Responses to Requests for Additional Information from the Review of WCAP-17483-P/WCAP-17483-NP, Revision 0, "Westinghouse Methodology for Spent Fuel Pool and New Fuel Rack Criticality Analysis" (Non-Proprietary)

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Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

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INTRODUCTION

In response to the Request for Additional Information (RAI) questions (Reference 1) and for clarification, numerous changes are being made to the Westinghouse topical report WCAP-17483-P/WCAP-17483-NP, Revision 0. Those changes are clearly identified in the RAI responses as they will appear in the report. Westinghouse intends to update the topical report with those changes and resubmit after finalizing the RAI responses to the satisfaction of the NRC.

Due to the nature of some of the RAI questions, it was apparent to Westinghouse that some sections of the topical report had created ambiguity. Those sections will be revised for clarification and in some cases completely removed. Only the parts that are concisely describing the calculation methodology and clearly defining what is covered by the standard methodology will be retained. The following major changes will be made in the topical report:

- All sections of the topical report will be reviewed for occurrences of "should" and "may" and those will be removed or replaced with "shall" when necessary to clearly identify and define the standard methodology.
- Monte Carlo code specificity (code name, version, and data library) has been replaced with guidance on reporting in the plant-specific licensing submittal the required information regarding code and nuclear data library.
- All Monte Carlo code validation suite information (Section 3.3.5) and examples for illustrating the code bias and bias uncertainty determination and application (Sections 3.3.6 through 3.3.8), including tables and trend plots will be removed along with "Validation Summary" in Section 3.4.
- Figure 5-1 will be removed from topical report to eliminate inconsistency with the text.
- Operation with RCCAs inserted, crediting RCCAs and integral burnable absorbers such as IFBA in fresh fuel criticality calculations will be excluded from the standard methodology. The integral absorber example in Section 6.6.4 will be removed.
- Tables 6-1 through 6-3, along with Section 6.4 will be removed to eliminate redundancy and for improved clarity.
- The extrapolation approach discussed in Section 7.3.2 will be eliminated and replaced by direct calculations at elevated pool temperatures.

Responses to 89 of the 109 RAI questions are provided in the following sections.

Reference:

1. Letter from Ekaterina Lenning (NRC) to James A. Gresham (Westinghouse), "Request for Additional Information Re: Westinghouse Electric Company Topical Report WCAP-17483-P/WCAP-17483-NP, Revision 0, 'Westinghouse Methodology For Spent Fuel Pool And New Fuel Rack Criticality Safety Analysis' (TAC No. ME7749)," December 9, 2014.

RAI Response Number: WCAP-17483-RAI-001
Revision: 0

Question:

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 [ ]^{a,c} should be included." Is this [ ]^{a,c} part of the standard methodology?

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

Westinghouse Response:

All sections of WCAP-17483-P/WCAP-17483-NP, Revision 0 have been reviewed for occurrences of "should" and "may" and those will be removed where necessary to clearly identify and define the standard methodology. Please note that [ ]^{a,c} is part of the standard methodology.

In the plant specific technical reports, calculations will refer to the methodology topical WCAP-17483-P/WCAP-17483-NP, Revision 0 when the standard methodology is being used. [ ]^{a,c} Any deviation from the standard methodology defined in the topical will clearly be identified and documented with proper justification in plant-specific submittals.

RAI Response Number: WCAP-17483-RAI-002
Revision: 0

Question:

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

Westinghouse Response:

The format and content for criticality safety analysis technical reports are outlined below, starting on the next page. Note that this outline includes items that need to be in the report at a minimum for a spent fuel pool criticality analysis, except for Appendix B, which outlines the data provided with a New Fuel Vault (NFV) analysis. The NFV analysis may or may not be submitted together with the SFP analysis. It may also be submitted as a stand-alone document.

1 INTRODUCTION

Statement of purpose of the document, including plant name and unit numbers, analysis type (spent fuel pool, new fuel racks, or both) and other relevant plant-specific reasons (e.g., power uprate, non-conservatism in the analysis of record, methodology update, etc.).

2 OVERVIEW

Brief description of what is evaluated (e.g., Region I racks, Region II racks) and allowed credits, including burnup, post-irradiation cooling time, presence of soluble boron and other neutron poisons (e.g., poison panels or inserts), and any other plant-specific items (e.g. control rod assemblies, fresh burnable absorbers).

