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

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Waste Package and Clad Temperature in the Presence of Drift Collapse Material

Presented to:
Nuclear Waste Technical Review Board

Presented by:
Ernest Hardin
Sandia National Laboratories

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Outline

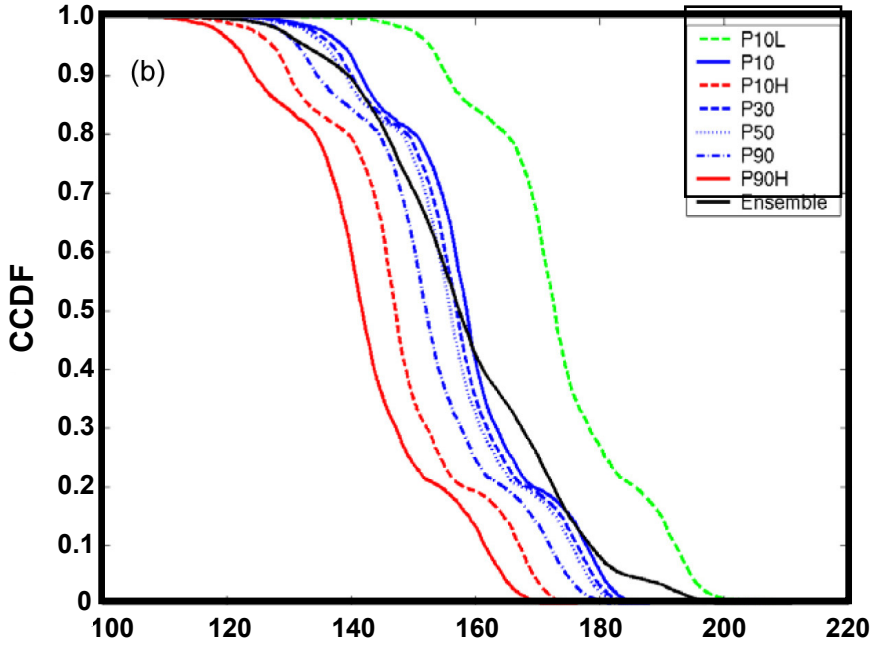
- Range of postclosure peak waste package temperatures *
  - Uncollapsed
  - Complete collapse
  - Partial collapse
- Waste package internal temperature
- Probabilistic analysis of drift collapse and waste package temperature, for screening features, events & processes (FEPs)
- Summary

* Hottest commercial spent fuel will be in transportation-aging-disposal (TAD) canisters

Waste Package and Clad Temperature with Drift Collapse
Peak Waste Package Temperature - Uncollapsed

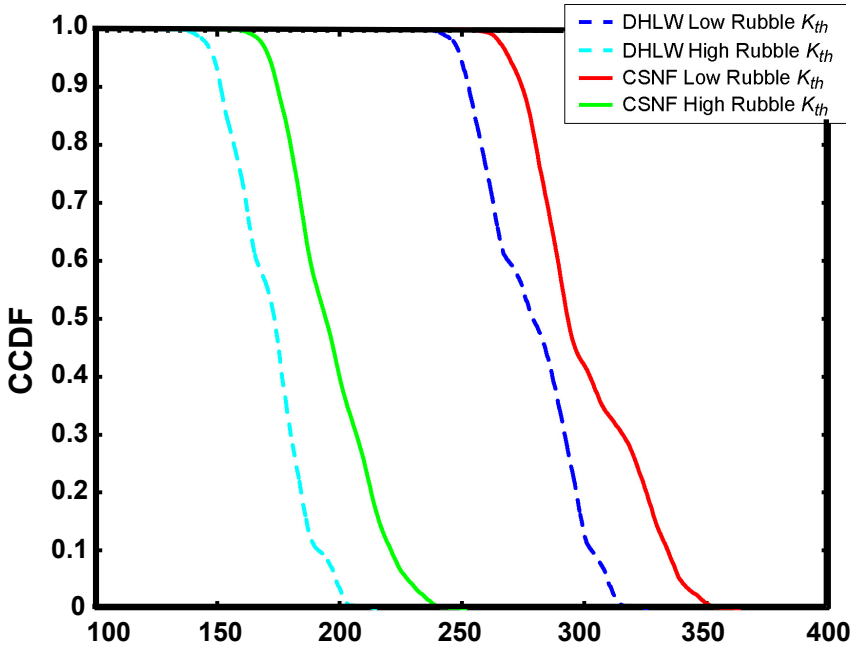
- **Multiscale model input to total system performance assessment (TSPA)**

