A Method to Determine the Maximum Permissible Rod Cladding Temperature for High Burnup SNF at Different Post Core Decay Times (PCDTs)

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Presentation to The USNRC
April 27, 2000

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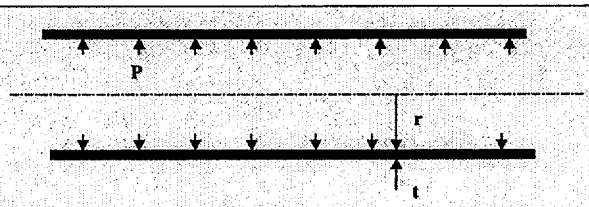
Proposed Method

- Utilizes existing creep data for low and medium burnup fuel in a conservative manner for high burnup fuel.
- Uses the universally accepted failure model for creep failure of pressurized cladding to establish permissible T.

The Fundamental Degradation Mode for Fuel Cladding is Increasing Hoop Strain with Time (Creep)



Hoop Stress (σ) = P r/t

Rate of Creep = f (σ,T)

Underlying Concepts

- Creep rate is a function of hoop stress, σ and clad temperature, T.
- The higher the burnup, the lower is the rate of creep.
- The higher the burnup, the smaller is the value of failure strain.
- The accumulated creep, ε, in an irradiated rod can be conservatively defined by the equation

  $\varepsilon = A\ (\tau-\tau_o)^m$; τ is PCDT

  and m is a function of hoop stress and cladding temperature.

Conservative Assumptions

- Assume a limiting value of σ (=150 megapascals) to determine T.
- Assume failure strain at 0.4%.
- Conservatively represent the creep rate of the high burnup rod by the *upper bound creep rate.*

In other words, use the most limiting σ, most limiting failure strain, and a most limiting creep rate curve.

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Comparison of the PNL Solution with Proposed Method for the Predicted T_{all}

Case I: σ = 100 Mpa				
		High Burnup Rod Creep Failure Model		
Fuel Age	PNL (°C)	Exp. (°C) (0.4%)	Exp. (°C) (0.2%)	Exp. (°C) (0.1%)
5-Yr	380.7	393.7	378.5	361.6
6-Yr	369.3	390.3	375.3	358.5
7-yr	346.2	386.7	371.8	355.4
10-Yr	341.0	379.7	365.5	349.6
15-Yr	333.2	375.6	361.6	346.1

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Comparison of the PNL Solution with Proposed Method for the Predicted T_{all}

Case II: σ = 150 MPa				
		High Burnup Rod Creep Failure Model		
Fuel Age	PNL (°C)	Exp. (°C) (0.4%)	Exp. (°C) (0.2%)	Exp. (°C) (0.1%)
5-Yr	346.9	361.1	345.7	329.0
6-Yr	339.1	357.7	342.6	326.0
7-yr	316.6	354.0	339.2	322.8
10-Yr	311.2	347.1	332.8	316.6
15-Yr	306.0	343.0	329.1	313.3

CONCLUSION

- The PNL data for low burnup at 100 megapascals hoop stress can be conservatively used for high burnup SNF.
- 150 megapascals (σ) will introduce additional (unnecessary!) conservatism.
- Just as the SFPO specifies acceptable limits of stress, dose rate, etc., it should also specify acceptable T_{all} for casks.