2.1 ACCEPTANCE CRITERIA

Requirements of the Code of Federal Regulations, Title 10, Part 50, Section 68 for the spent fuel pool and the new fuel storage racks, regulatory guides, and standard review plan sections, if applicable, are stated in this section.

2.2 DESIGN APPROACH

Applicable fuel assembly categories suitable for storage in storage arrays are described here. The acceptability of the storage arrays developed in the analysis is ensured by controlling the assemblies that can be stored in each array. Assemblies may be divided into groups (e.g., based on assembly type) and/or fuel categories based on assembly reactivity determined as a function of assembly average burnup, initial enrichment, and decay time.

2.3 COMPUTER CODES

Computer codes and cross-section libraries employed in the analysis are described in this section. Traceable version numbers for the codes and the nuclear data libraries, as well as any patches applied are documented herein. The descriptions include:

a. The lattice-physics code and its cross-section library used for simulation of in-reactor fuel assembly depletion;
b. The Monte Carlo code package and its cross-section library to determine the reactivity of the storage arrays in the spent fuel pool and new fuel racks.

3 NUCLEAR POWER PLANT DESCRIPTION

This section describes the physical characteristics of the nuclear power plant that are important to Spent Fuel Pool (SFP) criticality safety. The reactor and its associated fuel designs and fuel management history are discussed in Section 3.1 and the physical characteristics of the SFP are discussed in Section 3.2.

3.1 REACTOR DESCRIPTION

This section provides basic data on the type of reactor and the fuel types that are being operated or stored in the pool. Neutronically important physical characteristics, as well as mechanical features of each fuel design, are outlined here. Additionally, this section discusses the non-mechanical fuel features (e.g., burnable absorbers, axial blankets) which are important to criticality safety and how they impact the number of distinct fuel designs to be considered in the analysis.

3.2 SPENT FUEL POOL DESCRIPTION

The physical characteristics of the SFP(s) are described in this section, including the pool dimensions, and pool wall and liner thickness. Rack designs (e.g., low-density; high-density racks), dimensions, associated tolerances, applicable absorbers that are integral to the racks are discussed.

4 DEPLETION ANALYSIS

The depletion analysis is a vital part of any SFP criticality analysis which uses burnup credit. The isotopic inventory of the fuel as a function of burnup is generated through the depletion analysis and therefore the inputs used need to be conservative and bounding. This section describes the methods used to determine the appropriate inputs for the generation of isotopic number densities.

4.1 DEPLETION MODELING APPROACH

Simplifications and modeling considerations for depletion calculations are outlined.

4.2 FUEL DEPLETION PARAMETER SELECTION

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4.3 FUEL DESIGN SELECTION

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5 CRITICALITY ANALYSIS

This section describes the reactivity calculations and evaluations performed in developing the burnup requirements for fuel storage and confirming continued safe SFP operation during both normal and accident conditions.

5.1 MONTE CARLO MODELING APPROACH

Modeling approach, including simplifications/assumptions in Monte Carlo reactivity calculations are presented in this section. Monte Carlo calculations are performed to determine the absolute reactivity of burned and fresh fuel assemblies loaded in storage arrays, as well as the reactivity sensitivity of the storage arrays to manufacturing tolerances, fuel depletion, eccentric positioning, and the allowable temperature range of the pool. Accident scenarios are also modeled using Monte Carlo simulations to confirm there is sufficient soluble boron to meet the requirements. The dimensions and tolerances of the design basis fuel assemblies, fixed absorbers and the fuel storage racks are presented. These dimensions and tolerances are the basis for the Monte Carlo models used to determine the burnup requirements for each fuel storage array and to confirm the safe operation of the spent fuel pool under normal and accident conditions.

5.2 ARRAY DESCRIPTIONS

Descriptions of the fuel storage arrays allowable and the fuel categories that populate those arrays are described here. An array is allowed to be populated by assemblies of the fuel category dictated in the array definition or a lower reactivity fuel category.

