August 26, 2010

MEMORRANDUM FOR: Jack Guttmann, Chief
Performance Assessment Branch, HLWRS

FROM: Timothy Sippel, Nuclear Engineer **/RA/**
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SUBJECT: YUCCA MOUNTAIN CONFIRMATORY CRITICALITY CALCULATIONS

As part of my postclosure criticality review I performed some confirmatory calculations. The purposes of these calculations were to confirm that the applicant had supplied a sufficiently detailed description of its calculations to enable the calculations to be reproduced. Exact agreement with the applicant's calculations was not expected or required since the criticality models used different computer codes, different cross section versions, and contained other small differences. However, the calculations served to check that the applicant's model did not contain an error that would result in significantly different results.

The first set of confirmatory calculations was performed with SCALE5.1. The model was of a flooded (but otherwise intact) TAD canister containing Westinghouse 17x17 fuel assemblies. The fuel assemblies had a burnup of 44.1 GWd/MTU and an initial enrichment of 5.0 wt% U235. The applicant's burnt fuel composition (Table 4, RAI Response 2.2.1.2.1-4-34) was used. The resulting k_{eff} was **0.93711** + or - 0.00045. This calculated value is less than the applicant's USL of **0.9529** for burnt CSNF. Next a calculation was performed to evaluate how much margin may be available in the Borated Stainless Steel absorber plates. This calculation increased the boron credit from 75% to 90% resulting in the calculated k_{eff} decreasing to: **0.93412** + or - 0.00038. Based on the information in *CSNF Loading Curve Sensitivity Analysis* (DOC.20080211.0001) calculations were performed with the fuel degraded to Schoepite. In all cases evaluated reactivity decreased in comparison to the un-degraded case.

Tianqing Cao and I used SCALE6 and the information supplied by the applicant in RAI Response 2.2.1.2.1-4-23 and *Enrico Fermi Fast Reactor Spent Nuclear Fuel Criticality Calculations: Degraded Mode* (MOL.20000802.0002) to model a flooded and highly degraded codisposal waste package containing Enrico Fermi DOE SNF in a short DOE SNF canister as a check of the applicant's modeling of degraded configurations. The Enrico Fermi SNF is the representative fuel for DOE SNF group 8, which requires the addition of neutron absorber shot to prevent criticality for degraded configurations. Therefore the confirmatory calculations were focused on determining if the amount of Gadolinium specified by the applicant would maintain the k_{eff} below the USL (**0.9659**). The applicant specified the use of **9.04 kg** of Gd in (Table 2, RAI Response 2.2.1.2.1-4-34).

The degraded configuration model shown in the figure below assumes: no gadolinium, more fuel pins than are allowed in the loading plans, and waste package internals reduced to corrosion products. The DOE SNF canister was modeled as still remaining but buried in clay formed of degraded HLW glass and corrosion products.

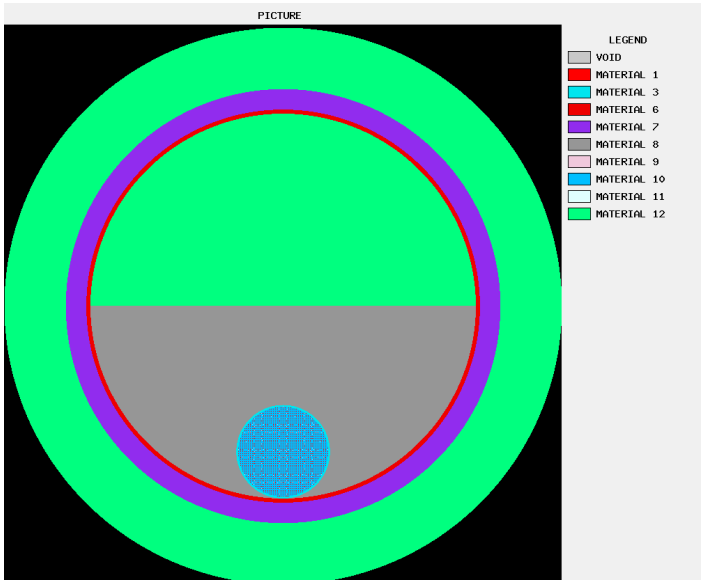

Figure 1: Intact Enrico Fermi DOE SNF Canister in a Degraded Codisposal WP

Our results for this configuration matched DOE's results. As expected of a flooded configuration without neutron absorbers this configuration is critical. So several other configurations were modeled which included degraded (but still present) gadolinium absorbers.

In the model below the DOE SNF canister components, including the gadolinium shot, have degraded and the corrosion products settled to the bottom, with a layer of clay on top. The fuel assemblies are stacked in a loose triangular configuration which is similar to DOE's model that was shown in Figure 5-12 of *Enrico Fermi Fast Reactor Spent Nuclear Fuel Criticality Calculations: Degraded Mode* (MOL.20000802.0002).