Uncollapsed Results by Percolation/Rock Thermal Conductivity Group



ANL-EBS-MD-000049 Rev. 03 AD2, Fig. 6.3-77[b]

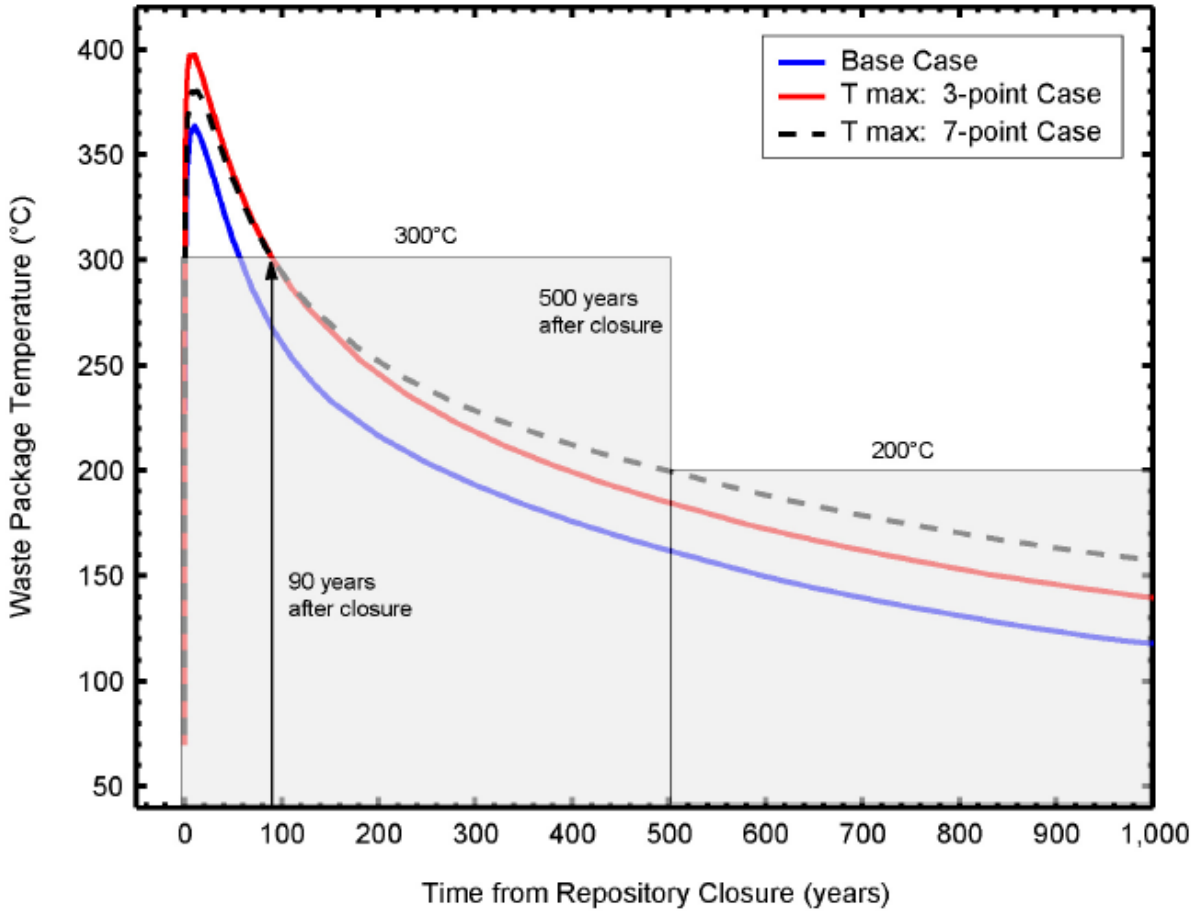
Collapsed Results by Waste Package Category



