ENCLOSURE 2

WESTINGHOUSE-PREPARED RAI RESPONSES

CE-17-3, REV. 1, ATTACHMENT 2

NON-PROPRIETARY

8 pages follow

RAI 6

Draft guidance document, NEI 12-16, "Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants," is in the process of being finalized. However, the NRC technical staff has reached agreement with NEI on many aspects of the document without exception. One of these aspects is in regards to accounting for the reactivity effect of ***[[eccentric positioning as a bias (rather than an uncertainty)]]****. The NRC staff did not identify that this accounting practice was not implemented during its initial review of WCAP-17400-P, Supplement 1, Revision 1, "Prairie Island Units 1 and 2 Spent Fuel Pool Criticality Safety Analysis: Supplemental Analysis for the Storage of IFBA Bearing Fuel," and consequently it was not identified in the corresponding requests for additional information issued on April 12, 2016.*

In order for the NRC staff to complete its review of WCAP-17400-P, Supplement 1, Revision 1, please correct the accounting of the ***[[fuel assembly eccentric positioning reactivity effect]]*** *to align with the current NRC and industry understanding of this phenomena to ensure that the 10 CFR 50.68(b)(4) requirements are met. The NRC staff believes this correction is particularly necessary in this case because of the large reactivity effect specific to Prairie Island spent fuel pool storage conditions.*

Response:

The [

][a,c] the underlying modeling strategy has been modified to provide a more realistic, though still conservative, quantification of the reactivity impact of eccentrically placed fuel assemblies. Note that the actual calculation of the reactivity change (the difference in reactivity between the eccentric case and the nominal case plus twice the root-sum-squared Monte Carlo uncertainties) remains the same as documented in References 1 and 2.

The eccentric positioning reactivity impact calculated in References 1 and 2 used a [

][a,c]

[a,c]

Figure 1: Reference 1 Eccentric Positioning Modeling Schematic (a) Fuel Assemblies Together (b) Fuel Assemblies Apart

The modeling strategy shown in Figure 1 provides an overly conservative representation of any expected fuel eccentricity. Because the reactivity impact will be treated as a bias rather than uncertainty, a more realistic, although still conservative modeling methodology has been used. For all 2x2 arrays (A, B, D, and E), the eccentric model consisted of a [

]^{a,c} This modeling strategy is shown in Figure 3.

a,c

Figure 2: RAI 6 Response Eccentric Positioning Modeling Schematic (a) Fuel Assemblies Together (b) Fuel Assemblies Apart

a,c

Figure 3: RAI 6 Response Eccentric Positioning Modeling Schematic Illustrating the Array G "Out" Eccentric Positioning Model

The modeling strategy utilized in Figure 2 provides for [ ]^{a,c} An example of the Array G eccentric positioning model is shown in Figure 3. Figure 4 shows how the model expands outward periodically (ad infinitum) based on the boundary conditions of the model. The Array G eccentric positioning model uses the same boundary conditions. [

]^{a,c}

a,c

Figure 4: RAI 6 Response Eccentric Positioning Modeling Schematic Illustrating the Effect of Periodic Boundary Conditions

Using the updated eccentric positioning methodology, the eccentric positioning reactivity quantification has been performed for Fuel Category 2 through Fuel Category 6. The new eccentric positioning bias results are contained within Table 1. Note these results represent the eccentric positioning values as a bias and not the overall impact to target k_{eff}. The target k_{eff} will also be impacted by the removal of the larger eccentric positioning uncertainty term and slight changes to the depletion and burnup measurement uncertainties. Results are given for both the fuel isotopics developed and described in Revision 2 of the Supplement to WCAP-17400 (Reference 3) as well as the isotopics developed and described for the original WCAP.

Table 1: Eccentric Positioning Bias Worth (Δk)

a,c

Since both RAI 6 and RAI 7 affect the final fuel storage limits for fuel in these categories, final updated results are included in Reference 3, which contains the combined impact of the eccentric positioning methodology change and grid growth impact as well as the updated burnup requirements with a detailed description of the entire analysis methodology.

Note that Fuel Category 1 fuel in Array C, while not explicitly evaluated in Reference 1, is acceptable because as indicated in References 1 and 2, the 0 ppm soluble boron concentration k_{eff} is less than 0.95. In Reference 2, it can be seen that the Array C target k_{eff} is [ ]^{a,c}, while the eccentric positioning uncertainty is [ ]^{a,c}. Adding the [ ]^{a,c} bias (without removing the eccentric positioning uncertainty contribution) reduces the target k_{eff} to [ ]^{a,c}, which is still greater than the best estimate reactivity (including Monte Carlo uncertainty at 2 sigma) of Array C.

