SAND2008-1029P

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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Waste Form Degradation Alternative Analysis (Water Balance Model)

Presented to:
Nuclear Waste Technical Review Board

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January 16, 2008
Las Vegas, NV

Outline

- Objectives of Performance Margin Analysis (PMA)
- TSPA treatment of water fluxes
- PMA treatment of water fluxes
- Results

Performance Margin Analysis

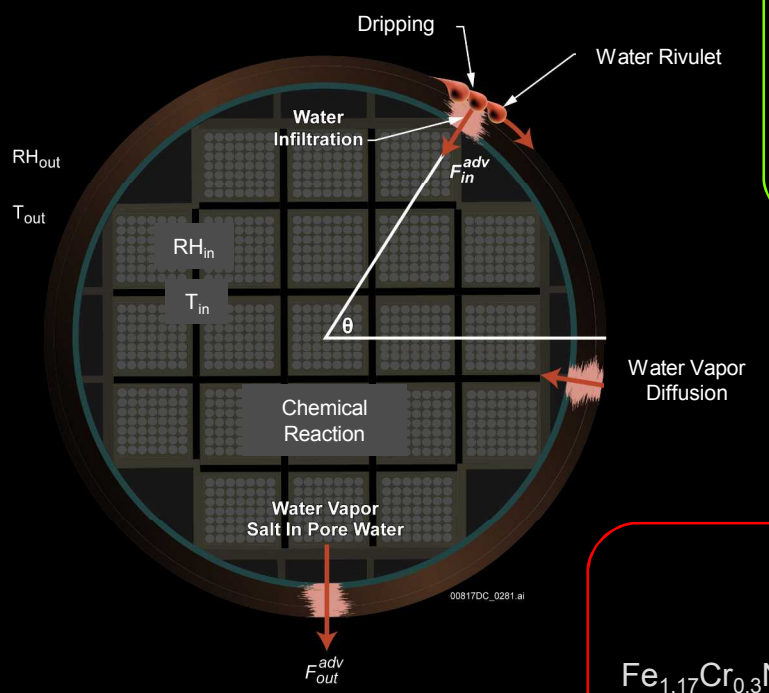
- **Quantify the extent to which conservatisms in the TSPA Model, individually and collectively, overestimate the total mean annual dose, relative to the model projections of the PMA**
- **Confirm that, when propagated through the TSPA Model, the evaluated conservatisms are indeed conservative with respect to the total system performance measures (e.g., total mean annual dose)**
- **The water balance model is a submodel in the PMA that addresses conservatisms in the treatment of water fluxes into a breached waste package**

TSPA Model

- **Assumptions made in the treatment of water fluxes**
  - **Breaches in the WP outer layer due to general corrosion provide no resistance to advective seepage flow**
  - **Water vapor condensation inside a WP is controlled by water sorption onto corrosion products**
  - **No water is consumed by corrosion reactions**

Source Term Water (Q) Fluxes

$$\frac{dQ}{dt} = \text{Advection} + \text{Diffusion} - \text{Reaction}$$



Water Vapor Diffusion

$$F_{in}^{adv} = f_{in}^{adv} Q_{drip}$$

$$f_{in}^{adv} = 1 - \int_{\pi/2}^{0} (-\sin\theta_0)(\cos\theta_0)^{\lambda} d\theta_0$$

$$\lambda = \frac{6\pi R_{wp} \phi f K_p^s}{h^3}$$

Advection

$$\frac{dQ}{dt} = \frac{D\phi^{5/3} A}{L}(\rho_{out} - \rho_{in})$$

Diffusion

$$\psi = \psi_e (s_w)^{-b}[1 - \alpha(T_{in} - T_0)](1 + \beta m) + \omega\eta m \rho_{water} R T_{in}$$

