U.S. NUCLEAR REGULATORY COMMISSION (NRC) REQUEST FOR ADDITIONAL INFORMATION (RAI) REGARDING WESTINGHOUSE ELECTRIC COMPANY (WESTINGHOUSE) TOPICAL REPORT (TR) WCAP-17483-P/WCAP-17483-NP, REVISION 0, "WESTINGHOUSE METHODOLOGY FOR SPENT FUEL POOL AND NEW FUEL RACK CRITICALITY SAFETY ANALYSIS”

1. Clearly identify and define the standard methodology. In situations where recommendations (i.e., “should” statements) or permission to deviate (i.e., “may” statements) are provided, clearly describe the conditions and prerequisites for doing so in the report. Where U. S. Nuclear Regulatory Commission (NRC) concurrence with deviations from the standard method is desired, discuss and provide justification. This is necessary so that it will be clear what methodology the NRC has approved. For example, Section 2.1 and Section 2.2 include text that notes that “an administrative margin of at least **[ ]** should be included.” Is this **[ ]** part of the standard methodology?

   Provide guidance concerning how deviations from the TR will be identified, documented, and justified.

2. Provide the expected format and content for criticality safety analysis technical reports to ensure that the information needed to facilitate the NRC staff reviews of licensing actions referencing WCAP-17483-P/WCAP-17483-NP, Revision 0, will be provided.

3. The second sentence in Section 2.1 indicates that the analysis must demonstrate that k-effective is less than 0.95 under all postulated accident conditions. Revise this to say k-effective is no greater than 0.95 under all credible accident conditions.

4. Revise the bulleted list in Section 2.2 to include consideration of temperature variation, concrete composition (if concrete floor and walls are modeled), and the potential impact of common mode failures, such as flooding following seismic event, facility fire, or heavy dropped load. Common mode failures could cause both flooding and storage geometry changes.

5. Provide guidance in Section 2.2 for when consideration of flooding is not needed and how the justification for “no flooding” analysis is to be documented. Clarify whether or not the standard methodology is to do the fully and optimally flooded analysis.

6. In Section 3, item number 2 and Section 3.3.2, does Standardized Computer Analyses for Licensing Evaluation (SCALE) 5.1 and the 44-group cross-section library include all available patches? Include guidance for the analyst to check that all available patches are included so that the NRC staff has assurance that a fully-patched code and cross-section library will be used.

7. In the last sentence before Section 3.1, the TR text states: "When other codes are used, their use will be justified on an analysis-specific basis." Revise this statement to include more appropriate guidance on the use of nuclear data that is different from what is used in the standard methodology. Please revise the guidance to address criticality analysis documentation requirements related to identification and justification of use of other codes or nuclear data.

8. In Section 3.1:

    a. Revise the text to require documentation of traceable version numbers for PARAGON and its nuclear data libraries.

    b. The second sentence in the first paragraph in Section 3.1 describes what seems like a "peak-reactivity" method for pressurized water reactor (PWR) criticality analysis. Revise the text to make it clearer that this is not part of the standard methodology.

    c. Provide a list of the nuclides that are credited in spent fuel k-effective calculations. Note that the list should not include short half-life radionuclides, noble gases, or nuclides considered to be volatile.

    d. The third paragraph notes that "there are no Safety Evaluation Report (SER) limitations for the use of PARAGON in UO2 criticality analysis." However, the SER does not explicitly approve use of PARAGON for calculating spent fuel compositions for criticality analyses. Also note that text in Section 3.1.1 states that "criticality methodology is not tied to the PARAGON SER."

       What work was done to qualify PARAGON for generating spent fuel compositions for use by other codes? Were all credited fission products and minor actinides considered in this work? Assuming that post-irradiation decay is handled by PARAGON, what work was done to qualify PARAGON for post-irradiation cooling times of 5 to 70 years?

9. The last sentence in Section 3.1.1 states:

    > Criticality methodology is not tied to the PARAGON SER;
    > therefore, the criticality safety analysis will use the latest version of
    > PARAGON and its library used in core-design calculations.

Revise the TR to include additional guidance concerning use of the latest version of PARAGON and its library. Each analysis must identify the PARAGON and library versions used. Furthermore, it will be necessary to validate each combination of PARAGON and the library used.

10. Please provide guidance in WCAP-17483-P/WCAP-17483-NP, Revision 0, concerning how PARAGON is to be used in the standard method. For example, discuss PARAGON input options, preparation of PARAGON input for burned fuel composition calculations, and convergence criteria to be used. Also, discuss how the PARAGON modeling results are checked, describe pre-criticality calculation processing of burned fuel compositions, and how these compositions are to be used in the criticality code.

11. Provide guidance in WCAP-17483-P for documenting and checking SCALE calculations. Include a discussion on source convergence checks, analysis of normality test results, warning and error message review, processing and checking of PARAGON compositions for use in SCALE, selection of the KENO k-effective value to be used in the various safety analyses, etc.

12. The last paragraph in Section 3.2 describes the use of **[**

    ] However, it needs to be supplemented with additional mixed oxide (MOX) experiments to minimize the effects of potential facility-specific or evaluation-specific biases associated with use of a single critical experiment series. Supplement the HTC MOX experiments with additional MOX experiments from other critical experiment facilities. Table B.1 in NUREG/CR-7109 and Table 6.1 in NUREG/CR-6979 may be useful in identifying additional applicable MOX experiments.

13. The last sentence in Section 3.2.1 is:

    > Thus, the 44-group library performs well for light-water reactor (LWR) lattices and is the recommended SCALE library for criticality safety analysis of arrays of LWR type fuel assemblies, as would be encountered in fresh or spent fuel storage environments (Reference 9).

    This was the recommended library in 2000. In 2014, the use of the 44-group library is no longer recommended.

The work documented in Reference 9 used SCALE 4.3 not SCALE 5.1. Furthermore, the text in Reference 9 also states:

> Because of the weighting spectrum used to generate the 238-group library, it is difficult to collapse a general-purpose broad-group library that is valid over a wide range of problems. **For all other systems, the parent 238-group ENDF/B-V library is recommended.**

The recommendation, which appears in bold font in the reference, would appear to be particularly relevant to storage of new fuel in a new fuel storage vault, which may not have a light water reactor (LWR) neutron energy spectrum.

Revise the text in Section 3.2.1 to more accurately reflect the cited reference. Furthermore, assuming that Westinghouse still intends to use the 44-group library, Westinghouse staff should understand that use of the 44-group library at low-moderator density conditions is questionable, therefore additional justification for using the 44-group library for conditions that are not similar to the LWR conditions is necessary. If the 44-group library is used for new fuel storage analysis, the validation of the new fuel low-moderator density storage vault calculations requires additional focus.

14. The second paragraph of Section 3.3.2 states:

    > **[**
    >
    > **]**

    There are two concerns with this statement. First, it is the responsibility of the analyst to ensure that use of the **[**

    ] Section 3 in each of the International Handbook of Evaluated Criticality Safety Benchmark Experiments (IHECSBE) evaluations provides compositions in number densities, which should be used for modeling experiments from the IHECSBE. Provide clearer guidance concerning material compositions used in validation study models.

15. The last paragraph of Section 3.3.2 addresses use of the validation study in future criticality analyses. Please revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to explicitly note that the analyst performing future analyses is responsible for ensuring that the validation is still applicable to their application and validation study

applicability to the new work must be explicitly addressed in the criticality safety analysis documentation.

16. Please revise Section 3 to address depletion code validation.

17. Section 3.3.3 notes that the criticality code validation is **[**

]

18. Section 3.3.3.2 notes that the **[** **]** Provide a reference for the **[** **]** where the normality test is described or provide a description of the test.

    The NRC staff has performed independent confirmatory analysis to verify the results of Westinghouse's normality testing since many of the statistical formulations for calculating the bias and bias uncertainty rely on the assumption of data normality. NUREG-1475, Revision 1, "Applying Statistics," discusses the D'Agostino test for normality, which similar to the **[** **]** test, is "considered an omnibus test for normality," but is only limited to sample sizes greater than approximately 20. Other applicable normality tests were also applied (i.e., the Lilliefors and Anderson-Darling tests).

    The only validation set where independent normality testing is in agreement with Westinghouse is for the fresh fuel with no strong absorbers set; visual examination provides additional evidence that this data is likely to be normally distributed (see Figure 1). For all other validation sets, there is strong evidence that these sets are not likely to be normally distributed; again, visual examination provides additional evidence supporting this finding (see Figures 2 through 4). The only test that does indicate that these sets are normally distributed is the test used by Westinghouse, which is the **[** **]** test, which is of relatively low statistical power (Reference: *Comparisons of various types of normality tests*, B. W. Yap, C. H. Sim, Journal of Statistical Computation and Simulation, Vol. 81, Iss. 12, 2011).

