ATTACHMENT 2

Westinghouse Electric Company Responses to RAIs

Non-Proprietary Version

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-001f
Revision: 0

Question:

WCAP-18030-P, Revision 0, "Criticality Safety Analysis for Palo Verde Nuclear Generating Station Units 1, 2, and 3 (Proprietary)," dated September 2015, fuel assembly reconstitution as normal condition is described as follows, "Fuel assembly reconstitution is defined as either pulling damaged fuel rods [pins] out of an assembly and reinserting intact rods with less reactivity than the damaged rod, or as removing undamaged rods from a damaged assembly for insertion in a new assembly. In most cases damaged rods will be replaced with stainless steel rods. Natural uranium rods may also be used. Additional information is provided in Section 5.4.2 of WCAP-18030-P." Please provide a full description of the fuel assembly reconstitution process, which includes at least the following:

f. In WCAP-18030 Section 5.4.2 it states, "If a fuel assembly has a rod removed and the lattice location is left empty, that fuel assembly shall be treated as fresh fuel until the location is filled or analysis is performed demonstrating that the fuel assembly is bounded by the design basis assembly at the same burnup and initial enrichment levels." Please provide the methodology that will be used to perform the analysis. Please provide the analysis that demonstrates it is acceptable to store fuel with missing fuel pins as fresh. Please justify any limitations or lack thereof.

Response:

Section 5.4.2 of WCAP-18030-P, Revision 0 will be revised, replacing the quoted paragraph with the following:

"All fuel assemblies that contain less than 236 pins will be analyzed to confirm that storage in Array A or Array B (Region 1 fuel) is acceptable. The confirmatory calculation will be performed with results using the following equation for storage confirmation:

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-002
Revision: 0

Question:

The burnup requirement coefficients given in WCAP-18030, Revision 0, Tables 6-2, 6-4, 6-6, and 6-8 are derived, by a curve fitting procedure, using the results from a series of depletion calculations that correspond to a specific average fuel assembly burnup and fuel enrichment. Please provide the burnup values used to define the burnup requirement coefficients given in WCAP-18030, Revision 0, Tables 6-2, 6-4, 6-6, and 6-8 so that the validity of the coefficients can be confirmed.

Response:

The burnup requirement coefficients provided in Tables 6-2, 6-4, 6-6, and 6-8 of WCAP-18030, Revision 0 are being updated in response to RAIs 2, 3, 8, 9 and 10. The revised burnup coefficients can be found in Tables 8-7, 8-9, 8-11, and 8-13 of RAI 8. The burnup values used to define the burnup coefficients can be found in Tables 2-1 through 2-4, below. The burnup coefficients provided in RAI 8 will also be provided to the NRC in WCAP-18030, Revision 1. Note that these values are the raw data that ultimately led to the development of the burnup requirement coefficients to be included in WCAP-18030, Revision 1.

Table 2-1: Fuel Region 3 Determined Burnup Requirements (GWd/MTU)

	Radial Average Initial Enrichment, wt% ^{235}U			
Decay Time (yr.)	**2.50**	**3.00**	**4.00**	**5.00**

a,c

Palo Verde will not take decay time credit for the Region 3 fuel assemblies with an initial enrichment of 3.0 wt% ^{235}U because the required burnup for 3.0 wt% ^{235}U is small and the amount of ^{241}Pu accumulated in the fuel is insignificant.

Table 2-2: Fuel Region 4 Determined Burnup Requirements (GWd/MTU)

	Radial Average Initial Enrichment, wt% ^{235}U			
Decay Time (yr.)	1.75	3.00	4.00	5.00

a,c

Table 2-3: Fuel Region 5 Determined Burnup Requirements (GWd/MTU)

	Radial Average Initial Enrichment, wt% ^{235}U			
Decay Time (yr.)	1.65	3.00	4.00	5.00

a,c

Table 2-4: Fuel Region 6 Determined Burnup Requirements (GWd/MTU)

	Radial Average Initial Enrichment, wt% ^{235}U			
Decay Time (yr.)	1.45	3.00	4.00	5.00

a,c

WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-003
Revision: 0

Question:

What isotopes were used in the nuclear criticality safety analysis? Please justify the use of any short lived or volatile isotopes.