5.3 BURNUP LIMIT GENERATION

To ensure the safe operation of the spent fuel pool, the analysis defines fuel storage arrays which dictate where assemblies can be placed in the SFP based on each assembly's enrichment (wt% ^{235}U), assembly average burnup (GWd/MTU), and decay time (years) since discharge. [

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5.4 INTERFACE CONDITIONS

Interfaces are the locations where there is a change in either the storage racks or the storage requirements of the fuel in question. Two types of interfaces, intra-region and inter-region, are defined, and addressed in this section.

5.5 NORMAL CONDITIONS

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5.6 SOLUBLE BORON CREDIT

The minimum soluble boron concentration to maintain keff ≤ 0.95 for the limiting normal condition including biases, uncertainties, and administrative margin is defined here, considering ^{10}B abundance assumptions.

5.7 POSTULATED ACCIDENT SCENARIOS

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5.8 RODDED OPERATION

Due to the potential impact of rodded operation on criticality safety assumptions, past and (potential) future rodded operation are evaluated to determine the impact of rodded operation.

6 ANALYSIS RESULTS & CONCLUSIONS

This section documents the results of the plant-specific criticality safety analysis. Included in this section are the burnup requirements for the fuel storage arrays, area of applicability, and restrictions of the analysis.

6.1 BURNUP LIMITS FOR STORAGE ARRAYS

Minimum burnup requirements as a function of initial enrichment and decay time for each array are provided as tables of polynomial coefficients. Decay time interpolation rules are also addressed.

6.2 ANALYSIS RESTRICTIONS

The purpose of this section is to summarize the restrictions of the fuel being stored at the plant.

6.3 SOLUBLE BORON CREDIT

The amount of soluble boron credited to keep keff ≤ 0.95 under all normal and credible accident scenarios is reported and compared to Technical Specification value.

7 REFERENCES

References used in the analysis are listed here.

APPENDIX A

VALIDATION OF MONTE CARLO CODE

A.1 INTRODUCTION

This section summarizes the validation of the Monte Carlo code system for use with the criticality safety analysis. The validation suite develops methodology biases and bias uncertainties through evaluation of critical experiments which were selected based on their applicability to the plant specific analysis.

A.2 CALCULATIONAL METHOD

The Monte Carlo code version and its library, the system state on which the software is installed and verified are introduced.

A.3 CRITICAL EXPERIMENT DESCRIPTION

Critical experiments included in the validation suite are described with information on experimental configuration, modeling approach, experiment conditions (e.g., temperature), simplifying assumptions, if applicable, and experimental and benchmark model eigenvalue.

A.4 RESULTS

This section presents the results of the validation analysis. This includes the raw calculational results, normality check, the calculation of the bias and bias uncertainty, the detailed statistical trending results, and the definition of the area of applicability.

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The area of applicability of the benchmark is defined by the range of parameters in the validation suite. A table with the parameters of interest and the applicable ranges will be presented.

A.5 SUMMARY OF THE BIAS AND BIAS UNCERTAINTY

A table with a summary of the bias and bias uncertainty (either trend or non-parametric results, or both) for different subsets of the validation suite will be provided.

A.6 REFERENCES

References pertaining to the validation studies will be provided in a list here.

APPENDIX B

NEW FUEL RACK ANALYSIS

B.1 OVERVIEW

Brief description of what is evaluated in the New Fuel Rack (NFR) analysis including allowed credits (e.g., poison panels or inserts), and any other plant-specific items. Acceptance criteria for NFR analysis and the design approach, including applicable fuel assembly types/categories suitable for storage in NFR are defined here. Requirements of the Code of Federal Regulations, Title 10, Part 50, Section 68, regulatory guides, and standard review plan sections for the new fuel storage racks, if applicable, are stated in this section. Applicable fuel assembly categories suitable for storage in storage arrays are described here.

B.2 FUEL AND RACK DESIGN DESCRIPTION

This section describes the physical characteristics of fuel and rack designs important to New Fuel Rack criticality safety. Those characteristics include assembly types, array sizes, rod pitch, rod, guide and instrument tube dimensions, and associated tolerances, rack designs, rack dimensions and associated tolerances.

B.3 NEW FUEL RACK CRITICALITY ANALYSIS

This section describes the reactivity calculations and evaluations performed in confirming safe NFR operation during accident conditions.

