ASSESSMENT OF SPENT FUEL AT THE POTENTIAL YUCCA MOUNTAIN REPOSITORY

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Potential Yucca Mountain (YM) Repository of High-Level Waste (HLW)

The Nuclear Regulatory Commission (NRC) evaluation includes:

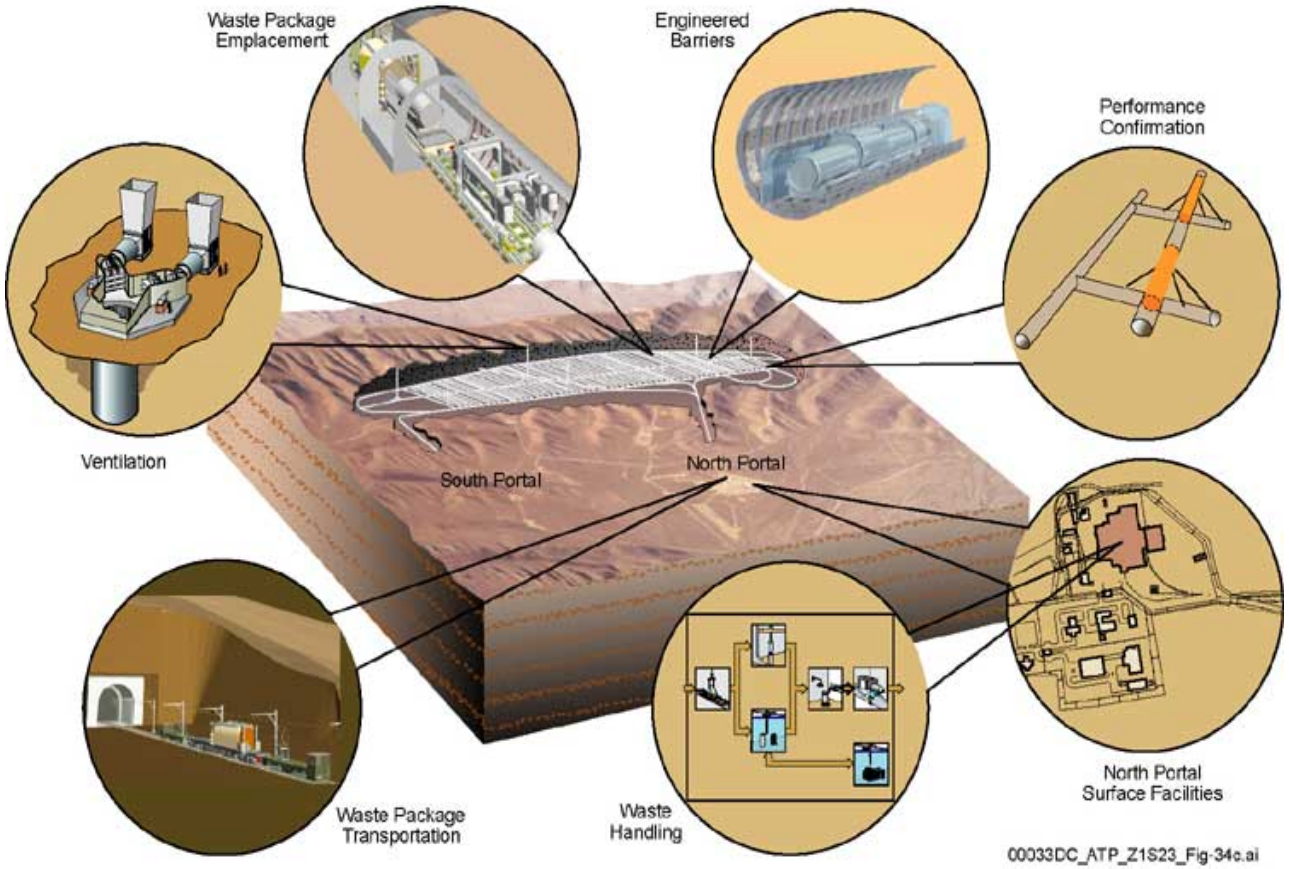
(i) Construction and operation of the pre-closure facilities (i.e., safety)