Response:

The list of fuel isotopes is provided in Table 3-1.

Table 3-1: Isotopes Used in the Nuclear Criticality Safety Analysis a,c

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Justification of Short Lived Isotopes:

Justification of short lived isotopes was performed by reassessing Section 4.2.1 of WCAP-18030-P. Section 4.2.1 states, [

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Table 3-2: Reactivity Comparison (Xe-135 removed, 100 to 130 hours decay)

Burnup [GWd/MTU]	Decay Time for Max Reactivity [hr]	Δk (max (100 hr to 130 hr) – 100 hr k_{eff})

a,c

All cases are well within any expected variation due to statistics, with all individual case standard deviation values falling between [

]a,c

Justification for Volatile Isotopes:

Noble gases such as Kr and Xe are insoluble in UO_2 and migrate to grain boundaries, dislocations, or pre-existing pores where they aggregate (Reference 1 and 2); therefore most remain in the pellet. Isotopes of I, Te, Cs, and Rb are considered volatile and a small portion may leak into the plenum or any other void volume, however the majority are still in the fuel assembly (Reference 2).

Reference 3 indicates that for cladding breaches under transportation scenarios, bounding values of up to 30% of fission gasses and 0.02% of alkalis are released from the fuel rod. Reference 3 has previously been cited in some spent fuel pool nuclear criticality analyses to support taking credit for volatile fission gases, as indicated in Reference 4. Reference 5, however, provides significantly more modern data for many of the isotopes for a more severe accident scenario of fuel failure during operation. [

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] a,c

Conclusions:

[ ] a,c

References:

1. D. R. Olander, "Fundamental Aspects of Nuclear Reactor Fuel Elements," 278-282, Technical Information Center, Office of Public Affairs, Berkeley (1976).
2. ISSN 0976-2108; No. 252, Bhabha Atomic Research Centre, Jan-Feb Bimonthly Newsletter, "Transport and release properties of gaseous and volatile fission products in nuclear fuels - relevance and state of art of their characterizations in the laboratory," January 2005.
3. NUREG/CR-6487, "Containment Analysis for Type B Packages Used to Transport Various Contents," November 1996.
4. ML15362A454, "STATUS OF SPENT FUEL POOL CRITICALITY SAFETY ANALYSIS REVIEW GUIDANCE", January 2016.
5. PNNL-18212 Rev 1 (ML112070118), "Update of the Gap Release Fractions for Non-Loca Events Utilizing the Revised ANS 5.4 Standard," June 2011.
6. Regulatory Guide 1.195 (ML031490640), "Methods and Assumptions for Evaluating Radiological consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors," May 2003.
7. Regulatory Guide 1.183 (ML003716792), "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," July 2000.

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-005
Revision: 0

Question:

WCAP-18030-P Section 5.4.1 states, "The SFP as a single system is over moderated. A single fuel assembly however, is significantly under-moderated, and reducing the interstitial [heatup] H/U ratio has a negative impact on the system k_{eff}." With respect to these statements, please provide the following:

> *a. The results of the SFP temperature bias sensitivity study mentioned in WCAP-18030-P Section 5.2.3.1.8 so that it can be confirmed that all proposed storage arrays for PVNGS are over moderated.*
>
> > *i. If one or more proposed storage arrays for PVNGS are not over moderated adjust the analysis accordingly or justify not making any adjustments.*
>
> *b. If the second sentence in the above quote is accurate, then several aspects of the analysis are potentially non-conservative.*
>
> > *i. Justify the assumptions and/or modeling simplifications that artificially reduce the interstitial H/U ratio.*
> >
> > *ii. Justify bias and uncertainty determinations that only consider aspects that reduce the interstitial H/U ratio.*