    Revise the analysis in WCAP-17483-P/WCAP-17483-NP, Revision 0, to include a more robust data normality assessment.

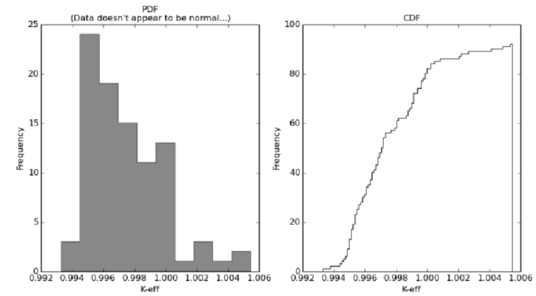

Figure 1: Fresh Fuel, Strong Absorbers k-eff Distribution.

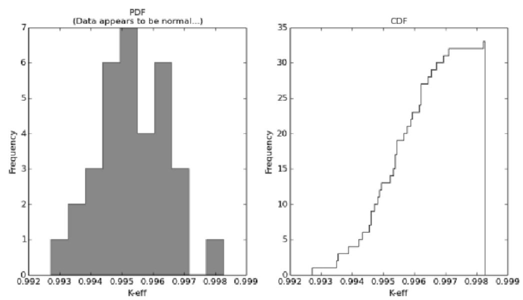

Figure 2: Fresh Fuel, Without Strong Absorbers k-eff Distribution.

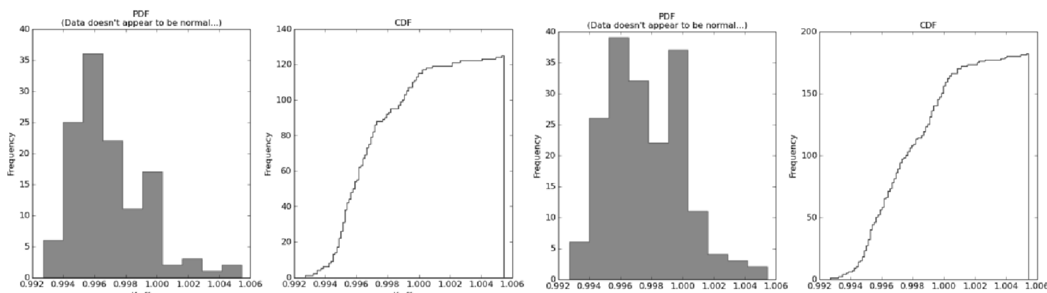

Figure 3: All Fresh Fuel and all HTC Experiments (Phases 1-3) k-eff Distribution (left: w/o HTC; right: w/ HTC).

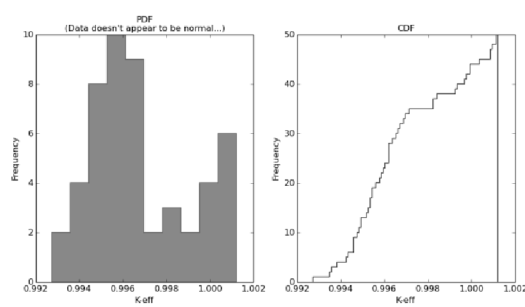

Figure 4: Fresh Fuel and HTC Experiments (Phase 1) Without Strong Absorbers k-eff Distribution.

19. In equation 3.8, to clarify the equations, replace **[ ]**

20. Text provided in the third paragraph below equation 3.10 addresses the hypothesis concerning the **[ ]** Provide the justification for defining the **[ ]** as described in WCAP-17483-P/WCAP-17483-NP, Revision 0. Why wouldn't it be more appropriate to switch the **[**

    ]

    In other words, ignoring a trend (unless there is 95 percent confidence that there is a trend) would be appropriate where the trend yields a less restrictive limit (or lower maximum k-effective). However, over the range that the trend produces a more restrictive limit, it would seem more appropriate to use the trend unless there is a 95 percent confidence that there is no trend.

    Revise the discussion to more clearly describe how the trends will be handled in the validation study. Where handling of trends is potentially non-conservative, provide a justification for use of non-conservative limits.

21. In the validation set with fresh fuel and no absorbers, two statistically significant trends were found as documented in WCAP-17483-P/WCAP-17483-NP, Revision 0, – **[**

    ] The NRC staff is unable to reproduce the bias uncertainty estimates for trended analyses. Is a penalty being applied for excessive extrapolation for trended analyses?

22. In equations 3.13 and 3.14, replace **[**

    ]

23. In the definitions provided below equation 3.14, change **[**

    ] However, only the linear fit is described in the TR.

24. In equations 3.20 and 3.21, change **[**

    ] to more accurately describe the quantities calculated.

25. Provide explicit definitions for **[**

    ]

The paragraph just above equation 3.23 mentions the **[ ]** Consider adding some text describing what **[ ]** is, whether or not the standard Westinghouse method permits use of **[ ]** values, and, if it does, guidance for using **[ ]** values.

26. In Section 3.3.5:

a. Why isn't there guidance for selecting critical experiments including a discussion as to why each evaluation set was included and why some configurations from selected sets were excluded? Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

b. Some of the laboratory critical experiments (LCEs) have **[**

] This may not be appropriate for validating calculations without these materials. Do the k_{eff} values for the subsets with **[ ]** vary from the remainder of the LCE results? In general, LCE sets used for validation should not include LCEs with fissile nuclides or strong absorbers that are not present in the safety analysis model calculations.

c. The text in the first paragraph states **[**

]

While this may be true, it is not enough to simply declare that **[ ]** will not be modeled. Provide a list of LCEs where **[ ]** was omitted from the model and provide an assessment of the impact of this modeling simplification on the expected k-effective value and its uncertainty.

d. Many of the LCE description subsections note that "simplifying assumptions" were made. From the text, it is not clear if these are the simplifying assumptions documented in the IHECSBE for the series or if the analyst made additional simplifying assumptions. Revise the text to more clearly describe what was done.

Note that whenever models deviate from the Section 3 of the IHECSBE for each evaluation, the analyst should identify and describe the deviations and must revise the "expected" k-effective value and uncertainty to include the impact of the deviation. The adjusted k-effective value and uncertainty is to be based on quantitative analysis, rather than qualitative analysis that the effect is expected to be small.

e. Was every LCE computer model input reviewed and confirmed to be correct by comparison with their references?

Text provided below Table 3-1 in Section 3.3.5.9 states: **[** **]** While it is acceptable to start with input files from NUREG/CR-6361, the analyst is still responsible for updating the input files and checking them against their original references.

Due to the independent review process used, the IHECSBE is considered an acceptable reference for criticality experiment descriptions. Analysts using the LCEs described in NUREG/CR-6361 need to compare the models against the original references that are stated in NUREG/CR-6361. It is not acceptable to simply assume that the input files provided in NUREG/CR-6361 are correct.

Other sources of critical experiment descriptions may be used, but the analyst is responsible for assessing the adequacy of the reference, and the accuracy and completeness of the information provided. The analyst must identify the expected experimental k-effective value and uncertainty, taking into consideration modeling approximations and assumptions used to prepare the LCE model.

27. Section 3.3.6.2 includes descriptions of **[** **]** Revise the text in Section 3.3.6.2 and Table 3-6 to incorporate the **[** **]** cases or justify leaving them out.

28. Regarding Section 3.3.7:

    a. **[** **]** Incorporate this information into the enrichment trending analysis.

    b. Why doesn't the trending analysis include a **[** **]** Inclusion of additional MOX LCEs could make this trend more meaningful. The intent is to provide a trend that may be applied to fuel with plutonium content that varies with burnup.

    c. Consider expanding the LCE sets to validate temperature-dependent nuclear data adjustments. Perform trending analysis as function of temperature or justify not doing so.

d. Figure 3-1 shows that there are only **[** **]**

e. Figure 3-5 shows that there is only **[** **]**

f. Table 3-7 and other tables like it indicate that there was no statistically significant trend for several of the parameters investigated. To cover these trending analysis results, revise the statistical analysis to derive and use a non-trending bias and uncertainty using a technique like the single-sided tolerance limit from NUREG/CR-6698.

g. In Table 3-8, the **[** **]** Please revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

h. The second set of LCEs includes **[** **]** Please revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

i. The last sentence in the text below Table 3-12 is the following: "In criticality analyses, **[** **]** It is important that this kind of guidance be provided, however, the guidance needs to be described more exactly. Does the existing text mean that the limit with **[** **]** If so, this is not necessarily appropriate. In some cases, the **[** **]** Instead, it would be more appropriate to say that the bias and associated uncertainty that yield the **[** **]** will be used. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to more clearly define how multiple bias and uncertainty values will be used in the criticality analysis.

j. The third group of experiments is defined in Section 3.3.6.2 as **[** **]** The text throughout Section 3.3.7.3 indicates that the analysis for this group is for **[** **]** Other than for enrichment, the results provided in the figures and tables in Section 3.3.7.3 seem to include **[** **]** (consistent with the group definition provided in Section 3.3.6.2). The enrichment trend analysis appears to include all **[** **]** Revise the WCAP-17483-P/WCAP-17483-NP, Revision 0, text and/or analysis to be consistent.

