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NUCLEAR ENERGY INSTITUTE

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Mr. Brian J. Benney
Project Manager, Division of Reactor Safety Systems
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: White Paper on a Conservative Approach to Depletion Analysis for Spent Fuel Pool Criticality Analyses

Project Number: 689

Dear Mr. Benney:

On behalf of the nuclear energy industry, the Nuclear Energy Institute (NEI)[1] is submitting supplementary information to support the NRC review of NEI 12-16, *Guidance for Performing Criticality Analyses of Fuel Storage at Light Water Reactor Power Plants,* Revision 2, Draft A that was submitted in May 2016 [Ref. 1]. On June 8th, 2016 [Ref. 2], NEI and EPRI met with NRC to discuss the technical approach contained in the EPRI Reports 1022503 and 1022909. During that meeting, NEI agreed to provide additional justification on the acceptability of the statistical approach in the context of the overall conservatism of the depletion analysis described in NEI 12-16.

The attached white paper provides additional information on the approach described in NEI 12-16 to ensure that criticality safety analyses performed in accordance with the guidance document will meet the regulatory requirements in 10 CFR 50.68(b)(4).

[1] The Nuclear Energy Institute (NEI) is the organization responsible for establishing unified industry policy on matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include all entities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect/engineering firms, fuel cycle facilities, nuclear materials licensees, and other organizations and entities involved in the nuclear energy industry.

BRIAN BENNEY
VERIFIED TO BE ORIGINAL

Sincerely,

Kristopher W. Cummings

References

[1] Final Response to Request for Additional Information Related to NEI 12-16, *Guidance for Performing Criticality Analyses of Fuel Storage at Light Water Reactor Power Plants,* and EPRI Report 3002003073, "Sensitivity Analysis for Spent Fuel Pool Criticality" and NEI 12-16, Revision 2 – DRAFT A (ML16155A120)

[2] Summary of June 8th, 2016, Meeting with the Nuclear Energy Institute to Discuss the Electric Power Research Institute Depletion Code Validation Approach (ML16175A323).

Attachment

c: Mr. William Dean, NRR, NRC
Mr. Brian McDermott, NRR, NRC
Mr. Timothy J. McGinty, NRR/DSS, NRC
Mr. Robert Taylor, NRR/DSS, NRC
Mr. Eric Oesterle, NRR/DSS/SRXB, NRC
Mr. Jeremy L. Dean, NRR/DSS/SNPB, NRC
Mr. Kent A. L. Wood, NRR/DSS/SNPB, NRC
Mr. Amrit D. Patel, NRR/DSS/SNPB, NRC

A Conservative Approach to Depletion Analysis for Spent Fuel Pool Criticality Analysis

A spent fuel pool criticality analysis that credits the reduction in reactivity (i.e., burnup credit) with irradiation is separated into two parts. The first is the calculation of the irradiated fuel composition in the depletion code. The second is the calculation of the neutron multiplication factor (i.e., k_{eff}) in the storage rack geometry using a Monte-Carlo criticality code. This white paper expands on the discussion detailing the conservative approach to the depletion analysis described in NEI 12-16, Revision 2, Draft A, ensuring that the regulatory requirements for maximum k_{eff} are met.

Depletion codes consist of a 2D representation of the fuel assembly cross-section, modeled in the core configuration at conservative operating conditions determined by the analyst (see below). Therefore, each calculation represents an individual node of the fuel assembly (approximately 6-8 inches in height, depending upon the node size in the 3D criticality code calculation). For simplification, the analyst may choose to use bounding operating conditions from the most limiting node for all other non-limiting nodes (for the nodes in the central, non-blanketed region), with representative operating conditions and burnable absorber configurations selected to bound the entire length of the fuel assembly.

Section 4.2.1 of NEI 12-16 provides guidance on selecting the operating parameters and burnable absorbers in the depletion analysis to ensure a conservative isotopic inventory is determined for subsequent calculations in the criticality code. The approach detailed in this section ensures that the isotopic inventory of the design bases assembly will produce a bounding reactivity compared to actual depleted fuel assemblies (or certain subsets of fuel assemblies controlled by Technical Specification requirements) in the spent fuel pool. Figure 1 illustrates this approach by comparing the 2D k_{eff} from the depletion code as a function of burnup to other fuel assemblies with different burnable absorber configurations, all at conservative operating conditions (fuel temperature, moderator temperature, power and core soluble boron). For the purposes of the examples provided in the figures a representative 17x17 PWR Westinghouse fuel assembly was considered. Table 1 provides a brief description of each curve.