Response:

a. [

] a,c

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]a,c

Table 5-1: Δk_{eff} Impact for Guide Tube (and Instrument Tube) Voiding

Fuel Array	Enrichment [wt%]	$\Delta k_{eff} \pm \sigma_{\Delta k_{eff}}$

a,c

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]a,c

i. All storage arrays (and constituent assemblies) are under-moderated as indicated in WCAP-18030-P.

b. The indicated sentence is true; however, the analysis remains conservative as discussed below.

i. In order to justify additional modeling assumptions that affect the H/U ratio, fuel modeling assumptions relating to dishing/chamfering were investigated. [

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Simulation results for these cases are given in Table 5-2. This results in a decrease in the denominator of the H/U ratio, slightly increasing the H/U ratio, but the overall fissile material is decreased. The increasing H/U ratio and decreasing fissile content are competing reactivity effects, whereby it was assumed the decrease in fissile material outweighs the increase in the H/U ratio in WCAP-18030-P Revision 0. All data in Table 5-2 shows that the reactivity impact from dishing/chamfering is always negative (i.e., the nominal case is always greater). As a result, the modeling assumption of solid cylindrical pellets with no dishing/chamfering is conservative.

Table 5-2: Δk_{eff} Impact for Dishing / Chamfering

Fuel Array	Enrichment [wt%]	$\Delta k_{eff} \pm \sigma_{\Delta k_{eff}}$

a,c

ii. Each bias and uncertainty which affects the H/U ratio is evaluated for both an increase and decrease.

Reference:

1. WCAP-18030-P, "Criticality Safety Analysis for Palo Verde Nuclear Generating Station Units 1, 2, and 3," September 2015.

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-006
Revision: 0

Question:

WCAP-18030-P Section 5.4.1 also states, "It has been shown in WCAP- 16541-NP, "Point Beach Units 1 and 2 Spent Fuel Pool Criticality Safety Analysis" (Reference 13) that even storage of fuel pins in [guide tubes] GTs has a negative reactivity impact. Similar calculations have been performed for Palo Verde previously which resulted in the same conclusion as the Point Beach study. These studies demonstrate that individual fuel assembly lattices are significantly under-moderated in the SFP environment and further reducing the H/U ratio will decrease reactivity." With respect to these statements:

a. Please provide the calculations that were performed for PVNGS.
b. Point Beach uses a [Westinghouse Electric Company LLC] WEC 14x14 fuel design whereas Palo Verde uses a [Combustion Engineering] CE 16x16 fuel design. Please provide justification as to why Point Beach a valid precedent for Palo Verde?
c. Please clarify whether or not storage of fuel pins in instrument tubes is being requested as part of this LAR.
d. The Point Beach WCAP-16541 was not a bounding analysis for all fuel pins stored in Point Beach's WEC 14x14 guide tubes. Please describe any limitations on storing fuel pins in PVNGS's CE 16x16 guide tubes and the justification for those limitations.

Response:

a. See the response to RAI #5.a.

b. Point Beach was a representative example to indicate that in general, storage arrays and their constituent assemblies are under-moderated. Detailed analysis results for Palo Verde are contained in the response to RAI #5.

c. Storage of fuel pins in instrument tubes or guide tubes is not being requested as part of the LAR, and is not intended as part of WCAP-18030-P.

d. Storage of fuel pins in instrument tubes or guide tubes is not being requested. Therefore, fuel pin storage in guide tubes is not authorized. Two depleted neutron sources are stored in guide tubes in each unit. Storage of neutron sources in guide tubes will not increase reactivity of the assembly for the following reasons:

- The introduction of the source displaces moderator which will reduce reactivity, while containing only a very small amount of fissile material, located far from the fuel.
- The majority of the source, greater than 90%, is composed of stainless steel, which is an absorber of neutrons and will result in a reduction of reactivity when placed within a guide tube.

WCAP-18030 will be updated to Revision 1 and will be enhanced for clarity as a result of this Request for Additional Information.