(ii) Ability of the repository to isolate HLW (i.e., isolation)

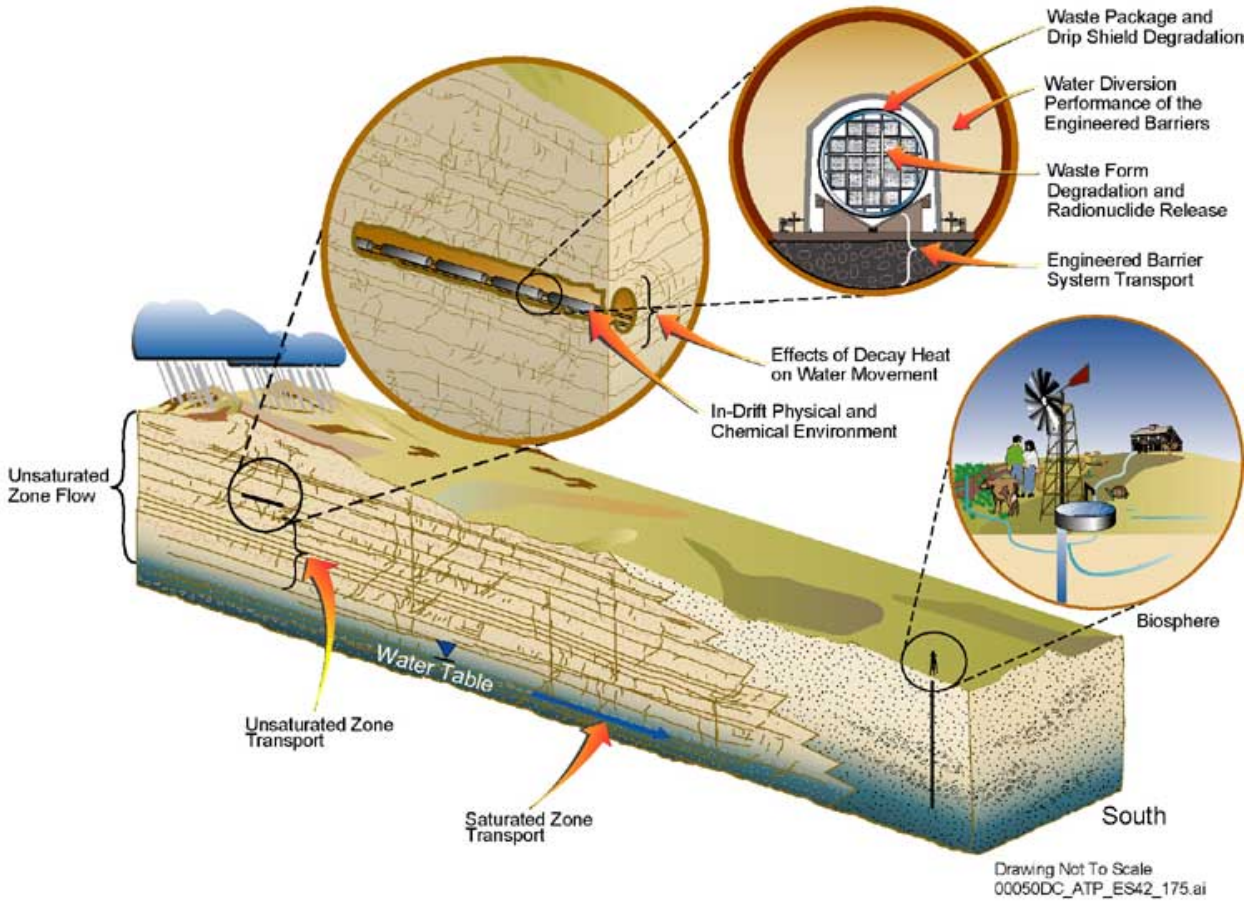
The condition of spent nuclear Fuel (SNF) received at the repository affect both safety and isolation.