   It seems that it would be more consistent to limit the third group to **[** **]** Analysis of the overall set would also be useful. If analysis of the overall set is retained, the text should be revised to clearly describe the work.

   The trend for enrichment appears to exclude the **[** **]** While it is debatable as to whether or not the **[** **]** should be included, the text should clearly describe the work, including exclusion or inclusion of the **[** **]** If the results from enrichment trending analysis for **[** **]** are used to generate bias and bias uncertainty for a safety analysis model with burned fuel, the as-burnt enrichment from the safety analysis models should be used to determine the limit rather than the initial enrichment.

   Based on the data included in the third group, it looks like the AoA should be limited to EALF values between **[** **]** Extension of the AoA to **[** **]** is questionable. Revise WCAP-17483-P/ WCAP-17483-NP, Revision 0, accordingly.

k. Review and adjust/correct the trending analyses and normality tests for the third validation set. Note that the normality test should be performed for each subgroup used to develop each separate bias and bias uncertainty. For example, if the HTC experiments are not used in the enrichment trend, it is necessary to perform a separate normality test on the modified subgroup.

29. The text in the 2nd paragraph of TR's Section 3.4 implies that the validation supports credit for **[** **]**

The Westinghouse **[**

] The LCEs used in the validation study do not include any configurations with **[** **]** Additional validation work would be required to support validation of **[**

] Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to make this clear.

30. Regarding Table 3-20:

    a. The fourth column in the table is listed as **[**

    ] While the text claimed to be evaluating this category, the LCE set used was instead **[** **]** Revise the table or update the analysis.

    b. In the row labeled "Fissionable Material," list **[** **]** in the fourth and fifth columns for clarity.

    c. In the row labeled "Isotopic Composition of Fuel (wt% ^{235}U)," the second and fourth columns claim the AoA includes enrichments up to **[** **]** This is not appropriate because there is only **[** **]** Revise the table to reflect a maximum of **[** **]** Extrapolation up to **[** **]** is acceptable, but this is to be addressed separately from the AoA definition, which characterizes the validation study, not how it will be used in the safety analysis.

    d. In the row labeled "Absorber Material," the LCEs evaluated do not include enough configurations with **[** **]** to claim they are adequately validated. No trending analysis was performed to identify biases and uncertainties as a function of **[** **]** content. Revise the entries to remove **[** **]**

    e. In the row labeled "Physical Form of Absorbers," remove **[** **]** because insufficient validation work was documented to support inclusion of these components in the AoA.

    f. In the row labeled "Soluble Boron Concentration (ppm)," change the **[** **]** upper boundary to **[** **]** because there is only one point above **[** **]** and this is not enough data to justify extension from **[** **]**

g. In the row labeled “EALF” add units of electron volts (eV) and change the ranges so that the ranges are not significantly extended based on only one or two data points. Based on the data presented in WCAP-17483-P/WCAP-17483-NP, Revision 0, acceptable ranges could be **[** **]** in the second through fifth columns.

h. In the row labeled “AEG,” revise the label to make it clear this is the average energy group (AEG) in the 44-group library. Also, adjust the AEG ranges to be consistent with any changes to EALF based on the discussion above.

31. Regarding Table 3-21:

a. As noted previously, the bias and bias uncertainty provided for **[** **]** was not based on only the LCEs with strong absorbers. It was instead based on all LCEs **[** **]** Update the validation study or revise the table.

b. The enrichment trend in the “Fresh and Spent Fuel, with Absorber” row did not include the **[** **]** Consequently, this enrichment-dependent bias and bias uncertainty is for **[** **]** The U-235 enrichment for the **[** **]** is known and could be used. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

c. The use of “Any” in the “Fresh Fuel, with Absorber” and “Fresh and Spent Fuel, no Absorber” rows is not appropriate. Provide limiting ranges consistent with the LCE data used.

d. In the “Fresh Fuel, no Absorber” row, the pin pitches provided are **[** **]** of the LCE data used to develop the limits. **[** **]** needs to be explicitly addressed and justified. The data is **[** **]** It may be necessary to add LEU LCEs without absorbers.

e. Add guidance for using this Table 3-21. For example, what bias and uncertainty are used for a checkerboard of fresh and spent fuel? What values are used for mixed poisoned and unpoisoned fuel (e.g., 1 rod cluster control assembly (RCCA) required in every 4 assemblies)? What values are used for interface conditions? For spent fuel, what enrichment is used? Is it acceptable to use the “Fresh and Spent Fuel” values for “Fresh fuel” storage? How is bias and uncertainty variation with burnup addressed?

32. Why doesn't Section 3 include a section on identification and handling of validation gaps and deficiencies? Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly. Consider providing guidance in this section for the analyst to:

    a. Compare the safety analysis models and the validation studies

    b. Identify validation study gaps and deficiencies

    c. Describe how validation gaps and deficiencies are addressed. Deficiencies include things like **[**

    ]

    The purpose of including this section is to induce the analyst and reviewer to consider whether or not the validation was adequate and whether or not the validation weaknesses were adequately addressed.

33. Section 4.1 covers "Design Basis Fuel Assembly Selection." Revise this section to include consideration of:

    a. The impact of tolerances and uncertainties. Larger uncertainties could make a less reactive assembly the limiting design basis fuel assembly.

    b. Potential variation of the bounding assembly with: **[**

    ]

34. Consider adding guidance in Section 4.1 reminding analysts that it is necessary to identify and address design variations such as **[** **]** if they are present or will be used since these variations are not within the scope of WCAP-17483-P/WCAP-17483-NP, Revision 0.

35. The text below Table 4-1 states:

    [

    ]

The meaning of “values” is vague. Explicitly characterize what the values should correspond to (e.g., materials, dimensions, and tolerance). Also, it is important that the analyst identify and discuss fuel from **[ ]** to document that it was considered, evaluated, and is equivalent. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

36. The last paragraph in Section 4.1.1.1 provides justification for **[ ]** when determining the bounding assembly designs. Augment the discussion to clarify that it may be necessary to reconsider **[ ]** changes significantly.

37. Section 4.1.1.5, addressing **[ ]** cites NUREG/CR-6760 as supporting that it is **[ ]** NUREG/CR-6760 is not clear on this subject. The studies with **[ ]** were performed using a two-dimensional (2D) lattice code and for a limited number of poisoned fuel rod configurations and for a limited number of initial fuel U-235 enrichments. As was noted in the same NUREG, three-dimensional (3D) modeling of part-length IFBA resulted in larger reactivity increases with burnup than did 2D calculations. Considering the limited nature of the study presented in NUREG/CR-6760, it is not appropriate to simply assume that ignoring **[ ]** is always conservative. The impact of these **[ ]** will need to be evaluated on an assembly design-specific basis. Revise the text to require evaluation of the impacts of integral burnable absorbers on the criticality analysis.

38. In Section 4.1.1.6, additional text should be added to address fuel that was used both before and after an uprate. Care needs to be exercised to avoid a potentially incorrect assumption that older fuel has not experienced uprate conditions. Older fuel may be returned to duty for various reasons including emergency core reload redesign, more complete utilization of residual reactivity, or return to service following repair/reconstitution.

39. Section 4.1.2.1 claims that it is acceptable to use **[ ]** This is not appropriate. It is necessary to evaluate the bounding assembly using **[ ]** used in the safety analysis to correctly capture the burnup at which there is a transition from one bounding assembly design to another. For example, at low

burnup values, it is likely that the **[ ]** is bounding due to its more optimal H/U ratio. Then at some higher burnup the **[ ]** assembly will likely become more limiting due to its higher uranium loading. Correctly identifying this transition burnup point requires evaluation using both uniform and distributed axial burnup profiles. Revise this section to include use of **[ ]** that are used in the safety analysis.

40. The last paragraph in Section 4.1.2.1 includes the following statement:

    [

    ]

    Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to clearly identify the standard method and then provide guidance for handling deviations from the standard method. The statement above does not describe the standard method, but provides an exception to what might normally be expected, and provides no justification for the exception.

41. Sections 4.2.2 and 4.2.4 discuss the simplified top and bottom nozzle models. This model is said to include at least **[ ]** above and below the active fuel length. No studies or other justification is provided for this model. Why is **[ ]** used and what is the distance between the ends of the active fuel and the **[ ]** Bearing in mind that sometimes layers of water and steel provide better reflection than water alone, clarify the justification for the simplified model used. Alternatively, provide a reference where the conservative nature of these simplifications has already been demonstrated in a generically applicable fashion.