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-007
Revision: 0

Question:

In Section 5.5 of WCAP-18030-P, it is not clear how k-effective for the soluble boron cases was calculated. The limiting accident isn't necessarily the one with the largest reactivity increase, but rather the one which requires the most soluble boron to offset the reactivity increase. A storage array with a lower soluble boron worth could take more soluble boron to offset the reactivity increase, even with a smaller reactivity increase. Please demonstrate that the array configuration selected in determining the minimum soluble boron requirements corresponds to the limiting configuration.

a. *The values in Note 2 of Table 5-12 and Section 5.2.3.1.9 do not agree. Please provide clarification on this apparent discrepancy.*

Response:

Westinghouse agrees with the reviewer. The limiting case to determine the soluble boron concentration is not necessarily the one with the largest reactivity increase; the effect of burnup on soluble boron worth must also be considered. Soluble boron worth decreases with increasing burnup, therefore, the highest burnup credited in the analysis must be bounded.

<u>Normal Operating Conditions:</u>

- The soluble boron concentration to maintain $k_{eff} \leq 0.95$ for the normal conditions including biases, uncertainties, and administrative margin has been determined for each of the storage arrays. To maximize reactivity in fresh fuel configurations and to minimize the boron worth in burned fuel configurations, fuel was modeled as follows:
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- [

]a,c

Single Assembly Misload Accident:

[

]a,c required an increase in soluble boron concentration from 1100 ppm reported in WCAP-18030-P to 1200 ppm, including all biases, uncertainties, and administrative margin.

Multiple Assembly Misload Accident:

[

]a,c

Response to a:

Because the results for soluble boron requirement for normal conditions have changed, Note 2 of Table 5-12 in WCAP-18030-P is not necessary and will be removed in WCAP-18030-P/NP Revision 1.

The second paragraph of Section 5.2.3.1.9 will be modified as follows:

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-008
Revision: 0

Question:

Section 5.2.3.2 of WCAP-18030-P makes reference to a study that Westinghouse performed to support its treatment of biases and uncertainties. Please provide the study or reference where the study has previously been submitted to the NRC.

Response:

The treatment of biases and uncertainties utilized in WCAP-18030-P Revision 0 is based on the study performed in Reference 1. [

]^{a,c}

Since the referenced study does not include the CE16x16 fuel assembly design, however, the biases, uncertainties, and burnup requirements for each fuel storage array described in WCAP-18030-P were calculated and are reported in this response. These results will be reflected in Revision 1 of WCAP-18030. The revised burnup requirements contain the cumulative impacts from the relevant Nuclear Regulatory Commission Requests for Additional Information #2, 3, 8, 9, and 10. As the biases and uncertainties are all explicitly analyzed for all Arrays for Palo Verde the study described in the second paragraph of Section 5.2.3.2 of WCAP-18030-P is no longer relevant and will be removed in Revision 1 of WCAP-18030.

Storage Array Biases and Uncertainties Results

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Table 8-1: Reactivity Impact [Δk] of Biases and Uncertainties for 4.65 wt% ^{235}U Fuel Stored in Storage Array A

a,c

Parameter	Δk

Table 8-2: Reactivity Impact [Δk] of Biases and Uncertainties for 4.65 wt% ^{235}U Fuel Stored in Storage Array B

a,c

Parameter	Δk

Table 8-3: Reactivity Impact [Δk] of Biases and Uncertainties for Spent Fuel Assemblies Stored in Storage Array C

	Enrichments (wt% ^{235}U)			
Parameter	2.50	3.0	4.0	5.0

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

Table 8-4: Reactivity Impact [Δk] of Biases and Uncertainties for Spent Fuel Assemblies Stored in Storage Array D

	Enrichments (wt% ^{235}U)			
Parameter	1.75	3.0	4.0	5.0

a,c

Table 8-5: Reactivity Impact [Δk] of Biases and Uncertainties for Spent Fuel Assemblies Stored in Storage Array E

a,c

	Enrichments (wt% ^{235}U)			
Parameter	1.65	3.0	4.0	5.0

Table 8-6: Reactivity Impact [Δk] of Biases and Uncertainties for Spent Fuel Assemblies Stored in Storage Array F