The condition of SNF (i.e., the matrix and cladding) is primarily determined by how the fuel performs during reactor operation, interim storage, and transportation.

Proposed Monitored Geologic Repository Facilities at Yucca Mountain (DOE, 2002)



Schematic Illustration of the Ten General Processes Considered and Modeled for Total System Performance Assessment (DOE, 2002)



Compliance Assessment

The radionuclide releases must comply with the performance objectives (i.e., regulatory dose requirements)

(i) safety: for workers and the public under normal operating and accident (e.g., drop/collision, seismicity, or aircraft attack) conditions

(ii) Isolation: for individual protection, human intrusion, and groundwater protection under nominal and disruptive (e.g., seismicity and volcanism) scenarios

Summarize the key data concerning the condition of SNF that are needed for the compliance assessment, and present future data needs

Initial Cladding Condition

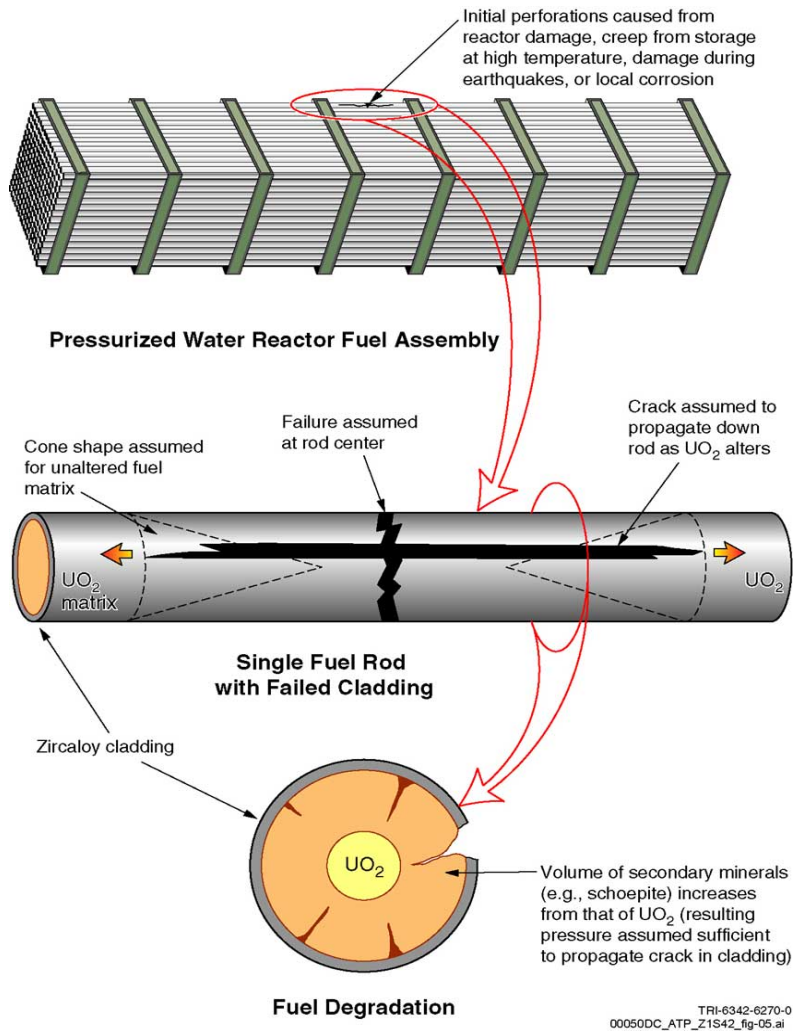
Safety: pin-holes and hairline cracks

(i) generated during the normal reactor operation; developed further during the subsequent handling operations, should the cladding have high stress or larger flaws or is subject to embrittlement