RAI 7

A concern was recently brought to the attention of the NRC staff regarding the potential for fuel assembly spacer grid growth during irradiation and its impact on spent fuel pool criticality safety analyses. This concern has also been identified and is being addressed as part of NEI 12-16 guidance development.

The fuel assembly grids have been shown to expand over the course of their utilization in the reactor (see Figure 4 of Ref. 1). How does this affect the Prairie Island spent fuel pool criticality safety analysis in WCAP-17400-P, Supplement 1, Revision 1 and the ability to meet 10 CFR 50.68(b)(4) requirements? The NRC staff has performed studies showing that the effect of uniform pitch changes of 0.5% and 1% under spent fuel pool storage conditions can result in reactivity effects of approximately 500 pcm and 1000 pcm, respectively.

Reference

[1] Janga, Young Ki, et al. "An Investigation on Irradiation-induced Grid Width Growth in Advanced Fuels." (2011).

Response:

The fuel assembly grids expand over the course of operation in the reactor, leading to a larger overall assembly envelope. This phenomenon has two separate potential effects on spent fuel pool reactivity. The first effect is due to the change in isotopic inventory due to the larger pin pitch impacting the in-core energy spectrum. The second effect is the reactivity impact due to the potential pin pitch increase during storage.

A conservative representation of the grid expansion is an assumption that the fuel pins expand in an ordered array, maximizing reactivity by increasing the moderator to fuel ratio in the fuel lattice. Because the grid springs and tabs which initially hold fuel rods in place relax during reactor operation, it is believed that both during and after operation, fuel is randomly placed within each slightly expanded fuel pin cell in the grid. However, at the time of this response there is no industry study to support this hypothesis. Therefore a very conservative methodology has been used to estimate the potential impact of grid growth on the spent fuel pool storage requirements for Prairie Island fuel containing IFBA.

A conservative burnup dependent bias has been developed in order to incorporate the impact of grid growth into the analysis. Grid growth measurements were reviewed, and based on [

]a,c

[

]a,c

[ ]a,c Table 2 shows the assembly envelope expansion bias that was incorporated into the analysis to develop new burnup requirements given in Reference 3.

a,c

[ ]

Figure 5: General Grid Growth Reactivity Impact as a Function of Burnup

a,c

[ ]

Figure 6: Array D Grid Growth Reactivity Impact as a Function of Burnup

Table 2: Assembly Envelope Expansion Bias Worth (Δk)

a,c

It is recognized that the Array E assembly envelope expansion bias looks different both when comparing the IFBA Bearing Fuel and All Fuel Design cases and when comparing the fresh and 3.4 wt. % ^{235}U for IFBA Bearing Fuel. The difference between the IFBA Bearing Fuel and All Prairie Island Fuel Design cases is due to the differing methodology utilized to determine the reactivity bias for Array E. For the IFBA bearing fuel case, grid growth was explicitly included in the Fuel Category 4 base cases. For the All Prairie Island Fuel Design case, grid growth is not included in the Fuel Category 4 base cases. Therefore the entire impact of grid growth for both Fuel Category 2 and Fuel Category 4 needs to be accounted for in the assembly envelope expansion bias for the All Prairie Island Fuel Design case.

When comparing the fresh and 3.4 wt. % ^{235}U cases for the IFBA only fuel, the bias goes down, the reason for this is the same as discussed above for the IFBA Bearing Fuel and All Prairie Island Fuel Design cases. In the fresh case, the assembly envelope expansion bias case quantifies the impact of the grid size tolerance for the Fuel Category 2 and Fuel Category 4 assemblies. The depleted cases only for the Fuel Category 2 reactivity increase because the Fuel Category 4 grid growth (and therefore the reactivity effect of the Fuel Category 4 grid growth) is explicitly included in the models and their resultant k_{eff}s.

As indicated in the response to RAI 6, both the effect of the eccentric positioning methodology change and the grid growth impact are explicitly incorporated into the final determined burnup requirements. The burnup requirements cover both IFBA bearing fuel and all fuel designs covered by "Fuel Not Operated in Cycles 1-4" from Reference 2. The details regarding the development of the final burnup limits are documented in Reference 3.