	Enrichments (wt% ^{235}U)			
Parameter	1.45	3.0	4.0	5.0

a,c

Burnup Limits for Storage Arrays

Assembly storage is controlled through the storage arrays defined in Section 5.2.1 of WCAP-18030-P. An array can only be populated by assemblies of the fuel region defined in the array definition or a lower reactivity fuel region (see Table 6-1 of WCAP-18030-P, Revision 0). Fuel regions are defined by assembly average burnup, initial enrichment[1], and decay time as provided in Tables 8-7 through Table 8-14.

Palo Verde will not take decay time credit for Region 3 fuel assemblies with an initial enrichment of 3.0 wt% ^{235}U because the required burnup for 3.0 wt% ^{235}U is small and the amount of ^{241}Pu accumulated in the fuel is insignificant. However, to have a conservative 3rd order polynomial fit, the burnup requirement coefficients for the Region 3 fuel were manually adjusted. The adjustment results in the conservative increase of the minimum burnup requirement for 3.0 wt% ^{235}U fuel and does not explicitly include decay time credit since all values are conservative to the 0 year calculated decay time burnup limit of 6.676 GWd/MTU.

Table 8-7: Fuel Region 3: Burnup Requirement Coefficients

	Coefficients			
Decay Time (yr.)	**A_1**	**A_2**	**A_3**	**A_4**
0	-0.8100	6.5551	-2.9050	-21.0499
5	-0.9373	7.6381	-6.0246	-18.0299
10	-0.8706	6.8181	-3.1913	-21.0299
15	-0.7646	5.6311	0.7657	-25.1599
20	-0.7233	5.1651	2.3084	-26.7499

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 Region, the assembly burnup must exceed the "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:
$$BU = A_1 * En^3 + A_2 * En^2 + A_3 * En + A_4$$
2. Initial enrichment, En, is the maximum radial average ^{235}U enrichment. Any enrichment between 2.50 wt% ^{235}U and 5.00 wt% ^{235}U may be used. Below 2.50 wt% ^{235}U, burnup credit is not required.
3. An assembly with a decay time greater than 20 years must use the 20 years limits.

[1] Initial Enrichment is the maximum radial average ^{235}U enrichment of the central zone region of fuel, excluding axial cutbacks, prior to reduction in ^{235}U content due to fuel depletion. If the fuel assembly contains axial regions of different ^{235}U enrichment values, such as axial cutbacks, the maximum Initial Enrichment value is to be used.

Table 8-8: Fuel Region 3: Burnup Requirement (GWd/MTU)

	Radial Average Initial Enrichment, wt% ^{235}U			
Decay Time (yr.)	2.50	3.00	4.00	5.00
0	0	7.36	20.37	27.05
5	0	7.33	20.09	25.63
10	0	7.25	19.57	24.63
15	0	7.17	19.06	23.86
20	0	7.13	18.83	23.50

Note that this table is included as an example, the burnup limits will be calculated using the coefficients provided.

Table 8-9: Fuel Region 4: Burnup Requirement Coefficients

	Coefficients			
Decay Time (yr.)	A_1	A_2	A_3	A_4
0	0.0333	-2.1141	27.4985	-41.8258
5	-0.2105	0.2472	19.7919	-34.2641
10	0.0542	-2.5298	28.0953	-41.7092
15	0.3010	-5.0718	35.6966	-48.5494
20	0.4829	-6.9436	41.3118	-53.6182

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 Region, the assembly burnup must exceed the "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:
$$BU = A_1 * En^3 + A_2 * En^2 + A_3 * En + A_4$$
2. Initial enrichment, En, is the maximum radial average ^{235}U enrichment. Any enrichment between 1.75 wt% ^{235}U and 5.00 wt% ^{235}U may be used. Below 1.75 wt% ^{235}U, burnup credit is not required.
3. An assembly with a decay time greater than 20 years must use the 20 years limits.

