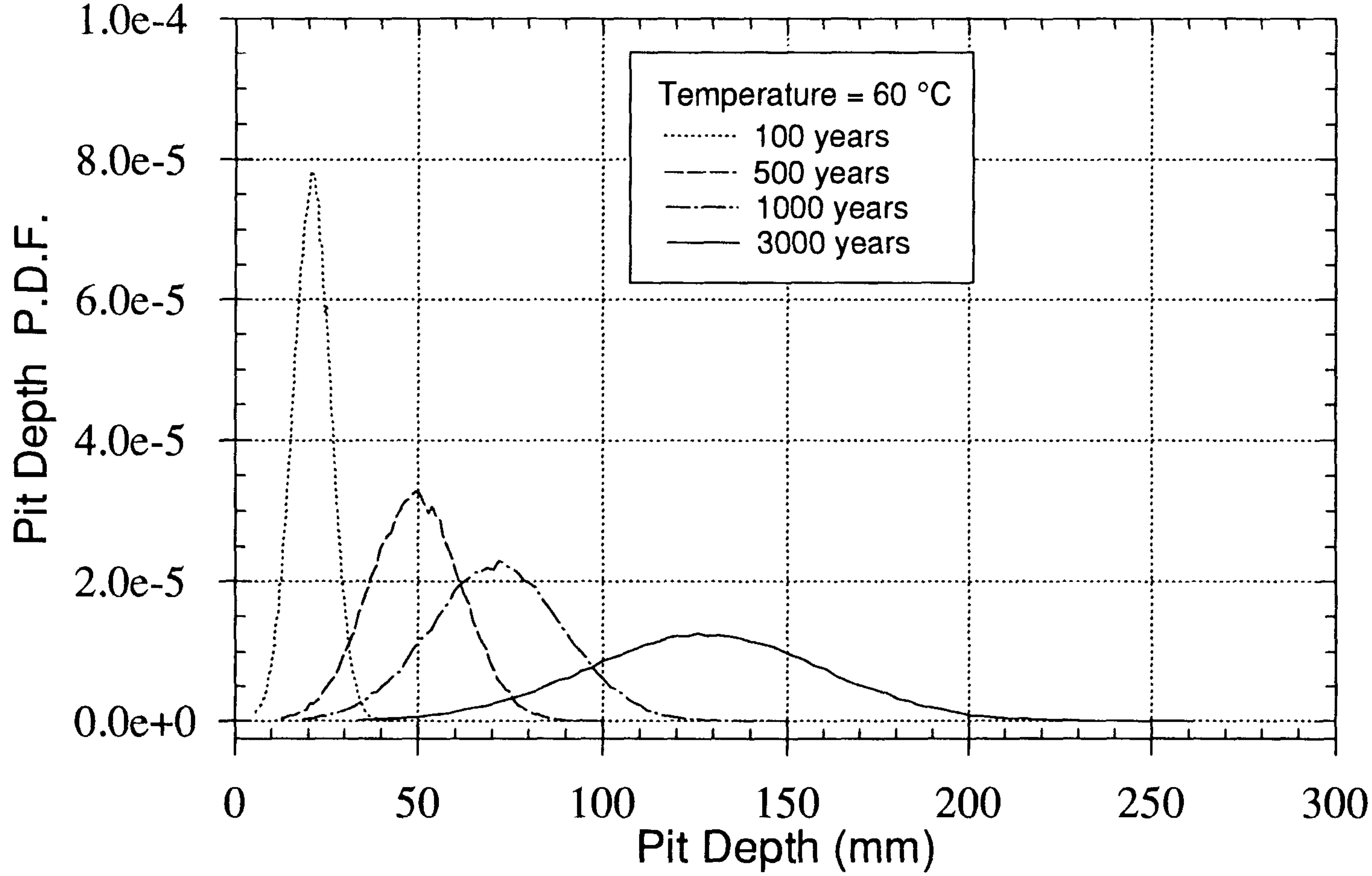
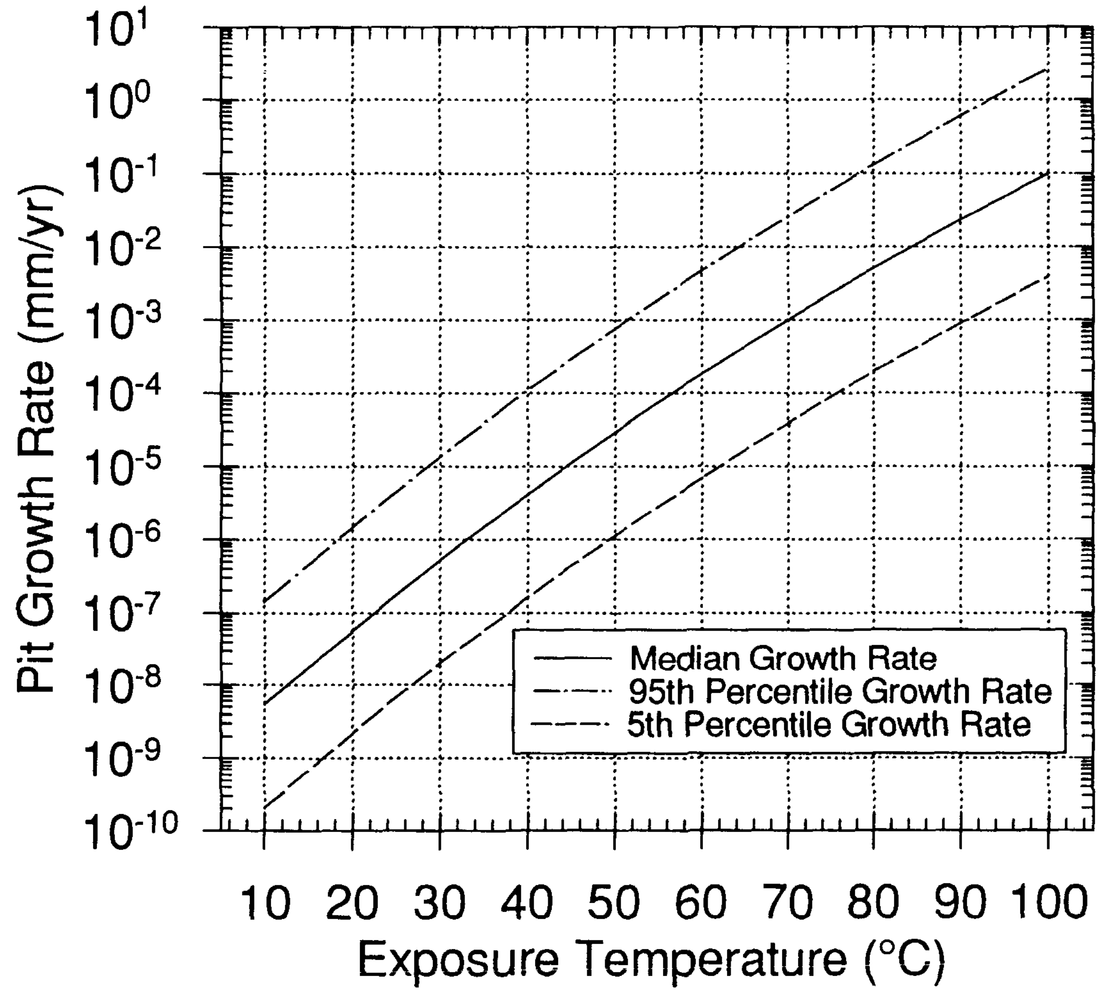
Predicted Pit Depth Distribution of Corrosion-Allowance Material in Constant Aqueous Condition Using Expected Values of Model Parameters