Reference:

1. WCAP-17400-P, Supplement 1, Revision 1, "Prairie Island Units 1 and 2 Spent Fuel Pool Criticality Safety Analysis Supplemental Analysis for the Storage of IFBA Bearing Fuel," October 2015.
2. WCAP-17400-P, "Prairie Island Units 1 and 2 Spent Fuel Pool Criticality Safety Analysis," July, 2011.
3. WCAP-17400-P, Supplement 1, Revision 2, "Prairie Island Units 1 and 2 Spent Fuel Pool Criticality Safety Analysis Supplemental Analysis for the Storage of IFBA Bearing Fuel," September 2017.

ENCLOSURE 3

MARKED-UP TECHNICAL SPECIFICATION PAGE

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1 page follows

Table 4.3.1-3 (page 1 of 1)
For Fuel Not Operated In Units 1 and 2 Cycles 1 - 4
Coefficients to Calculate the Minimum Required Fuel Assembly Burnup (Bu) as a Function of Decay Time and Enrichment (En)

FUEL CATEGORY	DECAY TIME	COEFFICIENTS			
		A_1	A_2	A_3	A_4
2	0	~~-0.669~~-1.1640	~~9.018~~15.1916	~~-32.080~~-56.7743	~~33.507~~65.2736
3	0	~~-0.120~~-0.2213	~~1.300~~2.6959	~~5.006~~-0.9136	~~-18.765~~-11.0959
	5	~~-0.167~~-0.2568	~~1.766~~2.9933	~~3.085~~-2.0421	~~-16.141~~-9.5730
	10	~~-0.218~~-0.3012	~~2.249~~3.4074	~~1.405~~-3.5247	~~-14.163~~-7.7578
	15	~~-0.281~~-0.2790	~~2.949~~3.1007	~~-1.267~~-2.4261	~~-10.873~~-8.9334
	20	~~-0.401~~-0.2959	~~4.237~~3.2578	~~-5.881~~-3.0233	~~-5.513~~-8.1560
4	0	~~1.355~~1.3659	~~-14.866~~-14.9709	~~62.715~~63.0347	~~-72.624~~-72.9223
5	0	~~0.569~~0.1255	~~-6.563~~-1.6774	~~37.088~~20.7491	~~-47.854~~-31.8434
	5	~~0.302~~-0.0520	~~-3.795~~0.0723	~~27.410~~14.5901	~~-37.964~~-25.4754
	10	~~0.151~~0.1681	~~-2.248~~-2.2188	~~21.874~~21.4991	~~-32.204~~-31.7286
	15	~~-0.198~~-0.3431	~~1.133~~3.0482	~~11.031~~4.0932	~~-21.713~~-14.6591
	20	~~-0.427~~-0.2576	~~3.424~~2.2345	~~3.614~~6.1980	~~-14.522~~-16.3085
6	0	~~0.567~~0.6666	~~-6.205~~-7.4900	~~35.936~~41.2094	~~-45.944~~-51.6844
	5	~~0.923~~0.5686	~~-9.720~~-6.3968	~~45.538~~36.4332	~~-53.858~~-46.2433
	10	~~0.728~~0.3895	~~-7.992~~-4.5024	~~40.264~~29.6132	~~-48.929~~-39.2399
	15	~~0.343~~0.1962	~~-4.016~~-2.5813	~~27.236~~23.2107	~~-36.380~~-32.9620
	20	~~0.283~~0.1192	~~-3.391~~-1.7984	~~24.925~~20.4749	~~-33.963~~-30.1950

Notes:

1. All relevant uncertainties are explicitly included in the criticality analysis. For instance, no additional allowance for burnup uncertainty or enrichment uncertainty is required. For a fuel assembly to meet the requirements of a Fuel Category, the assembly burnup must exceed "minimum burnup" (GWd/MTU) given by the curve fit for the assembly "decay time" and "initial enrichment". The specific minimum burnup required for each fuel assembly is calculated from the following equation for each increment of decay time:

$$Bu = A_1*En^3 + A_2*En^2 + A_3*En + A_4$$

2. Initial enrichment (En) is the nominal U-235 enrichment. Any enrichment between 1.7 and 5.0 weight percent U-235 may be used. If the computed Bu value is negative, zero shall be used.

3. Decay Time is in years. An assembly with a cooling time greater than 20 years must use 20 years. No extrapolation is permitted.

4. If Decay Time value falls between increments of the table, the lower Decay Time value shall be used or a linear interpolation may be performed as follows: Compute the Bu value using the coefficients associated with the Decay Time values that bracket the actual Decay Time. Interpolate between Bu values based on the increment of Decay Time between the actual Decay Time value and the computed Bu results.

5. This table applies to fuel assemblies that were not operated in the Unit 1 or Unit 2 core during operating Cycles 1 through 4.