Table 8-10: Fuel Region 4: Burnup Requirement (GWd/MTU)

	Radial Average Initial Enrichment, wt% ^{235}U			
Decay Time (yr.)	**1.75**	**3.00**	**4.00**	**5.00**
0	0	22.54	36.47	46.97
5	0	21.65	35.38	44.55
10	0	21.27	33.66	42.29
15	0	21.02	32.35	40.76
20	0	20.86	31.43	39.70
Note that this table is included as an example, the burnup limits will be calculated using the coefficients provided.				

Table 8-11: Fuel Region 5: Burnup Requirement Coefficients

	Coefficients			
Decay Time (yr.)	A_1	A_2	A_3	A_4
0	0.1586	-3.0177	28.7074	-39.8636
5	-0.2756	1.3433	14.5578	-26.4388
10	-0.2897	1.3218	14.6176	-26.4160
15	-0.0736	-0.9107	21.2118	-32.1887
20	0.1078	-2.7684	26.6911	-36.9873

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 Region, the assembly burnup must exceed the "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:

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

2. Initial enrichment, En, is the maximum radial average ^{235}U enrichment. Any enrichment between 1.65 wt% ^{235}U and 5.00 wt% ^{235}U may be used. Below 1.65 wt% ^{235}U, burnup credit is not required.
3. An assembly with a decay time greater than 20 years must use the 20 years limits.

Table 8-12: Fuel Region 5: Burnup Requirement (GWd/MTU)

	Radial Average Initial Enrichment, wt% ^{235}U			
Decay Time (yr.)	**1.65**	**3.00**	**4.00**	**5.00**
0	0	23.38	36.83	48.05
5	0	21.88	35.64	45.47
10	0	21.51	34.66	43.50
15	0	21.26	33.37	41.89
20	0	21.08	32.38	40.73

Note that this table is included as an example, the burnup limits will be calculated using the coefficients provided.

Table 8-13: Fuel Region 6: Burnup Requirement Coefficients

	Coefficients			
Decay Time (yr.)	A_1	A_2	A_3	A_4
0	0.4890	-6.7447	42.7619	-49.3143
5	0.5360	-6.9115	41.1003	-46.6977
10	0.4779	-6.1841	37.6389	-43.0309
15	0.4575	-5.8844	35.8656	-41.0274
20	0.3426	-4.7050	31.8126	-37.2800

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 Region, the assembly burnup must exceed the "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:
$$BU = A_1 * En^3 + A_2 * En^2 + A_3 * En + A_4$$
2. Initial enrichment, En, is the maximum radial average ^{235}U enrichment. Any enrichment between 1.45 wt% ^{235}U and 5.00 wt% ^{235}U may be used. Below 1.45 wt% ^{235}U, burnup credit is not required.
3. An assembly with a decay time greater than 20 years must use the 20 years limits.

Table 8-14: Fuel Region 6: Burnup Requirement (GWd/MTU)

	Radial Average Initial Enrichment, wt% ^{235}U			
Decay Time (yr.)	**1.45**	**3.00**	**4.00**	**5.00**
0	0	31.47	45.11	57.00
5	0	28.87	41.42	53.01
10	0	27.13	39.16	50.29
15	0	25.96	37.56	48.37
20	0	25.06	36.61	46.97
Note that this table is included as an example, the burnup limits will be calculated using the coefficients provided.				

Reference:

1. CN-CRIT-METH-007, "Bias and Uncertainty Calculation Guidance and Neutron Absorber Efficiency Write-up," September 2011.

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-009
Revision: 0

Question:

The uncertainty in the SCALE 6.1.2 validation was performed on the uncertainty of the mean instead of the uncertainty of the population, which is inconsistent with NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculated Methodology," as referenced. Please revise the SCALE 6.1.2 validation to include the uncertainty of the population.

a. Please provide Tables A-3, A-4, A-5, A-6, and A-7 in spreadsheet format so that the NRC can perform confirmatory analysis.