(ii) may lead to matrix oxidation should the SNF be exposed to oxygen at elevated temperatures, which may occur at SNF is transferred from transportation/staging packages to the disposal waste package at the potential pre-closure facilities

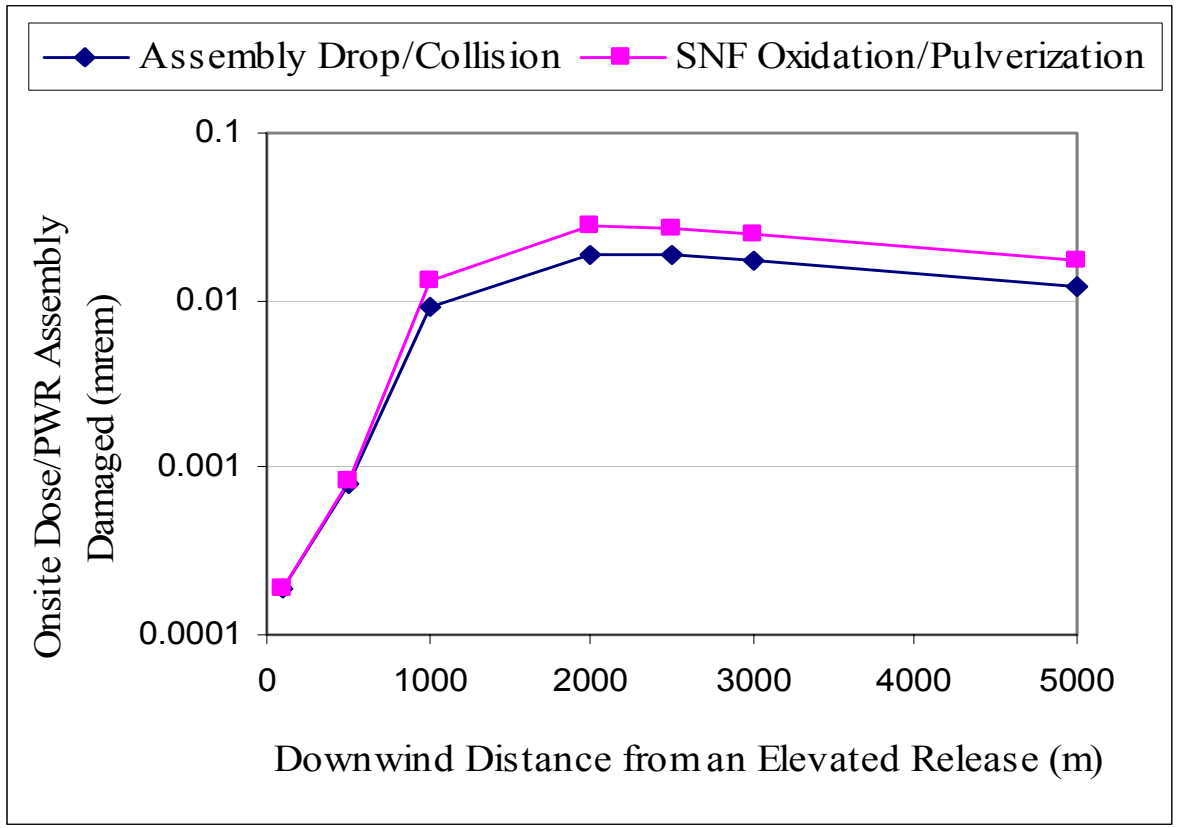
(iii) oxidation of UO_2 to U_3O_8 – about 35 % volume expansion at potential fuel handling temperatures (400 °C [752 °F]), potentially causing SNF pellets to crumble and generate particulates that could subsequently contaminate the facility

Conceptual Model of Commercial Spent Nuclear Fuel Cladding Degradation (DOE, 2002)



Example Dose Calculation Per SNF Assembly

(Kamas et al., 2005)



Isolation: pin-holes and hairline cracks

(i) Initially defected waste packages may allow radionuclide releases from SNF rods with pin-holes and hairline cracks.