42. Regarding Section 4.2.3:

    a. It appears that the intent of the studies presented in this section is to establish that it is conservative to **[ ]** If this was the intent, the study needs to be more extensive and more detail is required.

        i. How are grids and sleeves modeled in depletion calculations? How were grids and sleeves modeled in k-effective calculations? Smeared over axial zone where grids exist? Smeared over the axial zone containing the grid? Smeared over the active length of the fuel?

ii. Were the local burnup depressions created by the grids modeled?

iii. What other factors such as axial blankets, radial enrichment zoning, cell inserts, assembly inserts, rack designs, and assembly storage arrangements, might affect the sensitivity of the grid effects?

iv. The study needs to be expanded to consider other fuel assembly designs.

v. The results presented are not consistent with work reported by others where the **[ ]** yielded small, positive in some cases, but not insignificant, reactivity changes. Reactivity decreases have been calculated for replacement of grid and sleeve material with highly borated moderator.

b. In Table 4-6, the node 3 value for profile 1 should be 1.208, not 1.028. The data in this table appears to originally be from DOE/RW-472, Rev. 2, Table 4-3. It would be appropriate to credit such data sources. The assembly burnup ranges should be provided for each of the three profiles.

c. The last sentence in Section 4.2.3.5 reads:

> **[**
>
> **]**

While this statement may be true, the analysis needs to be augmented to defend the scope of the study and address the AoA under which the study is applicable.

Furthermore, the concept of “statistically significant” depends on the statistical hypothesis being adopted. The hypothesis used in this sentence and elsewhere in the report appears to be there is no difference unless proven otherwise. As used herein, this is a non-conservative hypothesis. It should be assumed that there is a difference unless proven otherwise. Usually, a conservative estimate is the difference between the two k-effective values increased by two standard deviations of the combined Monte Carlo uncertainty. This estimate can be driven down by running more neutron histories, if needed.

Based on the discussion above, provide and justify a more appropriate conclusion, which must identify and justify the AoA.

43. Nearly all of the items listed in Sections 4.3.1 and 4.3.2 are modeling simplifications and approximations, not assumptions. Assumptions are things that are “assumed to be true.” Assumptions should be restricted to things that are very likely and are generally not verifiable. If something is important to criticality safety and can be verified, it should be verified, thereby eliminating the need to make an assumption.

Use of assumptions in criticality analyses should be avoided, and if necessary, are to be explicitly identified and defended to provide clarity. Identify assumptions separately to avoid confusion about which items are simplifications and which are assumptions.

Modeling simplifications and approximations differ from assumptions in that they are made based on understanding and knowledge of the actual facts and are made to facilitate performance of practical analyses. Simplifications and approximations should be identified and justified based on analysis and comparison of the detailed and simplified systems. Where simplifications and approximations introduce non-conservative biases and uncertainties, these quantities should be included in the determination of the maximum k-effective value.

The first bullet in Section 4.3.1 states: **[**

]

Clearly, it is not assumed that a **[** **]**
Instead, this is a modeling simplification. In general, little or no justification has been provided for many of the modeling simplifications. For example, the first two bullets in Section 4.3.1 yield a simplified fuel assembly depletion environment that involves a 2D slice of an assembly reflected on the lateral faces, yielding an infinite array of assemblies. The actual fuel depletion environment in the reactor is far more complex. No justification is provided for this modeling simplification, which is commonly used in burnup credit criticality analyses. Please revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

44. In Section 4.3.1, the third bullet includes a parenthetical statement that implies that hardening the neutron energy spectrum during depletion leads to increased plutonium production and is conservative. This is generally true. However, if the presence of residual neutron absorber is credited, the fuel storage rack k-effective may increase as the burnable absorber is depleted. The height of the k-effective peak may be increased more by a softer neutron energy spectrum, which can cause burnable absorber to deplete faster. The faster burnable absorber depletion can result in an earlier and higher peak k-effective value. Based on the discussion above, modify the parenthetical statement accordingly, and provide additional guidance as necessary.

45. In Section 4.3.2:

    a. Provide a list of isotopes modeled in criticality calculations. These should not include neutron absorbers with short half-lives or noble gases or elements considered to be volatile. Describe post-depletion calculation processing of burned fuel compositions.

b. The fourth bullet on page 4-13 discusses new fuel storage rack modeling simplifications. Revise this item to make it clear that the bounding fuel assembly design is rack and condition dependent or provide justification showing that the bounding fuel assembly is not rack and condition dependent. If more than one assembly design may be stored in the new fuel storage vault (NFSV), it will be necessary to identify the bounding assembly design at full and optimum moderator density conditions.

c. The sixth bullet on page 4-13 states:

> **[**
>
> **]**

Describe how the "analyzed configurations" qualify temporary patterns encountered during loading, unloading and repositioning of fuel assemblies. Even if one restricts such operations to normal fuel handling activities, it is still necessary to evaluate potential interaction with other fuel in the racks, inspection stations, elevators. It becomes more problematic considering storage arrangements where reactivity control devices such as RCCAs or cell inserts are required. For example, is it acceptable to place the assembly or assemblies in the rack first and then insert the RCCA?

All normal and accident conditions associated with both fuel handling and storage must be evaluated. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

d. The seventh bullet on page 4-13 discusses modeling of Boraflex panels. The proposed modeling simplification may in some cases be non-conservative. It is not appropriate to simply **[** **]** In some cases, replacing the **[** **]** Modeling of the Boraflex in SFP racks needs to be addressed on an analysis-specific basis. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

e. The tenth bullet on page 4-13 discusses modeling of fixed neutron absorber panels. Expand the discussion to include the axial and horizontal location of the poison panel within the rack structure and the poison panel width and height.

f. The thirteenth bullet on page 4-13 appears to claim that the pool water is **[ ]** It is required that moderator conditions in the SFP and NFSV be evaluated over the full range of normal and accident condition densities and temperatures. Revise this bullet to clarify the intent, consistent with regulatory requirements.

g. The fourteenth bullet on page 4-13 describes a simplification where the **[ ]** to provide a conservative model of the assembly **[ ]** How does the as-modeled fuel assembly dimensions compare with the actual fuel assembly dimensions? What work has been done to demonstrate that this modeling simplification is conservative?

h. The intent of the last bullet on page 4-13 is not clear. Is the implication that the uncertainty analysis will be restricted to the listed parameters? Is the list of parameters used to define the parameters that need to be covered by the criticality validation study? In either case, some important parameters are missing. Revise the bulleted item to clarify its intent and, depending on its intent, expand the list of parameters as necessary.

i. The last two bullets on page 4-14 address “rack inserts.” The text in these last two bullets may be about storage cell inserts rather than assembly inserts. Revise the text to make clear what is meant by “rack insert.” Note that it may be necessary to include rack insert misorientation as an accident condition.

j. The criticality analysis modeling simplifications do not address the following: **[ ]**

46. The first paragraph in Section 5.1 includes a statement that **[ ]** A qualifier needs to be added to note that this may not be appropriate in analyses that credit residual integral burnable absorber. In such systems, a softer neutron energy spectrum may cause faster burnout of neutron absorber, thereby reaching an earlier and potentially higher peak k-effective value.

47. Regarding Section 5.2:

a. How is blanket material irradiation handled?

b. From Figure 5-1 it looks like the modeled actinides are limited to: **[ ]** Confirm that this is the standard method.

c. Provide a list of credited fission products.

d. The upper left-hand block in Figure 5-1 does not list **[ ]** Revise the text or Figure 5-1 to more completely describe the potential inputs.

48. Section 5.3 covers "Bounding Axial Burnup Shapes." A general concern that needs to be addressed throughout this section is that the bounding axial burnup shape may be different for mixed (i.e., low-burnup/fresh fuel and higher-burnup) systems. These mixed systems might include: (1) checkerboard storage arrangements of fresh, low-burnup or high-burnup fuel, (2) region and pattern interfaces and (3) accident configurations. Due to mismatch in the axial location of the most reactive parts of the fuel, placing burned assemblies with the least mismatch next to the fresh fuel assemblies may yield higher k-effective values.

    A second aspect of the same axial reactivity mismatch phenomena is that at low burnups a uniform axial burnup profile yields higher k-effective values than do more realistic axial burnup profiles. Consequently, up until some burnup around 10 to 20 GWd/MTU, uniform axial burnup profiles are limiting. After the transition, the distributed axial burnup profile becomes more reactive due to low burnup at the ends of the fuel. The burnup at which this transition from uniform being conservative to distributed axial burnup being conservative is affected by collocated fuel with a different axial burnup profile. Collocated high and low burnup is fairly common in SFP criticality analysis. This frequently occurs at region-to-region interfaces, mixed fresh/spent patterns within a region, and in accident analysis models.