Response:

The SCALE 6.1.2 validation was updated to include the uncertainty of the population. WCAP-18030-P will be updated to reflect this change by indicating the following:

Updated Section A.2.2 Data

Section A.2.2 of WCAP-18030-P will be modified to incorporate the usage of the uncertainty of the population distribution. This update will be incorporated after Equation A-11, indicating the following:

From Reference A1, when a relationship between a calculated k_{eff} and an independent variable cannot be determined (no trend exists), a one-sided lower tolerance limit should be used. This method provides a single lower limit above which a defined fraction of the true population of k_{eff} is expected to lie, with a prescribed confidence and within the area of applicability. Use of this method requires the experimental results to have a normal statistical distribution. Lower tolerance limits, at a minimum, should be calculated with a 95% confidence that 95% of the data lies above K_L. The equation for the one-sided lower tolerance band from Reference A1 is:

$$K_L = \bar{k}_{eff} - U_{(n)}S_P$$

Or, if $\bar{k}_{eff} \geq 1$,

$$K_L = 1 - U_{(n)}S_P$$

Where, *S_P is the pooled variance, and*

U is the one sided lower tolerance factor (found in Table T-11b of Reference A8, with n the number of experiments contained in the data set).

US_P is then taken as the uncertainty to the untrended bias (methodology bias uncertainty).

The text will be incorporated and equation numbers modified for its inclusion. Additionally, references back to the equation for bias uncertainty will be updated.

Additionally, the methodology (bias) uncertainty data will be updated as shown in Table 9-1, which gives the current and updated methodology (bias) uncertainty:

Table 9-1: Current and Updated Methodology Uncertainty

Fuel Combination Category	WCAP-18030-P Bias Uncertainty	Updated Bias Uncertainty

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These changes affect all tables containing the methodology uncertainty and will be updated. Additionally, specific listing of the bias uncertainty as in Page A-85 of WCAP-18030-P will be updated. All updates will be incorporated into updated burnup limits developed as a result of the overall RAIs causing changes in the main body of WCAP-18030-P to be incorporated in Revision 1 of WCAP-18030-P.

a. In order to facilitate review of the data from Tables A-3, A-4, A-5, A-6 and A-7 of WCAP-18030, each page that follows for this RAI response contains a full data set which should be able to be extracted more conveniently for confirmatory analysis.

Table A-3 [ ]^{a,c}

a,c

Table A-4 [ ]^{a,c}

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Table A-5 [ ]^{a,c}

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a,c

Table A-6 [ ]a,c

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Table A-7 [ ]^{a,c}

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WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-010
Revision: 0
Question:

Do the fuel assembly grids expand over the course of their utilization in the reactor? If they do expand, how does this affect the nuclear criticality safety analysis for the SFP?

Response:

[

]a,c Results of the spent fuel pool calculations were used to develop the following equation for impact on reactivity as a function of burnup in GWd/MTU for storage arrays containing burnup, and this reactivity impact due to grid growth is incorporated into the burnup coefficients proposed for use at Palo Verde Nuclear Generating Station.

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Figure 10-1: Grid Growth Reactivity Impact as a Function of Burnup

Westinghouse

Westinghouse Non-Proprietary Class 3

WCAP-18030-NP REVIEW

Suggested Response to Request For Additional Information (RAI)

RAI Response Number: WCAP-18030-NP-RAI-011
Revision: 0

Question:

Section 5.2.3.1.1 of WCAP-18030-P discusses the manufacturing tolerances. The information provided in Figures 5-2 and 5-3 appears to be too limited to support the NF-APS-16-29 conclusions drawn from them. With respect to Figures 5-2 and 5-3, please provide the following:

a. What is the source of the information presented in Figures 5-2 and 5-3? Please justify its applicability for PVNGS.
b. Please justify the use of the information under full and optimum moderation scenarios for new fuel storage.
c. Please justify not applying an instrument tube uncertainty.

