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

NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING

SUBJECT: EVALUATION OF ENGINEERED BARRIER SYSTEM RELEASES IN TSPA-1995

PRESENTER: JERRY A. McNEISH
PRESENTER'S TITLE AND ORGANIZATION: SENIOR PERFORMANCE ASSESSMENT ANALYST MANAGEMENT AND OPERATING CONTRACTOR LAS VEGAS, NEVADA
TELEPHONE NUMBER: (702) 295-9381

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Outline

• Objectives
• Description of Nominal Engineered Barrier System (EBS)
• Waste Form Alteration/Radionuclide Mobilization
• EBS Release Models
• Approach to EBS Release Sensitivity Analyses
• Results of Sensitivity Analyses
• Conclusions
Objectives

- Develop abstractions for radionuclide mobilization processes
  - alteration/dissolution \( (f ([CO_3]_T, \text{pH}, T)) \)
  - radionuclide solubility \( (f (\text{pH}, T)) \)
- Evaluate EBS release rate for various alternate conceptual models of EBS transport
- Provide EBS releases to geosphere for predicting total system performance
TSPA-1995 Information Flow Diagram
Engineered Barrier System

Information

Process-Level Models

Model Abstraction

Performance Assessment Models

Performance Measures

Site Biosphere

Site Geohydrology

Site Geochemistry

Repository Design

Waste Package Design

Material Properties

Waste Form Properties

Saturated Zone Flow Model

Unsaturated Zone Flow Model

Drift Scale Thermo-Hydrology Model

Waste Package Degradation Model

Saturated Zone Flux

Unsaturated Zone Flux

Drift Scale Flux

Drift Scale Temperature Humidity Saturation

Biosphere Transport Model

Geosphere Transport Model

EBS Transport Model

Peak Individual Dose

Cumulative Release to Accessible Environment

Peak EBS Release Rate

Substantially Complete Containment

Temperature

Humidity
Description of Nominal Engineered Barrier System

- Uniformly Distributed Solid Waste (spent fuel or HLW glass monolith)
- Container Wall
  - CAM - 10 cm
  - CRM - 2 cm
- Drift Wall
- Invert (1 m)
Engineered Barrier System Processes

Thermal-Hydrologic Results (T,RH,S)

Waste Package Degradation History

% of Waste Packages with Fracture Flow

Diffusion Coefficient

Waste Form Exposure (Cladding failure)

EBS Release Model

Waste Form Alteration Rate

Release from WP and EBS - diffusive - advective

Radionuclide Solubility
Waste Form Alteration/ Radionuclide Mobilization

- Spent fuel waste form dissolution rate based on data from Steward and Gray (1994)
  - \[ f(T, [CO3], pH) \]
- HLW glass waste form dissolution rate based on data from Bourcier (1993)
  - \[ f(T, pH) \]
- Radionuclide solubilities same as TSPA-1993 (Andrews et al., 1994)
- Diffusion coefficient from Conca Diffusion Curve
Spent Fuel Dissolution Rate

![Graph showing dissolution rate vs. temperature]

- **Dissolution Rate (mg/m² day)**
- **Temperature (°C)**

Lines represent:
- **Model Estimation** ([CO₃]ᵣ = 0.02 M; pH = 9.0)
- **± 2 s.d.** (Standard Deviation)
- **Measurement Data**

**pH** values:
- pH = 8.1
- pH = 9.1
- pH = 9.8

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Jerry 18.125 NWTRIB.PPT4/10-17-95
HLW Glass Dissolution Rate

Dissolution Rate (g/m²·day)

pH

25 °C
50 °C
70 °C
90 °C
80 °C
70 °C
50 °C
25 °C

Model Estimation
Neptunium Solubility

Data from Nitsche et al., (1993)

[Graph showing solubility of neptunium as a function of pH and temperature.]
Diffusion Coefficient (after Conca, 1990)

Volumetric Water Content (%)

Diffusion Coefficient (cm $^2$/sec)

- Soil
- Tuff Gravel
- Other Gravel
- Clay (Bentonite)
- Whole Rock

Model Estimation

± 2 s.d.
EBS Release Models

- Diffusive and advective release from waste container and EBS
  - Advective release only active if dripping fractures
- Diffusive release through waste container, then advective and diffusive release through EBS
- Diffusive release only
  - Capillary barrier effect does not allow advective release through waste container or EBS
Model for Diffusive and Advective Release from Waste Container and EBS