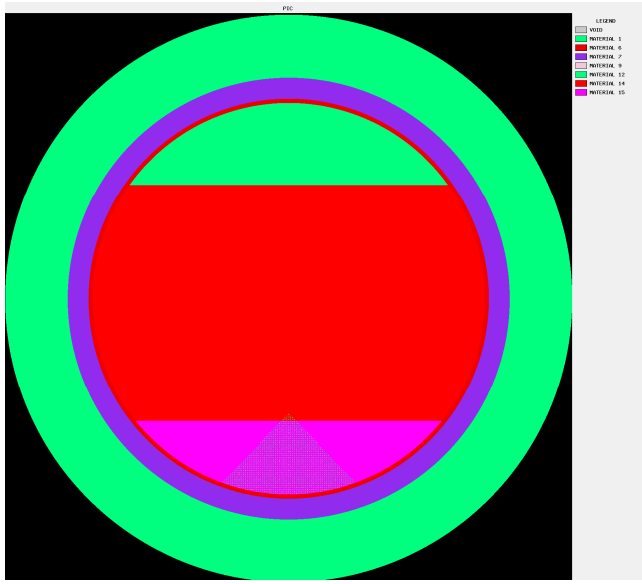

Figure 2: Degraded Enrico Fermi with a Pile of Fuel Rods

Tianqing Cao performed a parametric study were the amount of gadolinium in the degraded configuration model shown in Figure 2 was varied. The results of this parametric study are shown in the figure below.

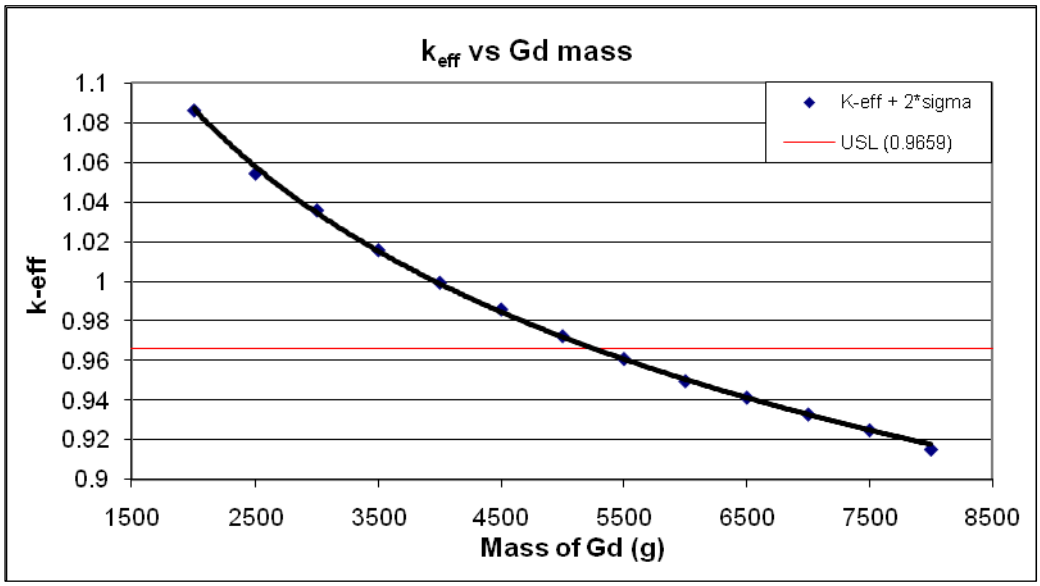

Figure 3: k_{eff} vs Gd mass

None of the configurations modeled by NRC staff exceed the USL with 9 kg of Gd present.

Referenced Documents:

CSNF Loading Curve Sensitivity Analysis. ANL–EBS–NU–000010. Rev. 00. February 2008. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080211.0001.

Enrico Fermi Fast Reactor Spent Nuclear Fuel Criticality Calculations: Degraded Mode. CAL-EDC-NU-000001 REV 00. Las Vegas, Nevada: DOE, Office of Civilian Radioactive Waste Management. ACC: MOL.20000802.0002.

RAI Response 2.2.1.2.1-4-34. "Yucca Mountain—Request for Additional Information Regarding License Application (Safety Analysis Report Section 2.2.1.2), Safety Evaluation Report, Vol. 3, Chapter 2.2.1.2.1, Set 4." Letter (March 26) J.R. Williams to J.H. Sulima; Enclosure (8). ML090860424. Washington, DC: DOE, Office of Technical Management.

RAI Response 2.2.1.2.1-4-23. “Yucca Mountain—Response to Request for Additional Information Regarding License Application (Safety Analysis Report Section 2.2.1.2), Safety Evaluation Report Vol. 3, Chapter 2.2.1.2.1, Set 4.” Letter (October 26) J.R. Williams to J.H. Sulima (NRC). ML093070154. Washington, DC: DOE, Office of Technical Management.

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RAI Response 2.2.1.2.1-4-23. “Yucca Mountain—Response to Request for Additional Information Regarding License Application (Safety Analysis Report Section 2.2.1.2), Safety Evaluation Report Vol. 3, Chapter 2.2.1.2.1, Set 4.” Letter (October 26) J.R. Williams to J.H. Sulima (NRC). ML093070154. Washington, DC: DOE, Office of Technical Management.

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