ANL-NBS-HS-000057 Rev. 00, Fig. 6.4.2-29

Waste Package and Clad Temperature with Drift Collapse
Range of Design Thermal Loading

- **Temperature-time window for Alloy 22 phase separation (FEP 2.1.11.06.0A)**
- **Hottest package T>300°C only if drift collapse occurs <90 years after closure**
  - **Base case**
  - **Hottest segments from loading study**
- **Probability of T>300°C is less than 10^{-4} for seismically induced collapse**



ANL-NBS-HS-000057 Rev. 00, Fig. 6.4.2-28

Waste Package and Clad Temperature with Drift Collapse
Internal Waste Package Peak Temperature

- **Intact Waste Package Configuration**
  - Postclosure and preclosure heat transfer are similar
  - Internal temperature depends on power output and outer wall temperature
- **TAD Canister Thermal Specification (Preclosure)**

Power	Canister Wall	
(kW)	(°F)	(°C)
11.8	525	274
18.0	450	232
25.0	358	181

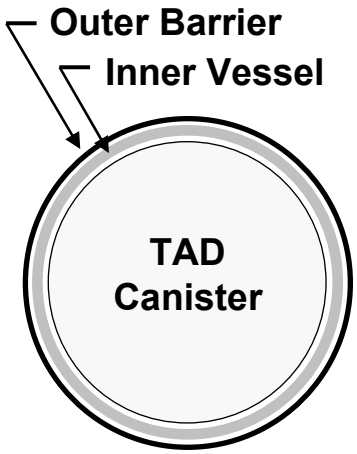
Maintains Cladding
$T \leq 350°$ C

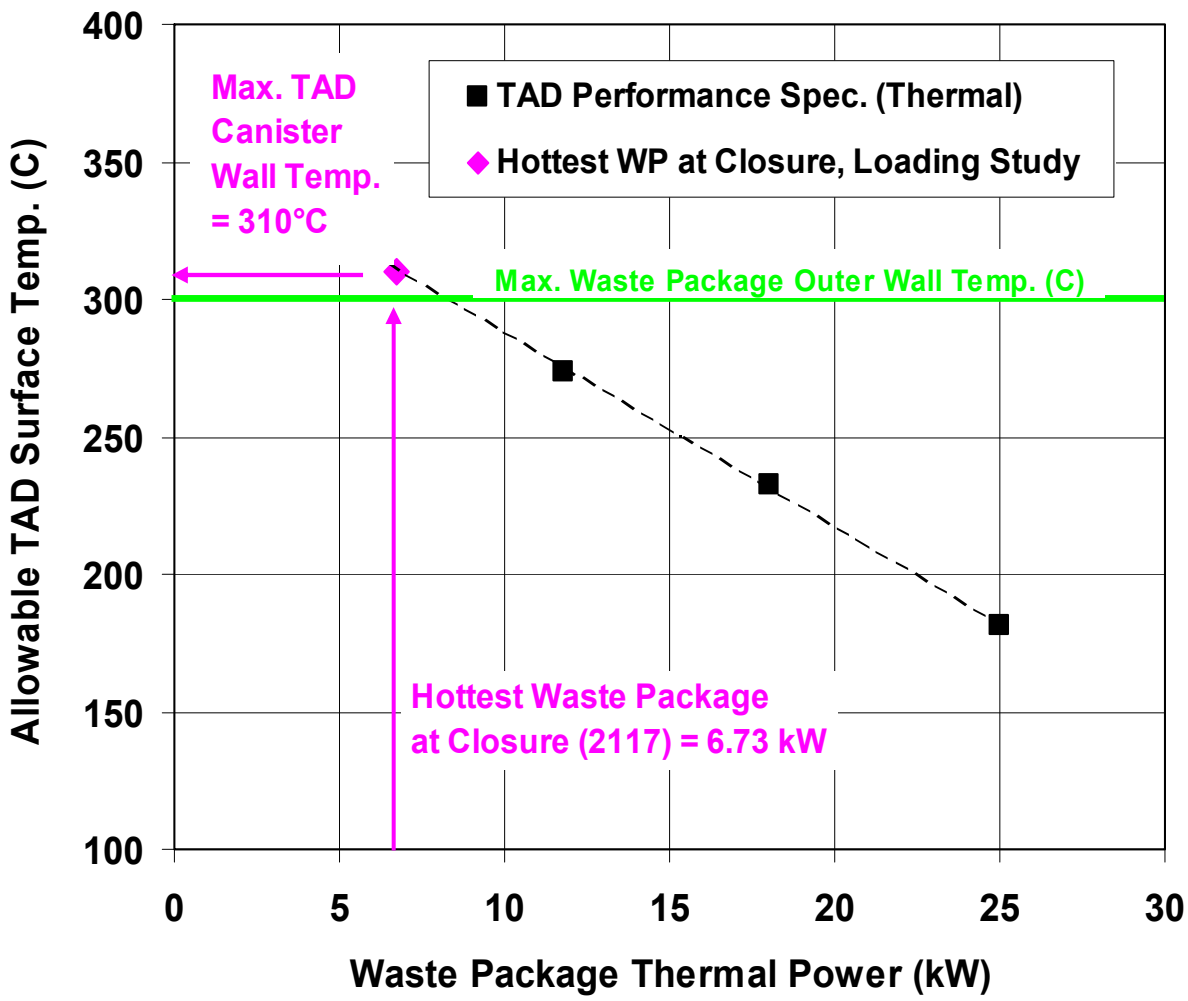
- **Hottest Waste Package at Closure**
  - Estimated Limiting Waste Stream (ELWS): 6.73 kW at closure
  - Extrapolating gives allowable TAD canister wall T < 310°C (or higher for less heat output)