Uniformly Distributed Solid Waste (spent fuel or HLW glass monolith)

Container Wall
CAM - 10 cm
CRM - 2 cm

Drift Wall

Porous Cylindrical Pit

Invert (1 m)

Radionuclide Release
Model for Diffusive Release from Waste Container and Diffusive/Adveotive Release from EBS

Uniformly Distributed Solid Waste (spent fuel or HLW glass monolith)

Container Wall
CAM -10cm
CRM - 2 cm

Drift Wall

Porous Cylindrical Pit

Invert (1 m)

Radionuclide Release
Model for Only Diffusive Release from Waste Container and EBS (capillary barrier effect)

Uniformly Distributed Solid Waste (spent fuel or HLW glass monolith)

Container Wall
CAM - 10 cm
CRM - 2 cm

Drift Wall

Porous Cylindrical Pit

Invert (1 m)

Radionuclide Release
Approach to EBS Release Sensitivity Analyses

- Evaluate EBS release of various spent fuel radionuclides ($^{14}$C, $^{237}$Np, and $^{99}$Tc)
- Evaluate sensitivity of peak EBS release rate to alternate conceptual models
  - Infiltration
  - Thermal load
  - Cladding
  - Cathodic protection
  - EBS release models
  - Thermal-hydrologic models
NRC Peak Release Rate Limit

• Peak release rate from EBS following the containment period shall be less than one part in 100,000 per year of the 1,000-year inventory

• Provides basis for looking at Peak Release Rate from EBS
Predicted EBS $^{14}$C Release Rate History: Sensitivity to Infiltration

![Graph showing the predicted EBS $^{14}$C release rate history with sensitivity to infiltration. The graph plots the total release from EBS (Ci/yr) against time (yrs). Two scenarios are shown: 83MTU/acre; no backfill; low infiltration (solid line) and 83MTU/acre; no backfill; high infiltration (dashed line).]
Predicted EBS $^{99}$Tc Release Rate History: Sensitivity to Infiltration

- 83 MTU/acre; no backfill; low infiltration
- 83 MTU/acre; no backfill; high infiltration
Predicted EBS $^{237}$Np Release Rate History: Sensitivity to Infiltration

- 83 MTU/acre; no backfill; low infiltration
- 83 MTU/acre; no backfill; high infiltration
Sensitivity of Predicted EBS Peak Release Rate to Infiltration

- 83 MTU/acre; no backfill; low infiltration
- 83 MTU/acre; no backfill; hi infiltration

Radionuclide: 14C, 237Np, 99Tc

Peak Release (Ci/yr)
Sensitivity of Predicted EBS Peak Release Rate to Thermal Load

![Graph showing sensitivity of predicted EBS peak release rate to thermal load. The graph compares peak releases of radionuclides 14C, 237Np, and 99Tc for two scenarios: 25 MTU/acre with no backfill and high infiltration, and 83 MTU/acre with no backfill and high infiltration.]
Sensitivity of Predicted EBS Peak Release Rate to Cladding Failure

- 83 MTU/acre; no backfill; high infiltration
- 10% cladding failure
- 1% cladding failure

Radionuclide:
- $^{14}$C
- $^{237}$Np
- $^{99}$Tc
Predicted EBS Peak Release Rate: Cathodic Protection Effect

Note: Time of cathodic protection case peak release is greater than 16,000 years.
Predicted EBS Peak Release Rate: EBS Release Model Comparison

- 83 MTU/acre; no backfill; high infiltration
- 83 MTU/acre; backfill; high infiltration
- 83 MTU/acre; no backfill; high infiltration; alternate adv release
- 83 MTU/acre; backfill; high infiltration; cap barrier effect
Predicted EBS Peak Release Rate: Alternate Thermal-hydrologic Model Comparison

- 25 MTU/acre; no backfill; cap barrier effect
- Buscheck-24 MTU/acre; no backfill; no infiltration

Bar chart showing peak release rates (Ci/yr) for different radionuclides: 14C, 237Np, 99Tc.
Conclusions

- Capillary barrier effect produces very large decrease in EBS peak release

- Diffusive release from waste container and diffusive/advective release from EBS produces a large decrease in EBS release due to diffusive release delay

- Alternate thermal-hydrologic model (Buscheck) produces a large decrease in EBS release due to low humidities and liquid saturations

- Advective release component is very important in determining total release