Response:

a. The source of the information presented in Figures 5-2 and 5-3 is Reference 1, in which Westinghouse has determined the biases and uncertainties sensitive to fuel enrichment or burnup (hence the neutron spectrum) through a study of the bias and uncertainty calculations performed in past analyses. [

b.

]a,c Table 11-1 shows the GT/IT dimensions and tolerances used in this study.

Table 11-1: GT/ID dimensions and tolerances

Parameter	Nominal Value (in)	Tolerance (in)
GT/IT OD	0.980	[ ]a,c
GT/IT ID	0.900	[ ]a,c

[

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Table 11-2: Cases Evaluated for GT/IT tolerance uncertainty

Case	Fuel
2 out of 4 Fresh Assemblies (Array A)	4.65wt% enriched fresh
2 out of 4 assemblies with 2 trash cans (Array B)	4.65wt% enriched fresh
2 High Reactivity Assemblies with 1 Low Reactivity Assembly (Array C)	Two 4.65 wt% at 16 GWd/MTU with one 2.55 wt% fresh Two 4.65 wt% at 16 GWd/MTU with one 3.00 wt% fresh Two 4.65 wt% at 16 GWd/MTU with one 3.00 wt% at 6 GWd/MTU Two 4.65 wt% at 16 GWd/MTU with one 4.00 wt% fresh Two 4.65 wt% at 16 GWd/MTU with one 4.00 wt% at 18 GWd/MTU Two 4.65 wt% at 16 GWd/MTU with one 5.00 wt% fresh Two 4.65 wt% at 16 GWd/MTU with one 5.00 wt% at 26 GWd/MTU
3 Low Reactivity Assemblies with 1 High Reactivity Assembly (Array D)	Three 1.75 wt% fresh with one 4.65 wt% fresh Three 3.00 wt% fresh with one 4.65 wt% fresh Three 3.00 wt% at 24 GWd/MTU with one 4.65 wt% fresh Three 4.00 wt% fresh with one 4.65 wt% fresh Three 4.00 wt% at 39 GWd/MTU with one 4.65 wt% fresh Three 5.00 wt% fresh with one 4.65 wt% fresh Three 5.00 wt% at 45 GWd/MTU with one 4.65 wt% fresh Three 5.00 wt% at 47 GWd/MTU with one 4.65 wt% fresh
All Cell with 1 insert (Array E)	1.65 wt% fresh 3.00 wt% fresh 3.00 wt% at 24 GWd/MTU 4.00 wt% fresh 4.00 wt% at 37 GWd/MTU 5.00 wt% fresh 5.00 wt% at 47 GWd/MTU
All Cell no insert (Array F)	1.45 wt% fresh 3.00 wt% fresh 3.00 wt% at 32 GWd/MTU 4.00 wt% fresh 4.00 wt% at 45 GWd/MTU 5.00 wt% fresh 5.00 wt% at 57 GWd/MTU
Optimum Moderation (VAP fuel)	5.00 wt% fresh
Fully Flooded Conditions (NGF fuel)	5.00 wt% fresh

Results of all cases from Table 11-2 are shown as a function of enrichment and burnup in Figures 11-1 and 11-2 below.

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Figure 11-1: GT/IT tolerance uncertainties with respect to enrichment

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Figure 11-2: GT/IT tolerance uncertainties with respect to burnup

The limiting GT/IT uncertainty values for all configurations are shown in Table 11-3.

Table 11-3: Limiting GT/IT uncertainty values

Configuration	Case	Enrich (w/o) /Burnup (MWd/MTU)	K_{eff}	Std Dev	Δk + unc

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[ ]a,c

c. IT uncertainty has been applied together with the GT uncertainty as indicated in response to RAI #11b, by changing the GT and IT dimensions at the same time.

Reference:

1. CN-CRIT-METH-007, "Bias and Uncertainty Calculation Guidance and Neutron Absorber Efficiency Write-up, September 2011.