(ii) radionuclide release assessment require:

- **the estimate of radionuclide inventory at the grain boundaries of SNF pellets and the gap between the cladding and the SNF pellets; and**

- **the radionuclide inventory in the SNF pellet matrix**

The grain boundary and gap inventories are considered to be mobilized rapidly, whereas the matrix inventory is considered to be mobilized at the slow SNF dissolution rate.

Recommended Instant Release Fraction Values for Triangular Distributions (Jain et al., 2004)

Instant Release Fraction	Lower (Percent)	Apex (Percent)	Upper (Percent)
I-129 and Cl-36	0.50	11	34
Cs-135	0.16	3.7	11.3
Tc-99	0.05	0.13	0.28
C-14	10	10	10

The Matrix Dissolution

- Groundwater Contact Mode
- Cation
- pH
- Oxygen and Iron Concentration
- Temperature
- Prior Oxidation/Hydration
- Grain Boundary Inventory

- Partial Cladding Protection

  - Slit (~0.015 cm [5.9×10^{-3} in] dia. X ~2.54 cm [1 in] length) - or Hole (~0.02 cm [7.9×10^{-3} in] dia.) – Defected SNF Immersion Tests in J-13 Well Water at 85 °C (Wilson, 1990)

  - release decreased by a factor of ~ 140 for Tc-99, ~7×10^{5} for I-129 and ~65 for Sr-90

High Burnup SNF

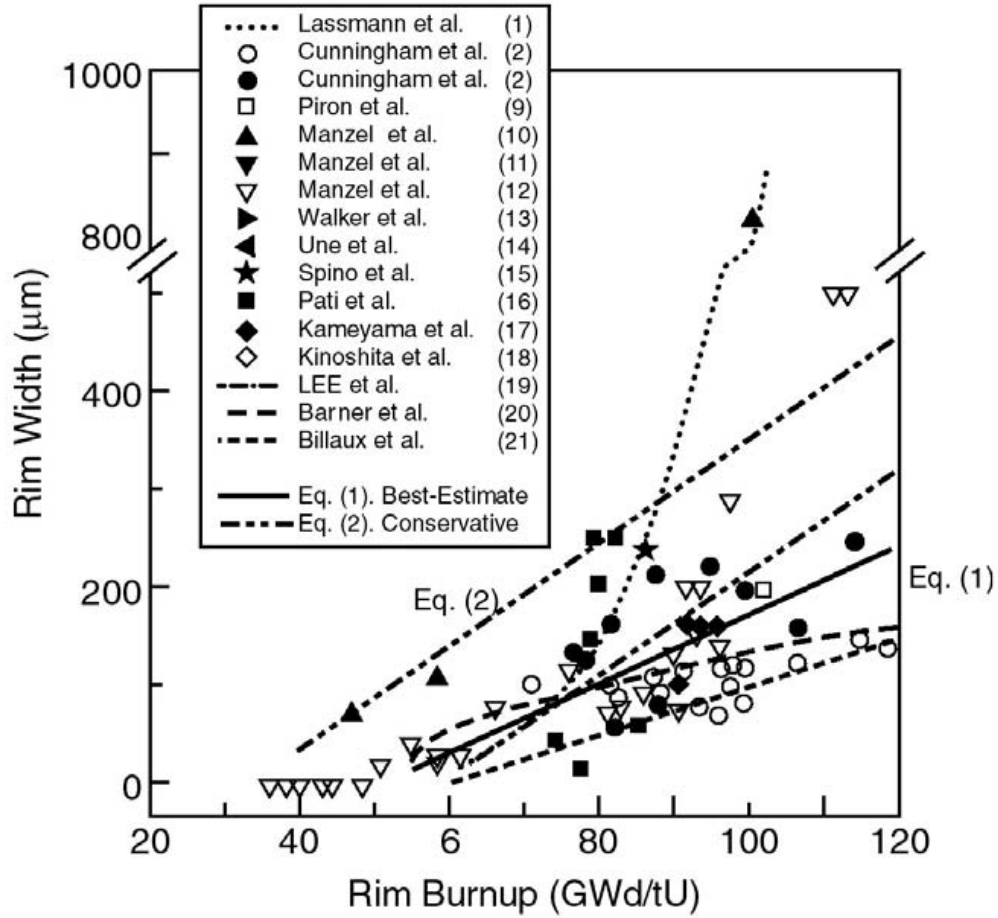
- Substantial thickness of rim zone at above 60 to 65 Gwd/MTU
  (1 ton = 2205 lb)