Development of Aqueous Pitting Corrosion Model for Corrosion-Resistant Barrier Material

- Incorporate "constant" pit growth rate model for corrosion-resistant barrier (Alloy 825)
  - The same model as in TSPA-1993 (developed from expert elicitation)
  - Pit growth rate varies with temperature and is log-normally distributed

Pit Growth Rate vs Temperature of Corrosion-Resistant Inner Barrier in Aqueous Condition

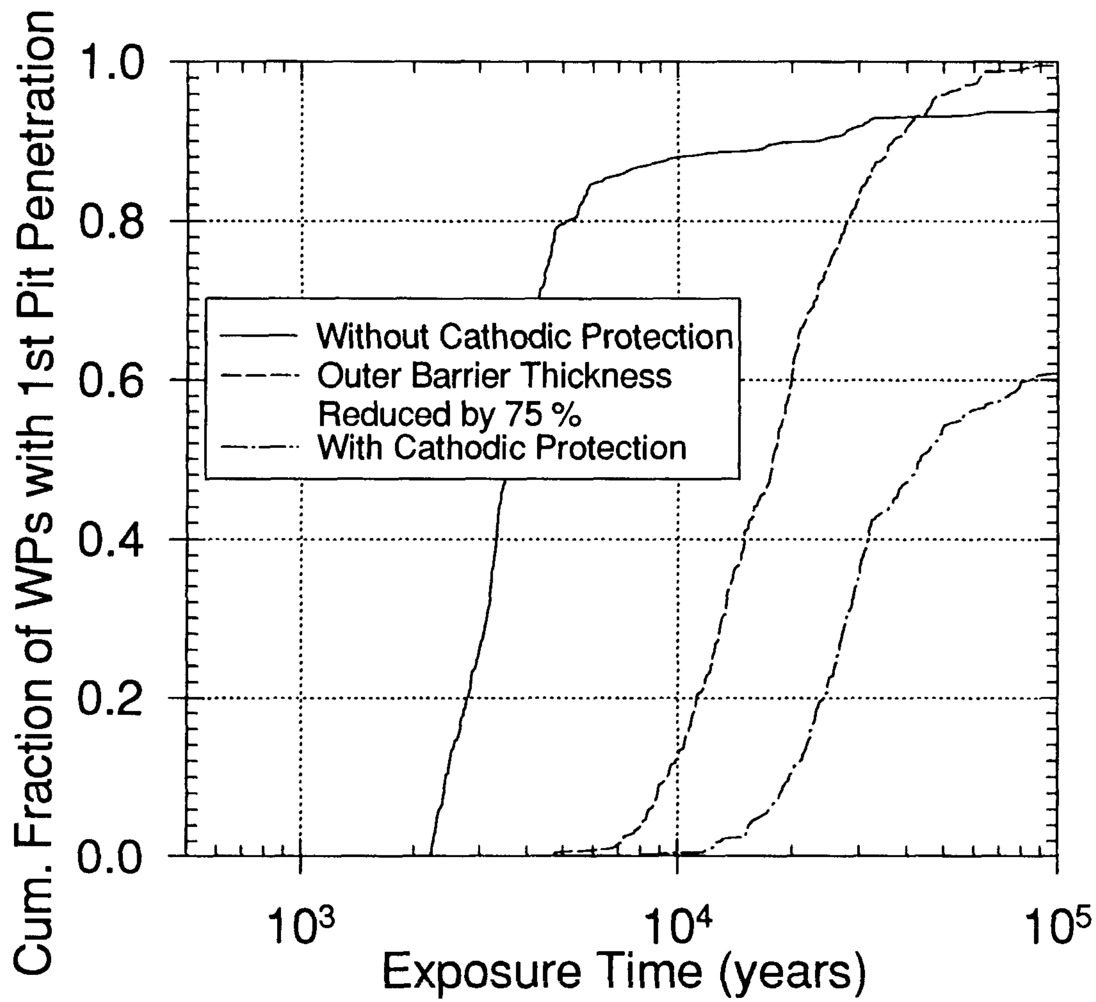


Major Assumptions in Stochastic Waste Package Degradation Simulation

- Initiate humid-air corrosion of corrosion-allowance outer barrier at relative humidity between 65 and 75 percent (uniformly distributed)
- Start aqueous corrosion at relative humidity between 85 and 95 percent (uniformly distributed)
- Corrosion-resistant inner barrier subjected to aqueous pitting corrosion only
- Represent pit-to-pit variability and WP-to-WP variability by equally splitting the uncertainties in the corrosion models