    Revise Section 5.3 and its subsections to include identification and use of limiting axial burnup distributions for mixed fresh, low-burnup, and high-burnup fuel arrangements.

49. The first sentence in Section 5.3.3 of TR notes that axial burnup data are typically available from plant data or core design analysis. How do plant and core design analysis axial burnup profiles compare? Is there a bias between measured and design data in the top 2 feet of fuel? This is relevant because the text suggests either data may be used in the process proposed in Section 5.3.4.

50. The Westinghouse **[**

] could also be compared to other work such as that published by Parish and Chen (1997), DOE/RW-0472, Rev. 2, NUREG/CR-6801, ORNL/TM-1999/246, and many others. The aim of these comparisons is to provide additional evidence that top 8 of 24 nodes MIBA yields similar or more conservative results.

51. Section 5.3.5 provides the demonstration that the **[** **]** The text, Table 5-2 and the plots need to be revised to more clearly establish the validity of the method. The demonstration provided shows how the reactivity of some **[** **]** The comparison does not appear to be comprehensive and presupposes that the axial profiles identified by the **[** **]** The proof of the method needs to include other fuel assembly types, other plant types, and a variety of axial features – i.e., part-length IFBA, wet annular burnable absorber (WABA), pressurized thermal shock (PTS) curtain rods, axial power shaping rods (APSR), etc., beyond axial blankets.

52. There may be a couple of problems with the data provided in Table 5-2 of WCAP-17483-P/WCAP-17483-NP, Revision 0. **[** **]** This may indicate typographical errors or the use of non-uniform axial zones. The second issue is that the **[** **]** These unexpected results may be an artifact of the assemblies around the profiled assembly or of use of part-length absorbers. The data should be checked to ensure the data is in the correct columns. If the data is correct, provide an explanation as to why the relative burnups for the ends of the fuel for the low-burnup, non-blanket profiles is so low.

53. A clear and complete statement of how the **[** **]** will be applied is required. Is the standard method to use the profiles from Table 5-2, or to use facility-specific

bounding profiles determined using the **[ ]** How will future cycles be compared to the **[ ]** profiles? How will exceptions be identified and handled?

54. Address the following items regarding the standard methodology for axial burnup profile selection and use:

    a. Define the AoA for this method. Note that it may be appropriate to do this on an analysis-specific basis.

    b. Identify potential exceptions. These might include unusual burnable absorber configurations, atypical control rod usage, part-length PTS curtain usage, transition cores (i.e., non-blanket to blanket, changes in burnable absorber usage, assembly design changes, reconstituted fuel, etc.), extended part-power operation, etc.

    c. Provide guidance for handling of exceptions.

    d. Provide guidance for minimum data requirements supporting usage of **[ ]**

    e. Provide guidance for documenting use of the **[ ]** in future work. This guidance should cover how the **[ ]** is to be implemented in criticality analyses that are based on WCAP-17483-P/WCAP-17483-NP, Revision 0, and how **[ ]** use will be documented in criticality analysis reports.

55. Regarding Section 5.4.2:

    a. The 1st paragraph in Section 5.4.2 states: **[**

       ] This statement might be true if there were no effects other than Doppler broadening of water cross sections and moderator density effects. However, the hydrogen cross sections do change as a function of temperature, just not due to Doppler broadening. Calculations performed with both MCNP and SCALE have demonstrated significant k-effective changes due solely to temperature changes with the density held constant. Revise WCAP-17483-P/ WCAP-17483-NP, Revision 0, accordingly.

    b. Revise the discussion in Section 5.4.2 to make it clearer that the sensitivities discussed are the sensitivities of spent fuel storage k-effective value to changes to depletion parameters.

    c. The standard method for determining a conservative moderator temperature for use in fuel depletion calculations is not clearly defined based on the discussion in Section 5.4.2. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

56. Section 5.4.5 discusses the effect of operating history on fuel depletion calculations. Reference 20 notes that “The net effect is rather small, up to 0.2% Δk/k for the operating histories considered.” The only recommendation on modeling of operating history provided in Reference 20 is in Table 4, which recommends that a simple operating history be used, with margin of 200 pcm **<u>or more</u>**. No guidance is provided in Reference 20 concerning how much more than 200 pcm may be needed.

    Figure 17 in ORNL/TM-12973 (M. D. DeHart, May 1996) indicates that, when both actinides and fission products are credited, fuel reactivity decreases with increasing power density. Consistent with DSS-ISG-2010-01, Section IV.2.b.ii, when two directly related depletion parameters have offsetting effects, the dominant parameter should be set to a conservative value and the related parameter should be set to the nominal value.

    Either (1) revise Section 5.4.5 to more accurately reflect the information and recommendation in NUREG/CR-6665, or (2) revise the text to refer to ORNL/TM-12973 and DSS-ISG-2010-01 and define the standard method to use conservative moderator and fuel temperatures and the nominal power density.

57. Regarding Section 5.4.6:

    a. Revise this section to explicitly address modeling of part-length insertable neutron absorbers. Where part-length absorbers such as WABAs and Hafnium Vessel Flux Depression (HVFD) absorbers are used, structures above and below the active neutron absorber displace water from the guide tubes. Provide guidance for modeling part-length insertable absorbers in fuel depletion calculations.

    b. Much of the text presented in Section 5.4.6.2 appears to be based on studies similar to those documented in NUREG/CR-6760. This is not clear because few references are provided in Section 5.4.6.2.

       The text in Section 5.4.6.2 implies that it is **[** **]** Typically, NUREG/CR-6760 is cited as the reference supporting this assertion. However, the **[** **]** studies reported in NUREG/CR-6760 were based on 2D calculations, with infinitely repeated assemblies not in a fuel storage rack structure. These calculations were performed using the HELIOS computer code. The calculations were performed for a limited range of initial fuel enrichments and a limited number of **[** **]** configurations. Note that a limited set of 3D calculations were reported in Section 3.3.5.5 of NUREG/CR-6760 with Westinghouse IFBA rods. These calculations indicated that, for systems with part-length IFBA, the 3D calculations yielded a larger positive effect on k-effective than did the 2D calculations. An even more limited set of results were reported in Section 3.3.5.4 with fuel in a GBC-32 storage cell. These calculations indicated that IFBA fuel in storage cell results yielded larger increases in reactivity than did the infinitely repeated assembly geometry, which was utilized in the sensitivity studies reported in NUREG/CR-6760 Sections 3.3.1 through 3.3.4.

The conclusion that it is conservative to ignore **[ ]** needs to be supported with studies that go beyond those presented in NUREG/CR-6760. Such studies need to be based on k-effective calculations performed using 3D fuel and rack models, and cover the parameter space (i.e., assembly designs, initial enrichment, burnup, integral burnable absorber configurations, fuel storage rack parameters, temperature, soluble boron concentrations, etc.) evaluated in the criticality analysis.

Validation of such calculations is also problematic due to the relative dearth of applicable benchmark data for use in validation studies. Consequently, many safety analyses include the integral burnable absorbers during the depletion calculations, and remove them from the k-effective calculations.

Revise Section 5.4.6 to:

i. Provide supporting references

ii. Clearly describe the standard method

iii. Provide appropriate justification for the current discussion or revise the discussion to a more defensible approach

58. Revise Section 5.4 to include discussion of the impact of post-irradiation cooling time.

59. Within Equations 6.1, 6.2, 6.3, and 6.4, and in several places in the text of WCAP-17483-P/WCAP-17483-NP, Revision 0, **[ ]** This is not appropriate.

Each uncertainty on the mean k-effective value associated with each Monte Carlo calculation is not known exactly. Instead, it is estimated from the variance of the mean k-effective value associated with each active generation. If one knew the true uncertainty in the mean, use of the **[ ]** would be more defensible. However, the SSTF for 10,000 active generations would be 1.67 and for 1000 active generations would be 1.727. Use of a smaller SSTF is not appropriate.

Furthermore, there are additional uncertainties associated with characterization of the distribution of many of the tolerances and uncertainties. It is not obvious that deviation or error in characterizing material properties and manufacturing tolerances and uncertainties is even approximately normal. For example, decisions on rejection or acceptance of manufacturing output are sometimes made on a "go-no-go" basis, which can result in chopped distributions that are clearly not normal. Common criticality safety engineering practice is to use two standard deviations for this sort of calculation of uncertainty estimates. The alternative is to perform detailed item-by-item analysis of the nature of the various distributions for which uncertainties are needed. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

60. The last paragraph on page 6-1 and equation 6.2 discuss the subject of "statistical significance". The idea of **[** **]** is based on the statistical hypothesis that there is no uncertainty unless it is statistically proven that there is. This non-conservative hypothesis is not appropriate. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to eliminate the concept of ignoring uncertainties that are not "statistically significant".