- Rim: loss of optically definable grain structure

  (1) Oxidation may generate more respirable particles.
  (2) Oxidation kinetics may be slowed.
  (3) Dissolution kinetics may be slowed.

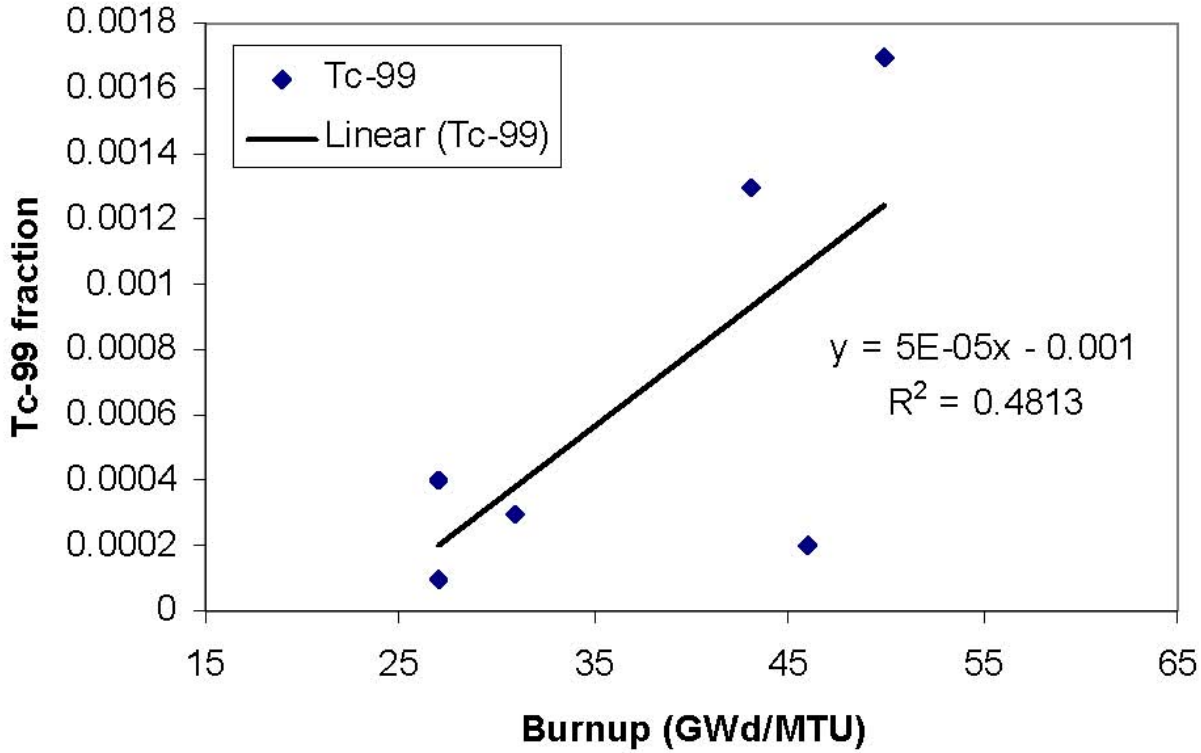
- Systematic data on the grain boundary and gap inventories are not well established.