For the purposes of illustrating the conservativism of this approach compared to other assemblies, Figure 2 compares the reactivity as a function of burnup between the design basis assembly (bounding operating parameters, max absorber hardening), an assembly with no burnable absorbers (no hardening, but conservative operating parameters) and an assembly with more representative, non-bounding operating parameters (but still with maximum absorber reactivity impact). Figure 2 demonstrates the level of conservatism associated with the design basis assembly compared to other assemblies in the core.

In addition to producing a conservative isotopic inventory through the selection of burnable absorbers and operating parameters to maximize reactivity, Section 5.1.4 of NEI 12-16 specifies the inclusion of the reactivity effect associated with the uncertainty of the burnup of the individual fuel assembly. As described in Section 5.1.4, use of a 5% burnup uncertainty is bounding. This burnup uncertainty is included to account for the deviation of the reactor record burnup from the "true" burnup of the assembly.

Finally, there may be some uncertainty in the reactivity of the fuel assembly at the given burnup, termed the "depletion uncertainty". The Kopp memo and ISG-DSS-2010-001, have identified the use of 5% of the reactivity decrement as an appropriate value in the absence of additional information. The industry, through the Electric Power Research Institute (EPRI) has performed additional work to provide a more robust and accurate assessment of the true depletion uncertainty [1,2].

Figure 3 illustrates the impact of including the burnup uncertainty and depletion uncertainty to the design basis fuel assembly reactivity curve compared to the design basis and more typical fuel assembly reactivity curves

In conclusion, the approach for depletion calculations detailed in NEI 12-16 is a conservative approach due to 1) biasing the isotopic inventory through inclusion of the impact of burnable absorbers (i.e., spectrum hardening) and conservative operating parameters, 2) inclusion of an uncertainty in the computation of reactivity from the depletion code through inclusion of a depletion uncertainty, and 3) inclusion of an uncertainty in the computation of burnup through inclusion of a burnup uncertainty. It should be noted that the inclusion of both the depletion uncertainty and the burnup uncertainty is essentially a "double-counting" of the uncertainty of the depletion code to accurately calculate the change in reactivity with burnup.

References

[1] *Benchmarks for Quantifying Fuel Reactivity Depletion Uncertainty* EPRI, Palo Alto, CA: 2011. 1022909

[2] *Utilization of the EPRI Depletion Benchmarks for Burnup Credit Validation* EPRI, Palo Alto, CA: 2012. 1025203

Table 1

Reactivity vs. Burnup Curve	**Description**
Design Basis	Bounding operating parameters, with same absorbers as Limiting Burnable Absorbers, no credit for residual absorber
No Burnable Absorbers	Bounding operating parameters, no burnable absorbers
WABA + IFBA	Bounding operating parameters, **W**et **A**nnular **B**urnable **A**bsorber rods (12) combined with **I**ntegral **B**urnable **F**uel **A**bsorbers rods (124), with credit for residual absorber.
Limiting Burnable Absorbers	Limiting absorber combination (WABA, IFBA and 2nd cycle weak absorber), with credit for residual absorber
BPRA	Bounding operating parameters, includes removable **B**urnable **P**oison **R**od **A**ssemblies, with credit for residual absorber
Max IFBA	Bounding operating parameters, max **I**ntegral **B**urnable **F**uel **A**bsorbers rods (200), with credit for residual absorber
DB, Non-Bounding OP (Operating Parameters)	Same as Design Basis, moderator temp. 40K lower, fuel temperature 200K lower, soluble boron 100ppm lower
DB with Uncerts.	Same as Design Basis with Depletion Uncertainty and Burnup Uncertainty