Source: ANL-NBS-HS-000057 Rev. 00, Section 6.1.6

Waste Package and Clad Temperature with Drift Collapse
Internal Waste Package Peak Temperature

ΔT ~ 10°C (310 minus 300°C) is available to propagate 6.73 kW to the waste package outer surface





Source: ANL-NBS-HS-000057 Rev. 00, Section 6.1.6

Waste Package and Clad Temperature with Drift Collapse

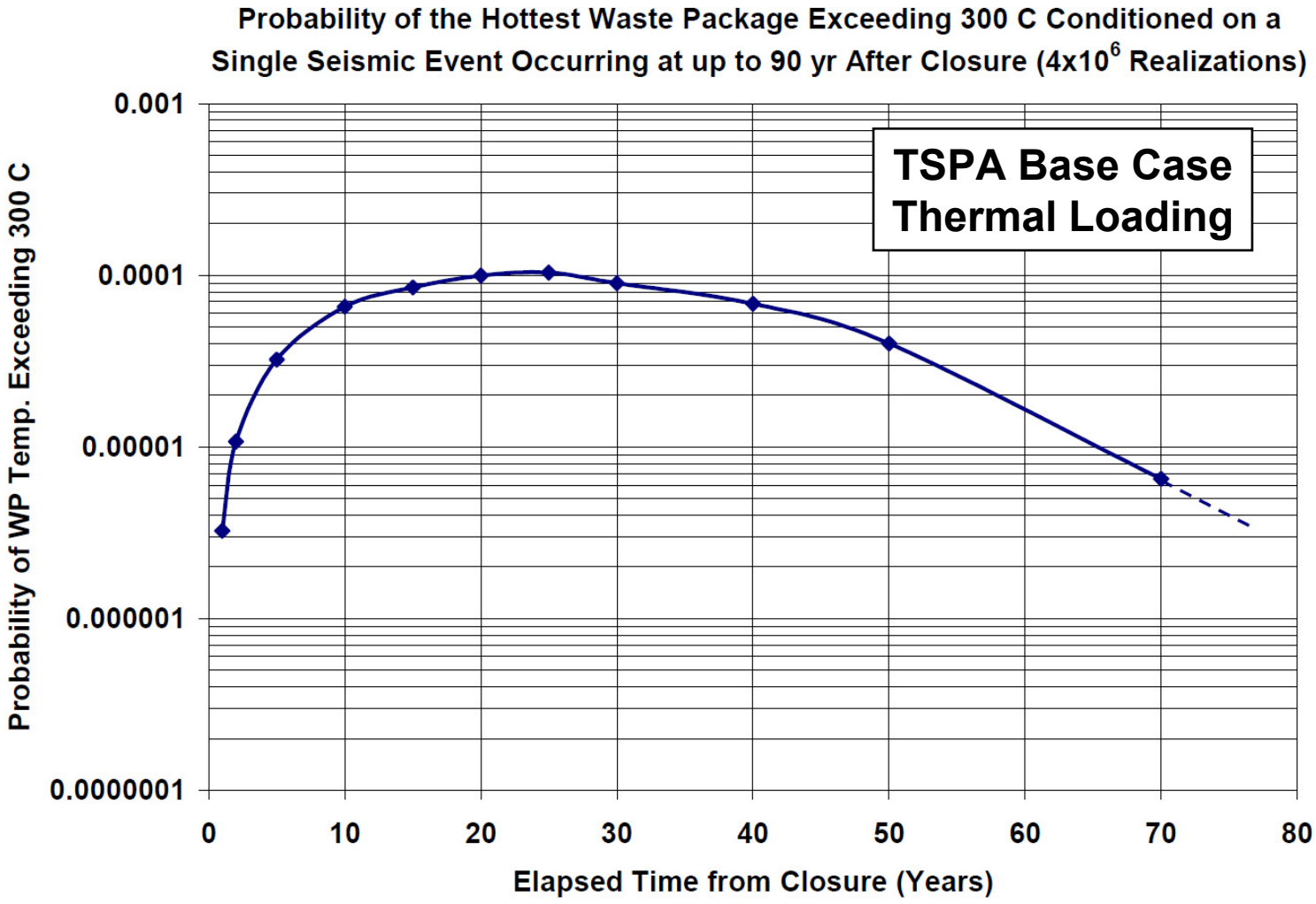
Postclosure Temperature Summary

- **Thermal models show that waste package temp. < 300°C, and cladding temp. < 350°C….**
- **Except for drift collapse within 90 years after closure**
  - **Thermally sensitive FEPs, e.g., thermal sensitization of Alloy 22 (300°C is an approximate limit)**
- **Seismic ground motion is the major cause for rockfall or collapse**
  - **Possible outcomes: no significant rockfall, or partial or complete collapse**
  - **Single-event seismic probabilities apply for 90 years**

Waste Package and Clad Temperature with Drift Collapse
Probalistic Analysis Approach