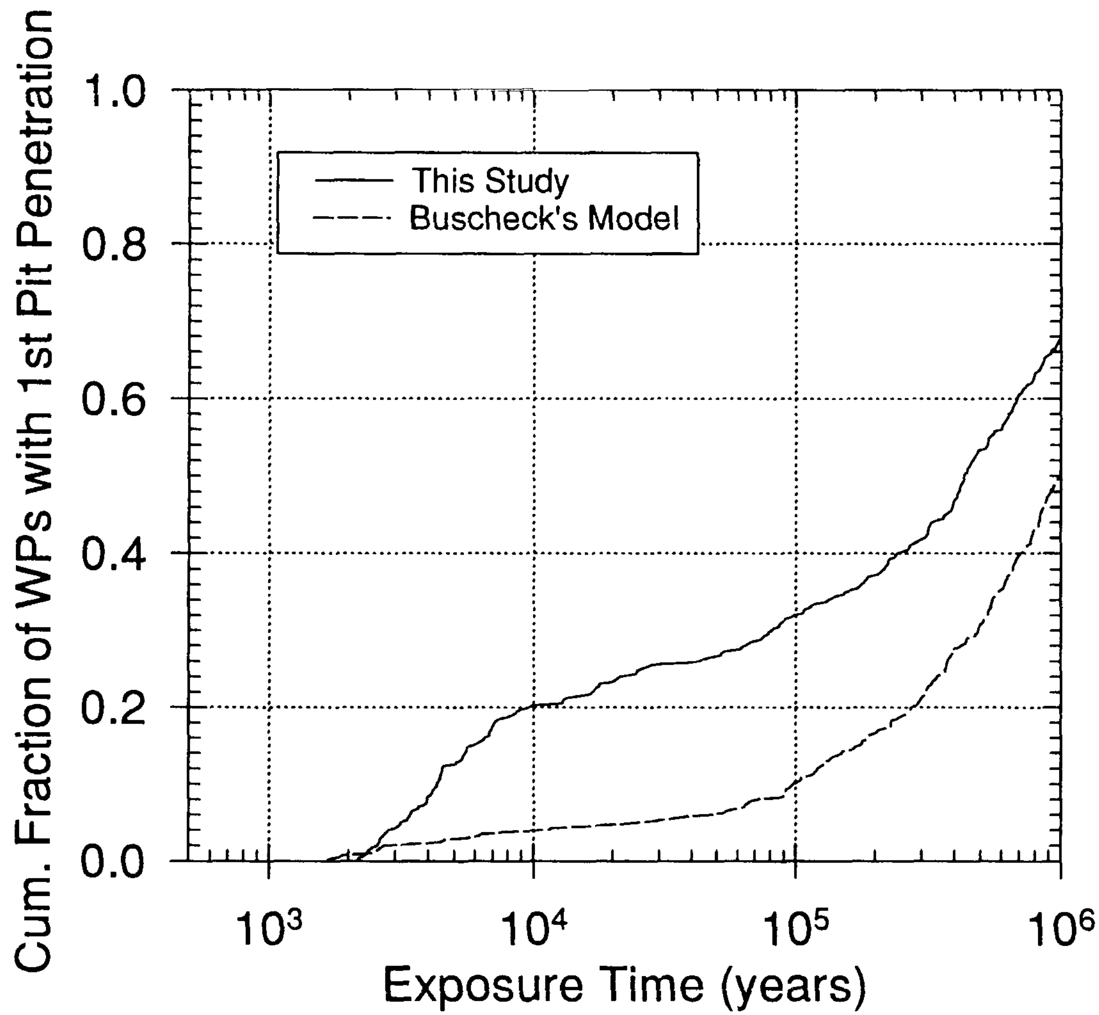
Waste Package Performance vs Cathodic Protection

RH & T Switch for Corrosion Initiation; 83 MTU/acre; No Backfill; High Infiltration Rate