$$RH_{in} = \frac{\rho_{in}}{\rho_s(T_{in})} = e^{-\frac{\psi s_w^0}{RT_{in}}}$$

H_2O Potential

$$F_{out}^{adv} = A_{out} K_c (s_w)$$

Advection

36,400 kg 316 Stainless Steel
29,700 kg UO_2

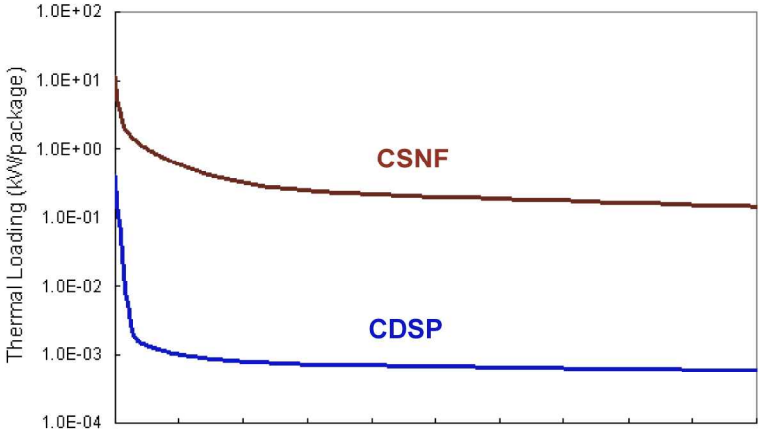
	mol H_2O/yr
$Fe_{1.17}Cr_{0.3}Ni_{0.2} + 1.2025O_2 + 0.385H_2O + 0.4H^+ \rightarrow 1.17FeOOH + 0.15Cr_2O_3 + 0.2Ni^{2+}$	3-30
$UO_2 + 1/2O_2 + 2H_2O \rightarrow UO_3{:}2H_2O_{Schoepite}$	60