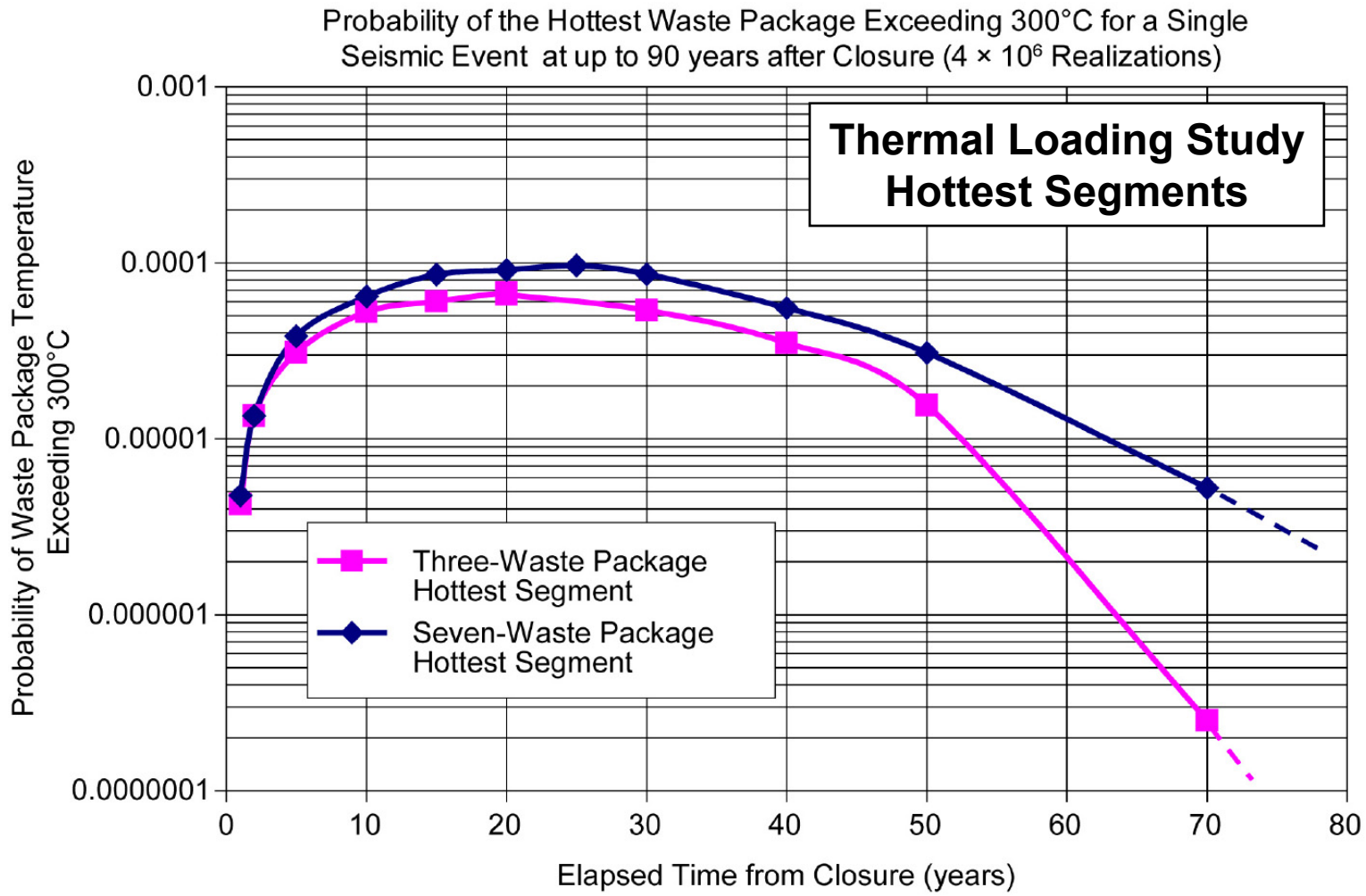
- **Implement seismic consequence abstraction for rockfall volume**
  - **Monte Carlo realization for seismic events in 90 years**
- **Thermal-hydrologic modeling of partial collapse (rubble volume from 1.26 to 83.36 m^3/m)**
  - **Weighted sampling of 10^{th} percentile, mean, and 90^{th} percentile of host rock K_{th}**
  - **Use average 10th percentile percolation flux**
- **Sampling of effective thermal conductivity (K_{th}) for collapse debris**

Waste Package and Clad Temperature with Drift Collapse
Probabilistic Analysis Results