61. The second paragraph in Section 6.1 states:

    [

    ]

    Provide a study or references supporting this assertion. The last sentence in the third paragraph goes on to say, **[** **]** Considering the unqualified extent of this guidance, the references or studies supporting it should span all of spent fuel storage analysis parameter space (i.e. all enrichments, assembly designs, burnable absorber usage, reactor designs, burnups, cooling times, storage rack designs, etc.). Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

62. The first paragraph in Section 6.1.2 suggests that it may be acceptable to **[** **]** Clearly state whether or not this credit is part of the standard methodology? If it is, provide additional guidance concerning how the supporting calculations are to be performed and validated.

63. Many of the tolerances and uncertainties discussed in Sections 6.1.2 through 6.1.19 do not include adequate justification for guidance provided. While parameter studies are provided in some of the subsections, the figures do not appear to cover the relevant parameter space well enough to justify the assertions made in each subsection.

For example, the second paragraph in Section 6.1.2 states:

[

]

Uncertainty information for two plants is provided in Figures 6-1 and 6-2 for varying initial enrichment and burnup, respectively. There is no indication that these studies considered different fuel assembly designs, different storage rack designs, storage pattern variations, temperature variations, burnable absorber use variation, moderator density variations, etc. Information for Plant A was provided with and without soluble boron, but there is no indication as to how much boron was included in the “Borated” data. The studies appear to be far too limited in scope to support the claim that the fuel pellet outside diameter uncertainty is not a function of initial enrichment or burnup.

Review and revise the subsections in Section 6.1 of WCAP-17483-P/ WCAP-17483-NP, Revision 0, to provide clear and defensible guidance on the quantification of uncertainties. The guidance should be based on statistical analysis of data rather than qualitative review of plotted information.

64. Section 6.1.6 covers quantification of the [ ] The following comments are provided on this subsection:

    a. Define the standard method.

    b. The second sentence in Section 6.1.6 does not seem to account for the uncertainty in the [ ] Revise TR accordingly.

    c. The logic for calculating the [ ] seems pretty clear. However, the [ ] could be limiting for some lattices in some conditions. For example, how does [ ] affect k-effective at optimum moderation conditions in the new fuel storage racks? Provide guidance for calculating [ ] in systems where [ ] yields a reactivity increase.

65. Revise Section 6.1 to address uncertainties associated with the following:

    a. Poison panel wrapper width and thickness
    b. Poison panel width, thickness, height and location
    c. Poison panel gap size
    d. Reactivity control devices (e.g., RCCAs, CEAs, B_4C rods, rack inserts)
    e. Material compositions

66. The last sentence in Section 6.1.11 states:

    > **[**
    >
    > **]**

    This is not an appropriate threshold. Using this guidance, the analyst can always state that they don't expect a significant effect. Examine the sensitivities and demonstrate that they do not have a significant effect. Revise the text to provide more defensible guidance.

67. Section 6.1.12 describes calculation of an uncertainty to cover poor validation of **[** **]** This appears to be the **[** **]** described in DSS-ISG-2010-01, which is from the Kopp memorandum. Include the appropriate reference to explicitly define the basis for the depletion uncertainty. If the standard method permits credit for integral burnable absorbers, include guidance for handling the depletion uncertainty for fuel with integral burnable absorbers.

68. Section 6.1.13 includes a list of nuclides that will be retained in the perturbed case when calculating the **[** **]** This list of nuclides is not consistent with those listed in Figure 5-1, which appears to track only **[** **]** The list in Section 6.1.13 also includes **[** **]** It is not clear why it is acceptable to include **[** **]** Revise the TR to identify and use a consistent set of actinides and fission products. Where appropriate, correct the errors in Section 6.1.13.

69. Section 6.1.14 describes calculation of an uncertainty in the **[** **]** Since equation 6.5 does not appear to include Monte Carlo calculation uncertainty, it appears as though the **[** **]** Provide more details on how the **[** **]** is calculated. The relevant sensitivity needs to be calculated in a 3D spent fuel storage rack environment.

The last sentence in Section 6.1.14 gives permission for the utility to handle **[** **]** To avoid confusion during implementation, revise the WCAP-17483-P/ WCAP-17483-NP, Revision 0, text to require the analyst to confirm and address **[** **]** treatment explicitly in the criticality analysis report.

70. The sentence starting at the bottom of page 6-14 and ending on 6-15 states:

    [

    ]

    The analysis is not clear because the sentence refers to "the initial enrichment and burnup credited in the analysis." Multiple enrichment/burnup points are typically credited in burnup credit analysis. Revise the text to clarify the scope of this **[** **]** determination. Is this done for each and every initial enrichment/burnup point? If not, describe and justify the more limited set of calculations.

71. Section 6.1.17 covers **[** **]** This is not an uncertainty because the **[** **]**

    Further, a relatively small number of assemblies, compared to the full inventory (9 or 16 out of a thousand), would need to accidentally end up in the worst case configuration to achieve the maximum k-effective. Considering the relatively large number of assemblies available for randomly achieving the worst case, it is more than likely that the worst case will exist, assuming that the assemblies are placed randomly.

    Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to handle **[** **]** It should also be noted that the location and arrangement of the worst case **[** **]** may vary for different analysis conditions such as optimum moderation and misloaded fuel assembly studies.

72. The text in Section 6.1.19 misquotes NUREG/CR-6665 (WCAP-17483-P, Reference 20). Section 4.2.4 of NUREG/CR-6665 does state: "The net effect is rather small, up to 0.2% Δk/k for the operating histories considered." Note that it qualifies the statement with "for the operating histories considered." The text goes

on to say that margin should be added to account for operating-history-induced effects. The following recommendation is provided in Table 4 of NUREG/CR-6665 (page 22): "Assume simple operating history, with margin of 200 pcm or more."

Note that the NUREG/CR-6665 recommendation suggests that more than 200 pcm may be needed and does not suggest that this should be treated as an uncertainty. Considering this more accurate description of the NUREG/CR-6665 analysis and recommendation, revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to address how plant operating history will be reviewed and how appropriate bias and/or uncertainty will be developed to cover plant-specific operating history effects. Note that it is also recommended that guidance be provided considering atypical plant operations (i.e., such as extended outages and extended part-power operation) that may occur in the future. Otherwise, a plant utilizing WCAP-17483-P/ WCAP-17483-NP, Revision 0, may find that occurrence of such atypical plant operations may invalidate the bases for the criticality analysis.

73. Revise equation 6.6 to include other potential bias terms such as **[** **]** and operating history bias as discussed in RAI-71 and RAI-72.

74. Sections 6.2.1 through 6.2.3 provide some guidance for determining **[** **]** These sections all suggest that the analyst needs to consider **[** **]** While it is likely true that evaluating uncertainties in this manner is appropriate, it is not clear that this should be generally assumed. Total bias and uncertainty information should be fully analyzed at the lowest levels. A **[** **]** may then be applied based on detailed knowledge. Revise the appropriate sections of the TR to make it clear that determination of **[** **]** values are based on detailed evaluation of all biases and uncertainties.

75. Add guidance for handling of bias and uncertainty for:

    a. Region-to-region interface conditions
    b. Where rack modules are modeled, interfaces between modules
    c. Varying configurations permitted within regions/modules
    d. Mixed fresh and spent fuel storage arrangements

76. It is not clear why Tables 6-1 through 6-3 and Figures 6-1 through 6-21 are provided. Is the intent that analysts will use this data to reach certain conclusions concerning their analysis? Is the data presented in support of assertions concerning the standard method? If so, the assertions and logic should be clearly stated. Also, insufficient information is provided about the configurations in Tables 6-1 and 6-2 to permit NRC staff to reach conclusions. Currently, only some bias terms are included

and the enrichment uncertainty is listed after the uncertainty subtotal. Provide example tables of uncertainties, biases and total rack-up to maximum k-effective for clarity and revise the text and tables to be more clearly relevant.

77. Section 6.3 addresses the effect of soluble boron on biases and uncertainties. This section relies on a very limited study of the effects to generate an overly broad conclusion. Either revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to require detailed analysis of biases and uncertainties with and without soluble boron or provide a more detailed and broad study demonstrating the basis for the conclusion provided below Figure 6-23.

    This study should also evaluate the impact of soluble boron on bias and uncertainty for **[**

    ]

78. In Section 6.4, based on trends in the data in Table 6-1 on page 6-22 and in Table 6-2 on page 6-25, it looks like the column containing values of 5, B, 0, and 45 should be 5, A, 0, and 45. Also, the enrichment uncertainty appears to be missing from Table 6-3 on page 6-28. Review and correct the tables as appropriate.