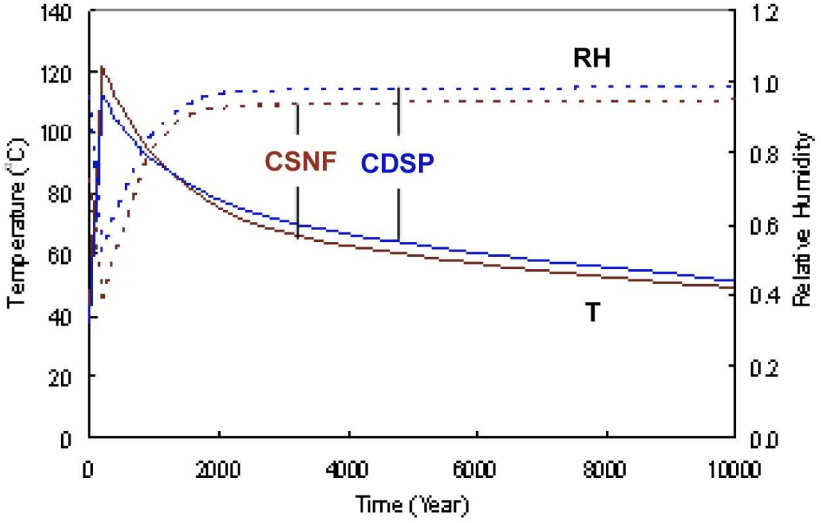
Reaction

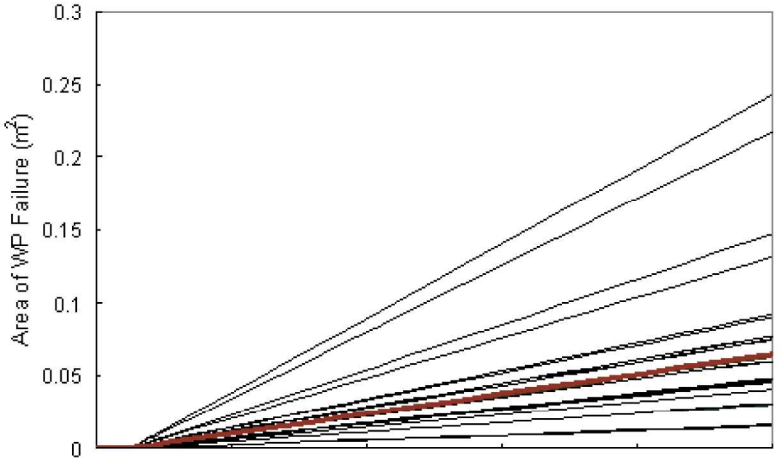
Monte Carlo Analysis

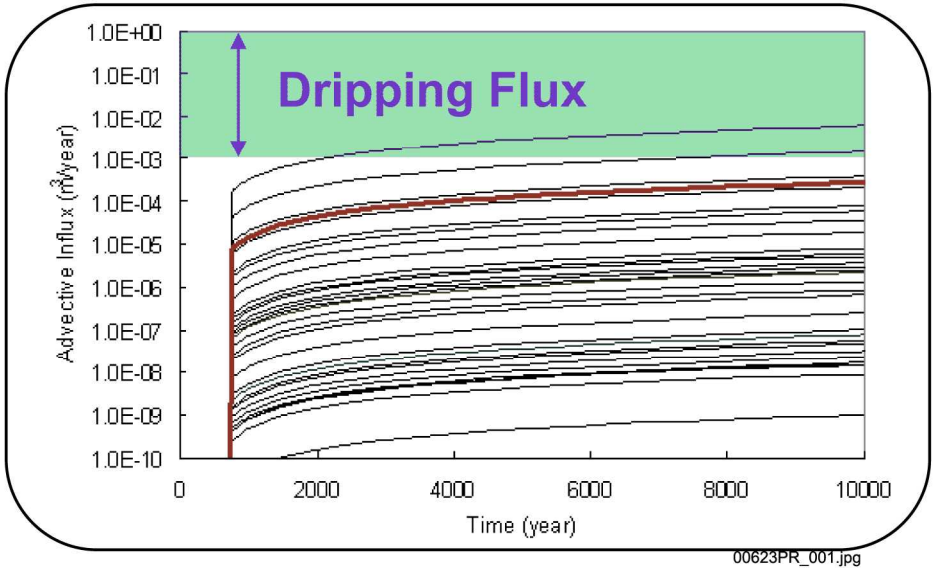
- **Thermal inputs, dripping flux, and patch area boundary conditions**
- **Sample on degradation rates (steel, fuel, glass) hydrologic conductivity, dripping flux, rivulet thickness**
- **Calculate 30 realizations to predict water flux over 10,000 years**