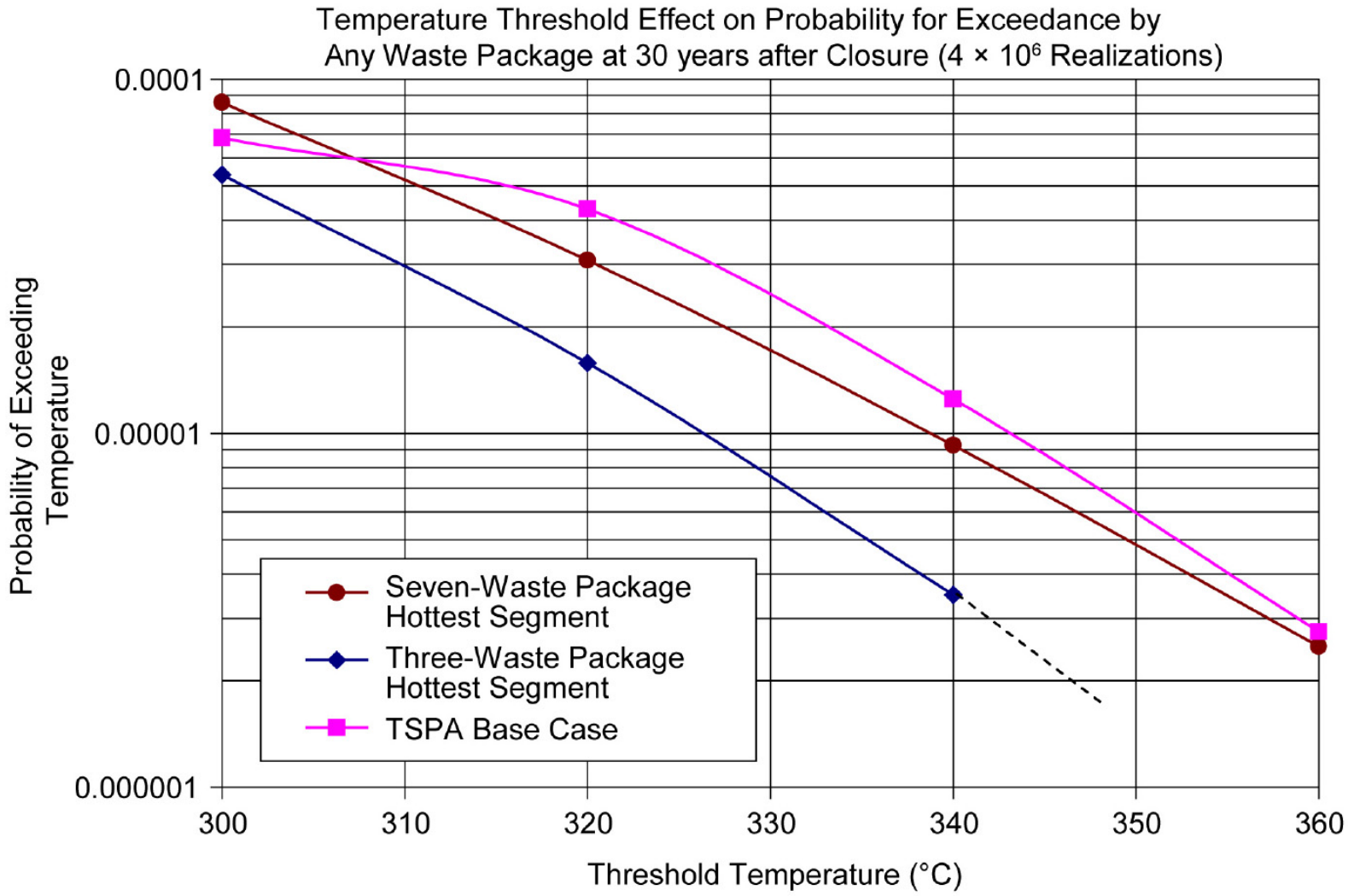
Source: ANL-NBS-HS-000057 Rev. 00, Fig. 6.5-1

Waste Package and Clad Temperature with Drift Collapse
Probabilistic Analysis Results (Continued)



Source: ANL-NBS-HS-000057 Rev. 00, Fig. 6.5-2

Waste Package and Clad Temperature with Drift Collapse
Probabilistic Analysis Results (Continued)



Source: ANL-NBS-HS-000057 Rev. 00, Fig. 6.5-3

Waste Package and Clad Temperature with Drift Collapse
Probabilistic Analysis (Continued)

- **Conservatisms in drift collapse thermal modeling**
  - **Collapse debris volume and effective K_{th} are uncorrelated (greater bulking will produce larger voids, and thus greater heat transfer)**
  - **Heat transfer by thermal convection is not included in the Multiscale model or probabilistic analysis**
  - **Stratification of debris is not included–debris in the upper part of the cavity may be more coarse, and transmissive**

Waste Package and Clad Temperature with Drift Collapse
Summary

- **Waste package temperature (T_{WP}) < 300°C and cladding temperature < 350°C**
  - **Except for drift collapse within 90 years after closure**
- **Probabilistic analysis: $P\{T_{WP} > 300°C\} \leq 10^{-4}$**
  - **Probability decreases steeply for $T_{WP} > 300°C$**
- **Conservatisms were used in probabilistic analysis**
  - **Thermal convection was not included**
- **Limited thermal impact of drift collapse on TSPA**
- **FEPs are only incrementally sensitive to peak temperature > 300°C**