- Embrittlement: the pressure in the gap is likely to be high enough to cause hydride reorientation to a radial direction; bigger flaws are likely to be present, increasing the applied stress intensification factor.



Measured Rim Width Both by Electron Microprobe Analyzer and Optical Microscopy (Koo, et al., 2001). (Reproduced with Permission from Copyright Clearance Center). NOTE: Refer to Koo, et al. (2001) for Information on References Cited in the Figure.

(From Jain et al., 2004)

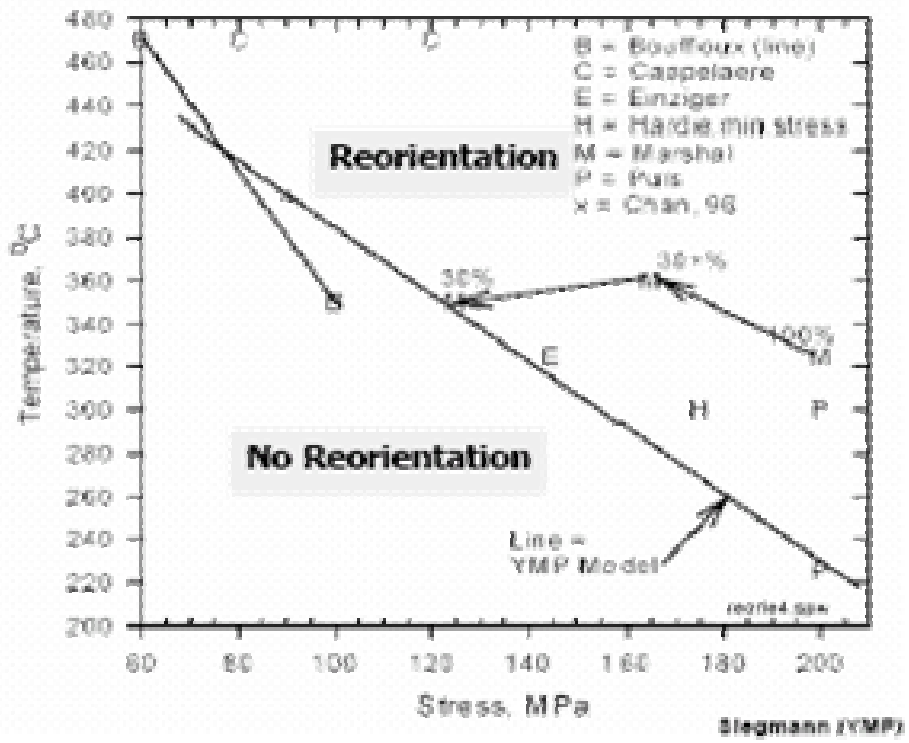


Instant Release Fraction for Tc-99 As a Function of Burnup. Data Are Extracted from Johnson and Tait (1997).

(From Jain et al., 2004)

Hydride Reorientation – Creep Tests

- Radial hydrides, as little as 40 wppm, can significantly degrade cladding's mechanical properties. (Marshall)
- Stress, temperature, cool-down rate, microstructure, H content, etc., all play important roles. (Einziger)
  - Threshold hoop stress for 400°C is ~ 100 MPa.



From Tsai, 2003 **(1 MPa = 0.145 ksi; 200°C = 392 °F)**

Summary

- The potential YM repository requires the safe construction/operation of the facility and the long-term isolation of HLW. For this purpose, the condition of the SNF received at the repository is important.
- Pinholes and hairline cracks need to be better characterized during the normal reactor operation, the subsequent SNF handling from a reactor discharge, the transportation and the storage.
- Oxidation kinetics for various burnup need to be determined.
- High burnup fuel needs to be better characterized for oxidation and dissolution kinetics of rim, grain boundary and gap inventory, and hydride embrittlement of cladding.

DISCLAIMER

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 geological repository at Yucca Mountain. This presentation is also an independent product of the CNWRA and does not necessarily reflect the views or regulatory position of the NRC.

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