79. Section 6.5.2 provides an example determination of the minimum burnup requirements.

    a. From the example provided in Section 6.5.2, it is not clear how burnup-dependent uncertainties will be incorporated. Provide text addressing this issue or incorporate the burnup-dependent uncertainties into the example.

    b. The calculation of the **[**

       ]

80. Regarding Section 6.5.3:

    a. Provide guidance and justification for the minimum set of initial enrichment points to be evaluated. Also, provide guidance and justification on the spacing of initial enrichment points and on the **[**
       ]

    b. The text below Table 6-11 suggests that use of **[**
       ] What is the standard method and what criteria should analysts use to determine whether or not a **[** **]** is warranted and acceptable?

81. The second paragraph of Section 6.6.1 of the TR states: **[**

] It will be necessary to evaluate their contribution to uncertainty and whether or not they are adequately validated. Revise the text to reflect these considerations.

Section 6.6.1 also discusses **[**

] is to be implemented in the standard analysis.

Furthermore, it is proposed that it would be appropriate to reduce **[** **]** as a modeling simplification to bound the effect of both depletion and manufacturing tolerances. The manufacturing tolerances on **[** **]** may yield a larger effect on k-effective than a **[** **]** Eliminate this modeling simplification or provide a study justifying its use.

Provide additional detailed guidance for crediting irradiated burnable absorbers or note that modeling of irradiated burnable absorbers is to be justified on an analysis-specific basis.

82. Section 6.6.2 describes credit for fresh integral burnable absorbers. The third paragraph introduces an option to have **[** **]** Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to require that the determination of bounding axial burnup distributions used for the burned fuel to be revisited for **[** **]** and revisited again when **[** **]** or provide justification for not modifying the discussion. It is also stated in Section 6.6.2 that **[** **]** Provide additional discussion explaining why every pattern does not need to be evaluated.

83. Regarding Section 6.6.3:

   a. Recently, blistering of BORAL panels has been observed at some plants. It is recommended that guidance for handling BORAL panel degradation be provided for crediting BORAL panels.

   b. The last paragraph in Section 6.6.3 proposes that it is acceptable to **[** **]** How will the analyst know the B_4C particle sizes?

What should be done for racks already installed and where particle size information is not available?

It is likely that a sieve was or will be used to ensure that the B_4C particles are no larger than a specified size. Consequently, all BORAL panels past, present and future will have a distribution of particle sizes with maximum particle size set by the sieve. Virtually all BORAL panels will have some particles that are no larger than **[ ]** Does this mean they all meet the recommendation screening criteria? Provide more clear and complete guidance.

The two references cited looked at a limited range of panel B-10 areal densities in a limited number of rack designs with a limited number of fuel assembly designs. It is not clear whether or not soluble boron was included for PWR cases. While Stan Turner's publications provide useful information, it is not clear that they fully address the issue of the effects of B_4C particle size. From Turner's 2010 journal article, it looks like the effect for Case 4 could have been as large as 200 pcm (0.0012 +/- 2*0.0006) even at the **[ ]** particle size.

Provide additional justification supporting the recommendation that it is acceptable to ignore particle size effects for B_4C particles no larger than **[ ]**

84. Regarding Section 6.6.4:

    a. Why doesn't the analysis include consideration of bounding axial burnup profiles for the burned fuel?

    b. Why isn't there a discussion of the axial extent and location of the IFBA being modeled?

    c. How does the analysis address validation of the IFBA fuel rods? This may be non-trivial since the ZrB_2 is in a very thin layer on the outside of the pellet.

    d. How does the analysis consider IFBA uncertainties associated with B-10 loading, length and location of coated pellets, rod-to-rod and pellet to pellet variability of the B-10 coating?

85. Revise the guidance in Section 6.7.1 to direct the analyst to use the limiting normal conditions that will maximize the accident model k-effective value.

86. The last sentence in Section 6.7.1 indicates that a **[**

]

87. When modeling the SFP (either the whole pool or a more localized region), how is spatial source convergence determined? That is, how is undersampling of important regions avoided in SFP models? Add guidance to WCAP-17483-P/ WCAP-17483-NP, Revision 0, as necessary.

88. Section 6.7.3.1 addresses interfaces between arrays within a region. The following comments are provided on this section:

    a. From the analysis described, it appears that the **[**

       ]

    b. As per the first sentence in Section 6.7.3.1, **[**
       ] There appear to be some errors in Figure 6-28.

        i. The Array 1 checkerboard pattern should require every other cell be empty in all Array 2 cells adjacent to Array 1. Row 2, Column 5 should be empty.

        ii. All Array 1 cells next to Array 2 should require medium burnup. Row 1, Column 3 should be medium burnup. Row 3, Column 3 should be medium burnup.

        iii. All Array 2 cells next to Array 3 must be high burnup. Column 7, Rows 2, 3, and 4 should be high burnup.

        iv. Some RCCAs may be required in the Array 1 and 3 cells adjacent to Array 2.

    Either correct the errors, provide a better explanation of what was intended, or provide a better example.

89. Section 6.7.3.2 addresses evaluation of interfaces between regions. The proposed method appears to be to **[**

    ]

    a. Guidance is needed concerning how the interface should be modeled. Should the interface model include one, two, three, four, or more rows on each side of the interface? It may also be necessary to revisit determination of the bounding axial burnup profile for the interface.

b. The method involves comparison of the **[**

] Revise the standard method description to explicitly describe how this comparison and decision is made.

c. As described, the evaluation of the interface configuration relies on the **[**

] or provide justification for not doing so.

d. This approach does not consider the potential for each region to affect the bias and uncertainty analysis for the other region. Using the example provided in Table 6-16, the presence of Region I-A may cause the biases and uncertainties for Region II-B to increase, but if the interface model yields a calculated k-effective between 0.97 and 0.96 the proposed method would not capture the increased bias and uncertainty. Justify why the proposed method does not address potential increases in bias and uncertainty.

90. The first paragraph in Section 7 of the TR attempts to quote from 10 CFR 50.68. The text provided in Section 7 has some minor differences from the 10 CFR 50.68 text. Since it is a quote, it should reproduce 10 CFR 50.68. Revise the text to match the text in 10 CFR 50.68(b)(4), or revise the text so that it is not a quote.

91. Regarding Section 7.2:

a. In the first paragraph, revise the text to describe the modeling of **[** **]** more completely. Is this **[** **]** immediately above the active fuel length? Is it restricted to the area directly above and below the fuel rods?

b. It is not clear that all normal conditions are considered when determining soluble boron requirements. This may include assemblies other than those in storage. For example, if the outer face of a rack module has no poison panels, the analyst may find that moving a fuel assembly next to the storage rack yields a higher k-effective than does an infinitely repeated 2x2 array with poison panels. The normal condition soluble boron concentration needs to identify the soluble boron concentration needed to cover the most reactive normal flooded SFP condition. Revise the text accordingly to provide clarification.

c. The last paragraph directs the analyst to use **[**

] While this certainly should be checked, all other conditions also need to be evaluated. It may be that fresh fuel storage may have been designed with significantly less margin to the limit than was the burned fuel storage. Consequently, the fresh fuel configuration needs to be considered. It is not appropriate to provide any blanket guidance that restricts evaluation of the normal operating soluble boron concentration. Revise the last paragraph of Section 7.2 to remove inappropriate restrictions on the evaluation to determine the minimum required soluble boron concentration for normal conditions.

d. The determination of required soluble boron concentration needs to consider the entire normal operating conditions parameter space, including the impact of non-storage operations and moderator temperature/density variation.

92. The first two sentences in Section 7.3 state:

[

]

The double contingency principle (DCP) does not state this.

In ANSI/ANS-8.1(1998), Section 4.2.2, the DCP is defined by the following:

> 4.2.2 Double Contingency Principle. Process designs should incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible.

This recommendation from ANSI/ANS-8.1 should not be paraphrased and reinterpreted; revise accordingly. Furthermore, the ANSI/ANS-8.1 requirement from Section 4.1.2 is the following:

> 4.1.2 Process Analysis. Before a new operation with fissionable material is begun, or before an existing operation is changed, it

shall be determined that the entire process will be subcritical under both normal and credible abnormal conditions.

Section 4.2.2 is a supplement to Section 4.1.2 and does not replace Section 4.1.2. Revise the text to more accurately reflect the ANSI/ANS 8.1 requirements and recommendations or remove ANSI/ANS standards from the discussion.

It is essential that the criticality analysis consider the potential for events that may have a common initiator, but might otherwise be considered independent. These are typically referred to as common mode failures. Revise the text to require consideration of common mode failures. Such abnormal conditions might include multiple fuel assembly misloads, dropped loads, and the consequences of a seismic event (i.e., flooding of dry fuel storage, change in storage configuration, and change in assembly geometry), facility fire, or facility flooding events.