Water Balance in the Package: Boundary Conditions and Results









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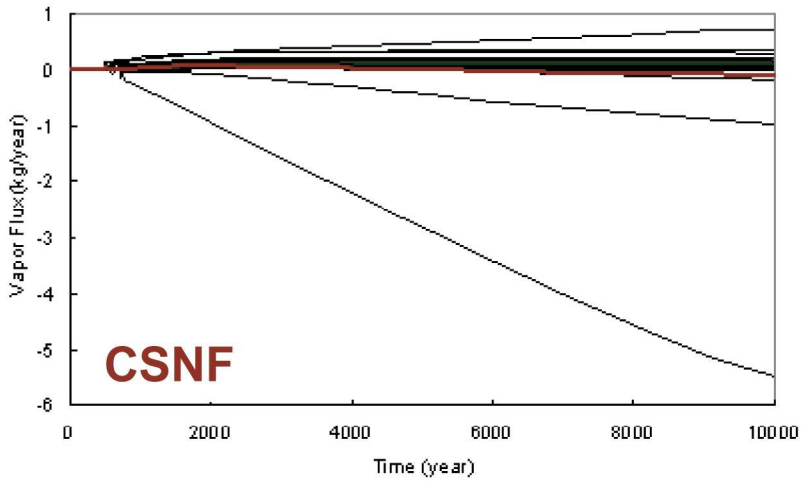
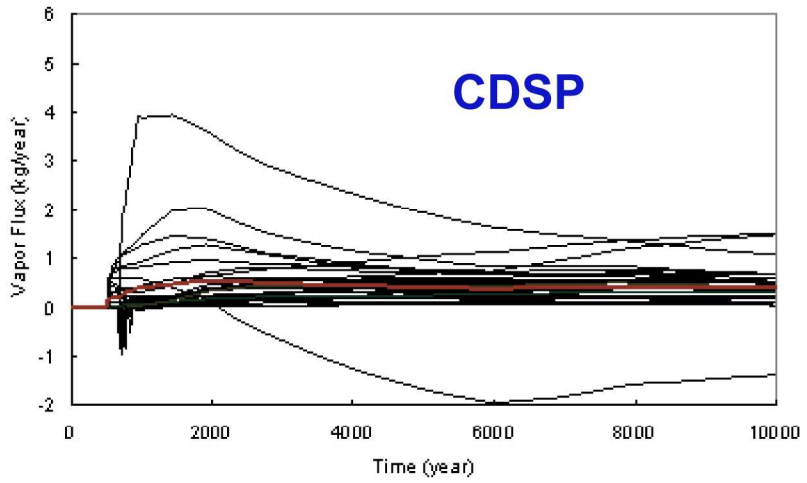
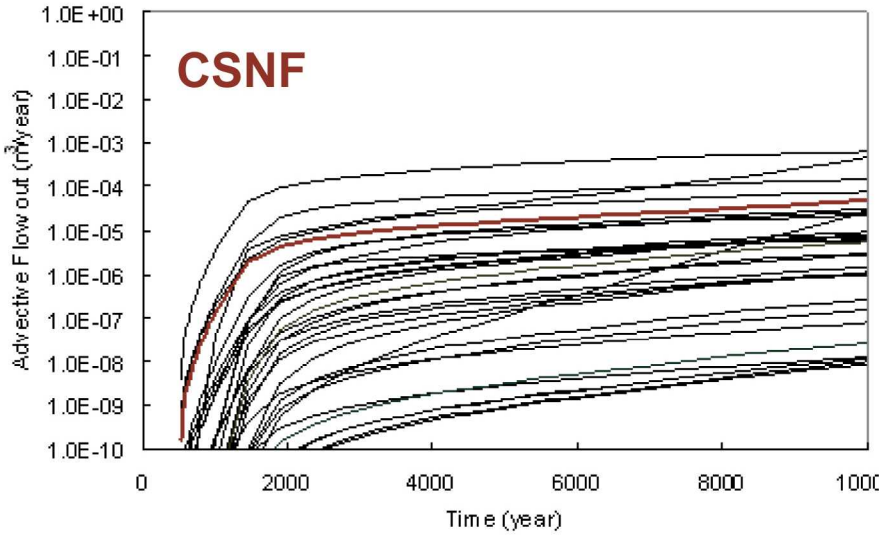
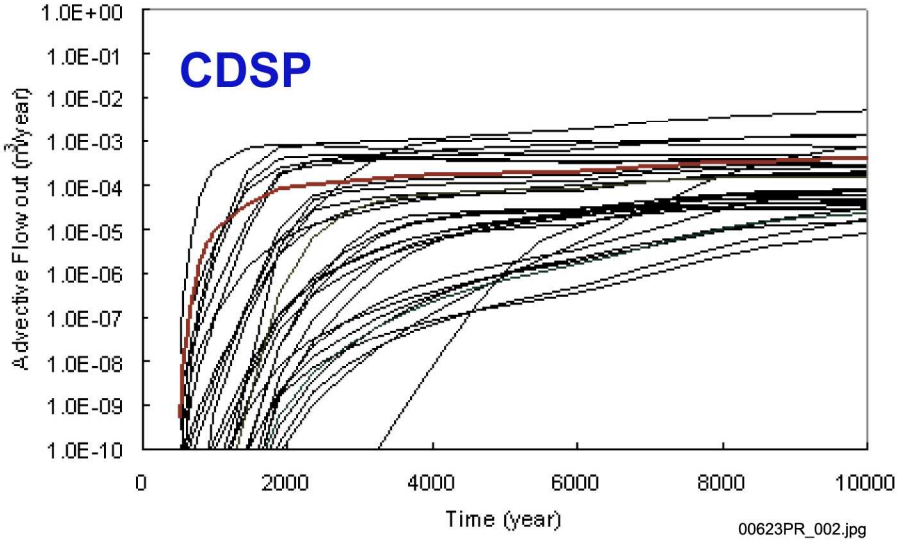
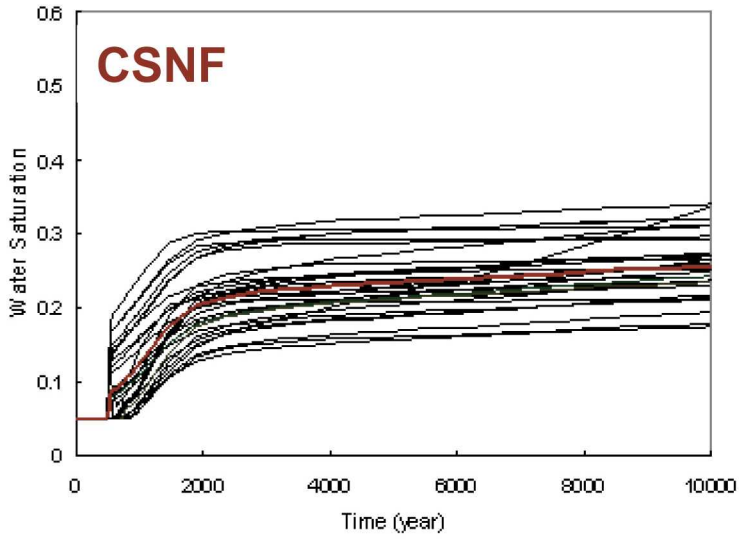
Water Balance in the Package: Predictions