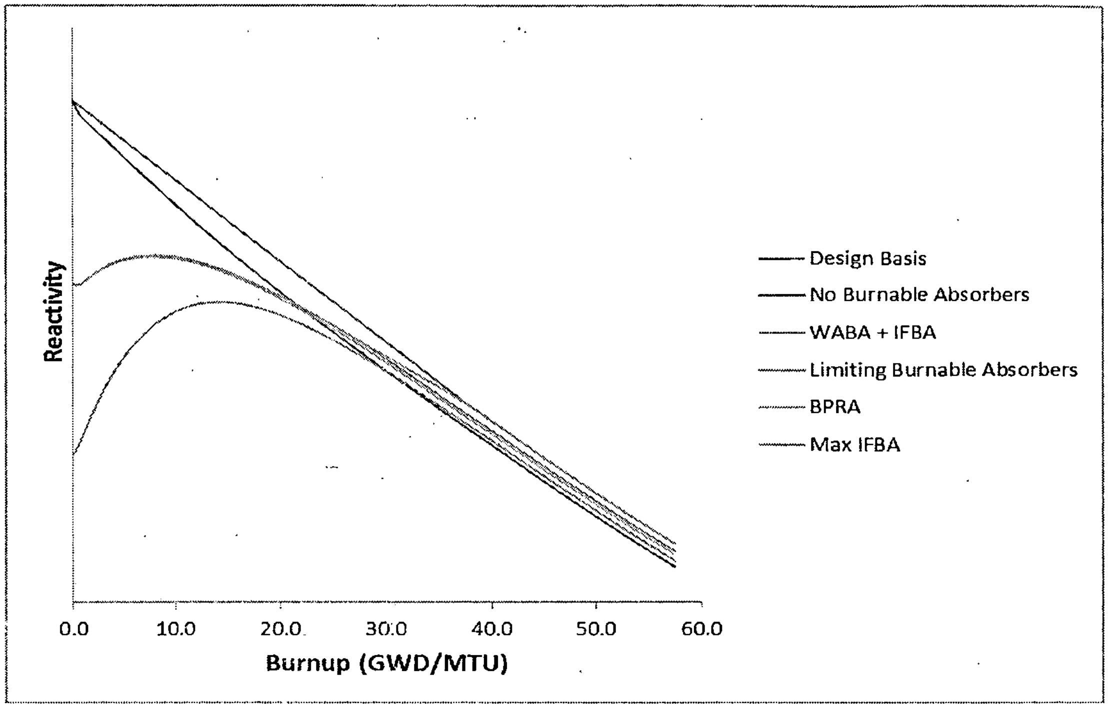

Figure 1: Comparison of Fuel Assembly Reactivity as a Function of Burnup for Different Burnable Absorber Configurations