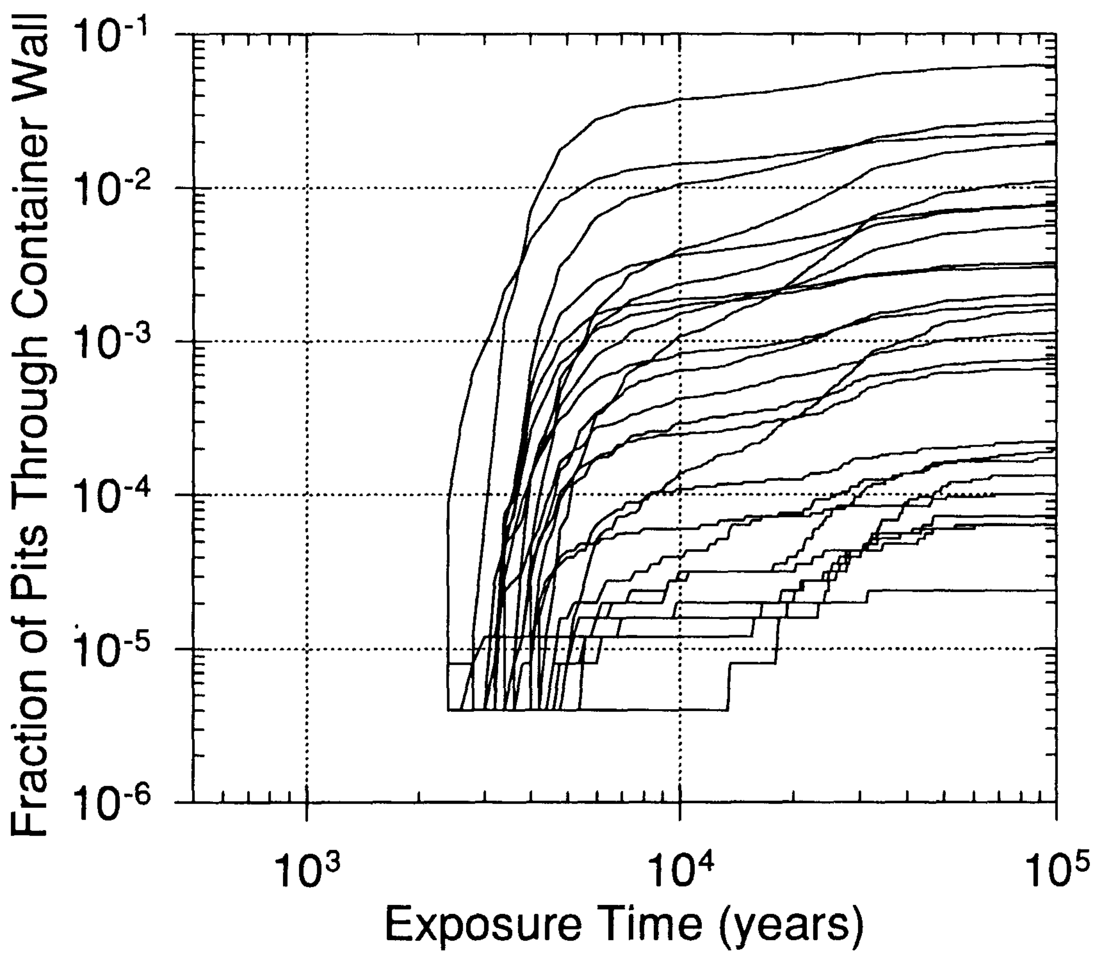
Waste Package Performance vs Alternative Thermal-Hydrologic Models

<u>This Study</u>: 25 MTU/acre; No Backfill; High Infiltration Rate
<u>Buscheck's Model</u>: 24 MTU/acre; No Backfill; No Infiltration



Representative Pitting Histories of 25 Waste Packages

RH & T Switch for Corrosion Initiation; Without Cathodic Protection; 83 MTU/acre; No Backfill; High Infiltration Rate



Summary and Conclusions

- The current waste package design appears to meet the substantially complete containment requirement within the conditions of the degradation modes, assumptions and near-field environments considered in the simulation
- Cathodic protection of the inner barrier by the outer barrier has significant impacts on waste package performance
- In future TSPA
  - Substantiate the inner barrier pitting model and cathodic protection model
  - Include stress-corrosion cracking of the inner barrier
  - Include potential effects of microbiologically influenced corrosion