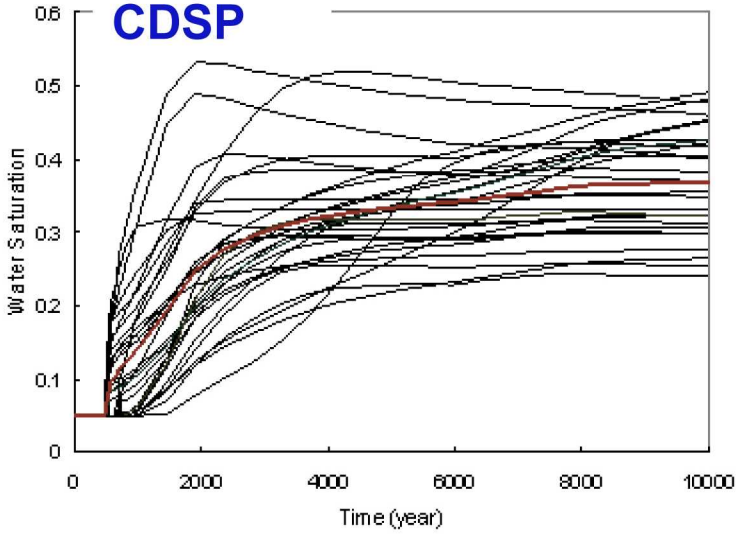









CSNF
Water Saturation
0
0.1
0.2
0.3
0.4
0.5
0.6
0
2000
4000
6000
8000
10000
Time (year)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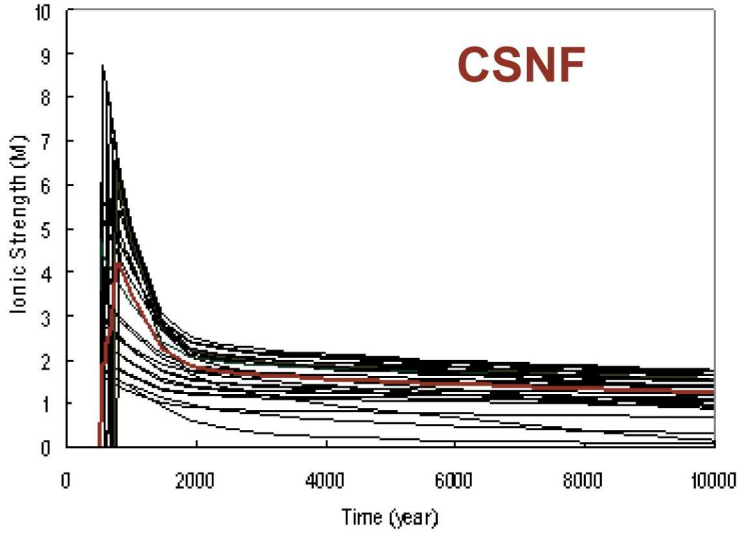
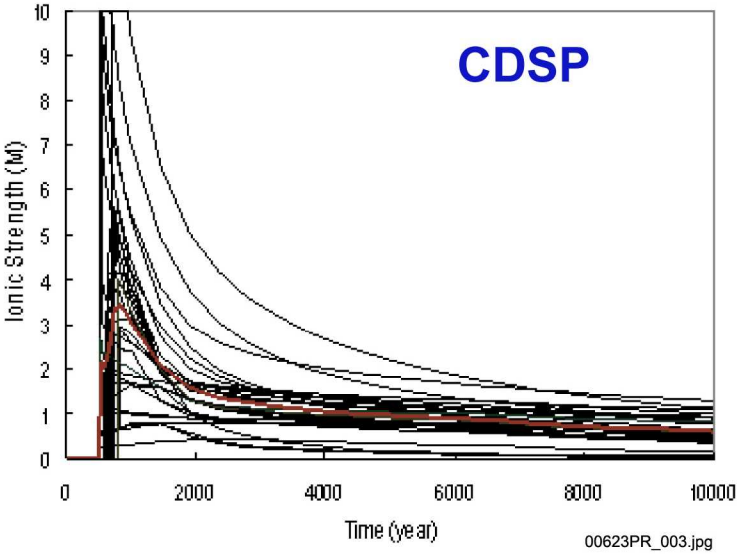

CSNF
Ionic Strength (M)
0
1
2
3
4
5
6
7
8
9
10
0
2000
4000
6000
8000
10000
Time (year)


CDSP
Ionic Strength (M)
0
1
2
3
4
5
6
7
8
9
10
0
2000
4000
6000
8000
10000
Time (year)
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Preliminary Results

- **Water saturations less than 0.5**
- **Advective outflows small (< 0.5 L/yr)**
- **Ionic strengths > 1M**