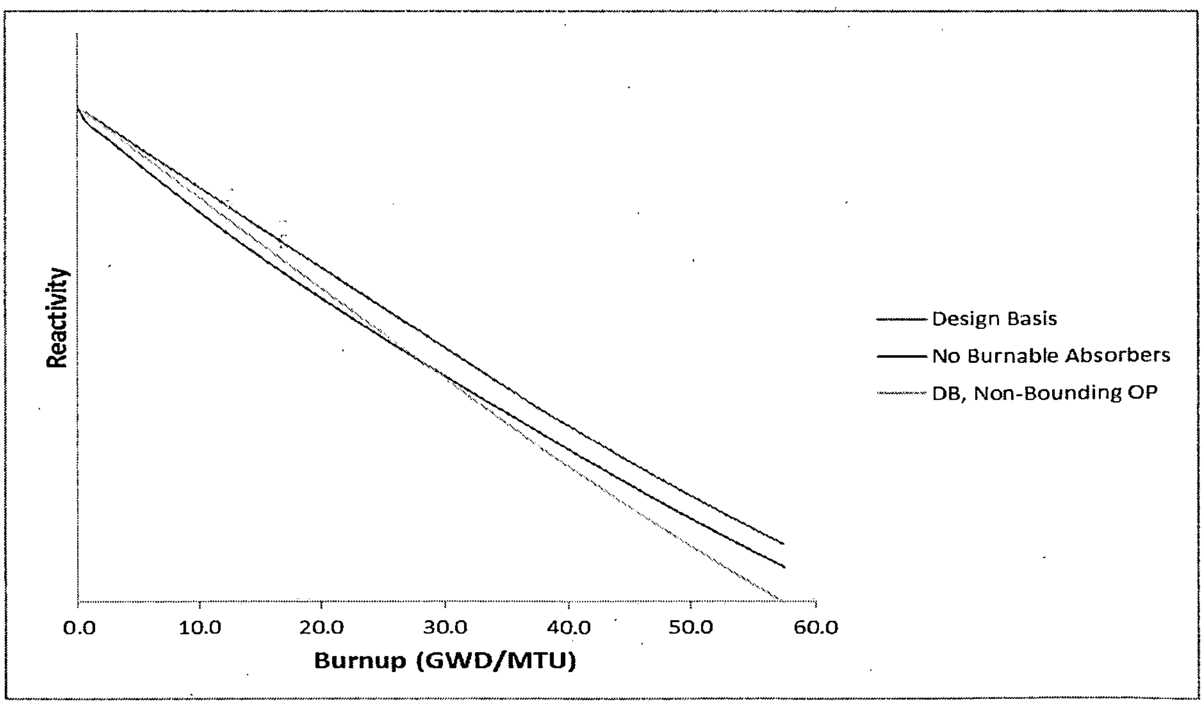

Figure 2: Comparison of Fuel Assembly Reactivity as a Function of Burnup for Design Basis Assembly versus Non-Limiting Fuel Assemblies

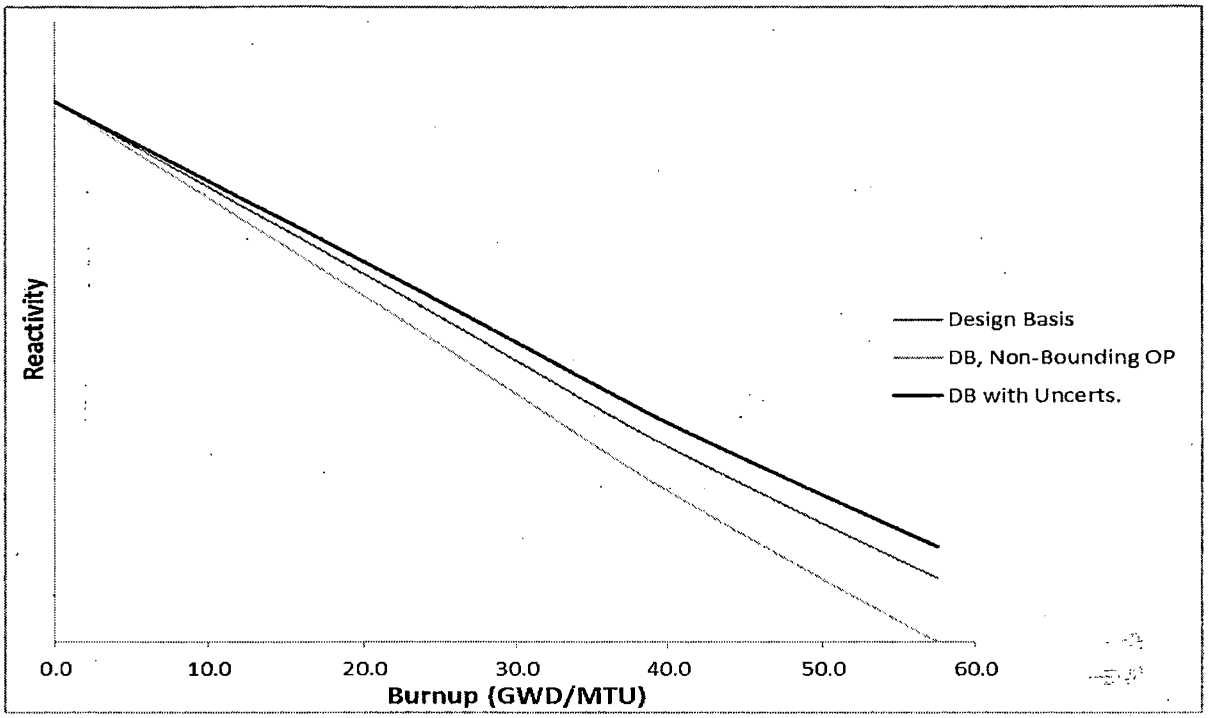

Figure 3: Comparison of Fuel Assembly Reactivity as a Function of Burnup for Design Basis Assembly with Uncertainties