93. Section 7.3.2 of WCAP-17483-P/WCAP-17483-NP, Revision 0, discusses evaluation of SFP temperatures above the normal range. This first paragraph suggests that it may be acceptable to **[** **]**

    a. From the text, **[** **]** Specify the criteria used in determining the value of "much less."

    b. Revise the text to clarify the mechanics of how the **[** **]** Is this calculated using the calculated k-effective value or on the calculated k-effective + bias + uncertainty value? How is the uncertainty on the slope handled?

    c. **[** **]** does not include consideration of how the bias and uncertainty may vary with temperature. Justify ignoring the potential change in bias and uncertainty at elevated temperatures.

    d. **[** **]** may not be appropriate since there is an associated variation in water density. Consequently, boron worth will vary with water density. **[** **]** may also miss optimum moderation behavior. Justify not performing criticality calculations over the range of abnormal temperatures/densities to identify the maximum k-effective value.

94. Section 7.3.3 describes evaluation of fuel assemblies in non-storage locations. An assembly moved next to the fuel storage rack or next to assemblies in elevators or inspection stations is **[** **]** Revise Section 7.3.3 of WCAP-17483-P/WCAP-17483-NP, Revision 0, to

clarify the scope of the normal condition analyses performed as part of the standard methodology.

95. Include guidance for the analyst to confirm whether or not poison panels are installed on the outside face of rack modules, where assemblies outside the rack may be moved. If panels are not present, this needs to be accounted for in all models that are affected.

96. In Section 7.3.3 and 7.3.4, it is stated that **[**

] Will integral burnable absorbers be credited for this analysis? If so, fresh fuel may not be bounding. Revise the text to clarify handling of credited burnable absorbers.

97. Section 7.3.4 addresses the fuel assembly misload accident. Revise this section to provide more complete guidance on analysis of this accident. Since multiple fuel assembly misload accidents have occurred, it will be necessary to determine the extent to which this accident may occur. The analysis should provide or reference a probability based study supporting the argument that multiple fuel assembly misload accidents are unlikely where administrative controls are credited.

    WCAP-17483-P/WCAP-17483-NP, Revision 0, should also address the following:

    a. The analysis of the misloaded fuel assembly accident may require re-evaluation of the bounding axial burnup profile

    b. The analysis should consider all potential misload positions, including along array and region interfaces

98. Section 7.3.5 addresses an assembly dropped on top of the storage racks. Some plants permit use of raised platforms in storage cells for use during fuel inspection, repair, and reconstitution work. Where these platforms are permitted, it may be necessary to perform an evaluation of an assembly dropped next to an assembly sitting on a platform. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

99. Section 7.3.6 addresses accidents involving reactivity control devices that may be inserted into fuel storage cells or into assemblies. The guidance provided suggests that it may be appropriate to limit evaluation to **[**

] This is not appropriate since the analyst needs to determine a credible range for the accident. As occurred with multiple misloaded assemblies, a breakdown in the fuel management process may permit multiple co-located failures.

100. Revise Section 7.3 to include evaluation of a boron dilution accident. The analysis should compare the extent to which accidental boron dilution is credible to the maximum soluble boron concentration required for normal operations.

101. The Section 7.4 guidance does not include consideration of the variation in boron worth with moderator temperature/density variation. Revise WCAP-17483-P/ WCAP-17483-NP, Revision 0, to include consideration of the variation of boron worth with water temperature/density. For accidents other than abnormal temperature, the temperature/density variation may be limited to normal condition range.

102. Section 8 of WCAP-17483-P/WCAP-17483-NP, Revision 0, covers new fuel storage criticality analysis. The criticality safety analyses for handling and storage of fresh fuel outside the SFP is very different compared to SFP criticality safety analyses. Consequently, the topical report should deal with each one separately. Information on requirements, analytical methods, validation, bounding fuel assembly identification, modeling of normal and abnormal conditions, and determination of maximum k-effective values should be handled separately for clarity. Consider revising the TR with separate sections focusing on dry new fuel storage and handling in the NFSV and wet new and spent fuel storage and handling in the SFP.

103. Regarding Section 8:

    a. The title for Section 8, "New Fuel Storage Criticality Safety Analysis," implies that new fuel handling is not considered. Revise the title accordingly.

    b. The first paragraph notes that the analysis with flooded new fuel storage racks need not be performed if administrative controls and/or design features prevent such moderation, or if new fuel storage racks are not used. Provide additional guidance for using and documenting use of this exemption. The guidance should include a recommendation that this exemption be discussed with the NRC staff during a pre-acceptance or acceptance meeting.

    c. The last sentence in the second paragraph of Section 8 states:

    > The new fuel storage area goes by many different names; in this report it is referred to generically as the new fuel vault or the new fuel rack, but the methodology applies to any new fuel storage area outside of the spent fuel pool.

    Add text either to or following this sentence that notes that the new fuel criticality analysis covers receiving, unpacking, inspection, movement, and storage of new fuel assemblies outside the spent fuel storage and reactor pools. If multiple unpackaged fresh fuel assemblies are accumulated in any area prior to storage, criticality analysis of such areas, optimally flooded, may be required.

d. Consider adding guidance in Section 8 to address the following:

   i. If concrete walls and floor are modeled, the full density and optimum moderation studies should include consideration of the real concrete composition or a bounding concrete composition.

   ii. The full and optimum moderation studies should cover the temperature range that may credibly be attained in accident scenarios.

   iii. Evaluation of fuel assembly, storage rack, and storage vault dimensional and material uncertainties.

   iv. Evaluation of dry fuel storage and handling operations to identify credible accident conditions, giving explicit consideration to potential common mode failure scenarios.

   v. The analyst must evaluate the adequacy and applicability of the validation study to the new fuel storage and handling criticality analysis. This evaluation should be documented in the criticality analysis report.

104. Section 9.1 notes that a short description of each normal condition must be provided. The description needs to be extensive enough to support evaluation and review. The criticality analysis needs to state the logic supporting regulatory compliance for each operation. The analyst needs to evaluate and document whether or not there are any abnormal conditions associated with each operation. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

105. In Section 9.2 under the label **[**

]

This statement does not appear to be generically applicable. The most reactive part of fresh fuel assembly is near its axial mid-plane. The most reactive part of a spent fuel assembly is near its top. As a fresh fuel assembly is pulled out of a storage cell, neutronic interaction with a neighboring spent fuel assembly will be maximized as the axial mid-plane of the fresh assembly passes the top of the spent fuel assembly. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

106. In Section 9.2 under the label “A single isolated assembly,” the text claims that an **[** **]** however this claim is unsubstantiated. Perform and document studies demonstrating that **[** **]**

107. Regarding Section 9.3:

a. The text under item 1) notes that **[**

] This is not necessarily true. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

b. The text under item 2) in Section 9.3 addresses fuel assemblies on a pedestal or in the new fuel elevator. The analysis provided states that no special consideration needs to be made for the new fuel elevator because it is isolated. This is not true if movement of another assembly is permitted while fuel is in the elevator. Unless prohibited by criticality controls, the fuel assembly could be moved next to the assembly in the elevator.

The text under item 2) goes on to note again that **[**

] Again, this is not necessarily true. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

c. The text under item 3) addresses fuel assembly reconstitution. Consider the following and revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly:

   i. Is rod removal limited to one rod per assembly?

   ii. The second paragraph states that the **[**

   ] Without additional knowledge and control on the properties of the replacement rod, it is not possible to demonstrate that **[** **]**

   iii. The third paragraph states that if the original rod is removed, the assembly is bounded by the criticality safety analysis. This is either misstated or incorrect. It is well known that removal of some specific individual rods will result in a more reactive bundle.

   iv. The last paragraph implies that, **[**

   ] Without additional information, this should not be done. Depending on the enrichment of the replacement fuel rod and its location, the bundle may be significantly more reactive than it would be based on its adjusted burnup.

d. The text under item 4) claims that **[** **]** While it is agreed that a **[**

] it is not as obvious that, if all of the fuel pellets fell out of a damaged rod and accumulated into a well moderated pile, they could not achieve criticality. If the fuel rod was accidentally dropped or placed into a large water hole in a Combustion Engineering assembly, it would appear to violate the criticality analysis bases. Based on this discussion, how will removed fuel rods be controlled? Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

e. The text under item 8) claims that **[** **]** This is true only if criticality controls are implemented to ensure that spacing between the in-transit fuel assembly and other assemblies is maintained. What criticality controls will be implemented to ensure that this statement is generically true?

108. Correct Reference 10 to indicate March 2002 rather than March 2001.

109. Correct Reference 29 to indicate “Nucl. Tech.” rather than “Nuclear.”