Modeling approach, including simplifications/assumptions in Monte Carlo reactivity calculations are presented in this section. Monte Carlo calculations are performed to determine the absolute reactivity of fresh fuel assemblies loaded in storage arrays, as well as the reactivity sensitivity of the storage arrays to manufacturing tolerances, eccentric positioning, and the allowable temperature range of the NFR.

B.4 POSTULATED ACCIDENT SCENARIOS

Accidents which share a common initiator with flooding are considered and addressed to demonstrate the safe operation of the NFR.

B.5 ANALYSIS RESULTS & CONCLUSIONS

This section documents the results of the plant specific criticality safety analysis as well as the restrictions of the fuel being stored at the plant.

B.6 REFERENCES

References used in the analysis are listed here.

RAI Response Number: WCAP-17483-RAI-003
Revision: 0

Question:

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.

Westinghouse Response:

The second sentence in Section 2.1 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be revised as follows:

"Also, the analysis must demonstrate that k_{eff} is no greater than 0.95 under all credible accident conditions."

RAI Response Number: WCAP-17483-RAI-006
Revision: 0

Question:

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.

Westinghouse Response:

The Westinghouse Quality Management System (Reference 1) requires that qualified personnel authoring and verifying analyses supporting the general Spent Fuel Pool (SFP) criticality analysis confirm that code and library versions include all available patches. A paragraph in Section 3 is added as follows:

"Information regarding code and nuclear data library versions utilized in the depletion and criticality analyses shall be stated in the licensing submittal. The analyst shall ensure that all available code and library patches are included for the code version used in the analysis. Documentation of the codes and libraries shall be referenced to provide traceable version numbers of the codes and the libraries."

Reference:

1. QMS, Revision 7, Westinghouse Electric Company Quality Management System, October, 2013.

RAI Response Number: WCAP-17483-RAI-007
Revision: 0

Question:

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.

Westinghouse Response:

Section 3 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be revised to remove code and library specifics and include guidance on analysis documentation requirements related to code and library version identification and justification of use. See the response to RAI 6 for additional information regarding code and library specifics.

RAI Response Number: WCAP-17483-RAI-008
Revision: 0

Question:

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?

Westinghouse Response:

a. Text in Section 3.1 is revised as described in response to RAI 6:

   "Information regarding code and nuclear data library versions utilized in the depletion and criticality analyses shall be stated in the licensing submittal. The analyst shall ensure that all available code and library patches are included for the code version used in the analysis. Documentation of the codes and libraries shall be referenced to provide traceable version numbers of the codes and the libraries."

b. The text in Section 3.1 will be revised to remove the "peak-reactivity" statement as follows:

"A 2-D lattice physics code is used for the simulation of in-reactor fuel assembly depletion to generate isotopics for burnup credit applications in the fuel pool."

c. No changes will be made to Section 3.1; however, the list of isotopes is provided below:

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d. Reference 3 addresses the qualification of the basic methodology used in PARAGON and proceeds through logical steps to the implementation of that methodology, and its application within a nuclear design system. [

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References:

1. D. R. Olander, "Fundamental Aspects of Nuclear Reactor Fuel Elements," 278-282, Technical Information Center, Office of Public Affairs, Berkeley (1976).
2. "Review of Fuel Failures in Water Cooled Reactors," IAEA Nuclear Energy Series, ISSN 1995–7807; no. NF-T-2.1.
3. WCAP-16045-P-A, "Qualification of the Two-Dimensional Transport Code PARAGON," August, 2004.
4. Kord Smith, Shaun Tarves, et al., "Benchmarks for Quantifying Fuel Reactivity Depletion Uncertainty," EPRI, Palo Alto, CA, 1022909 (2011).
5. Dale Lancaster, "Utilization of the EPRI Depletion Benchmarks for Burnup Credit Validation," EPRI, Palo Alto, CA, 1025203 (2012).
6. Kucukboyaci, V. N. "EPRI Depletion Benchmark Calculations Using PARAGON," Proceedings of the ANS NCSD 2013 - Criticality Safety in the Modern Era: Raising the Bar, Wilmington, NC, October 1, 2013.

RAI Response Number: WCAP-17483-RAI-009
Revision: 0

Question:

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.

Westinghouse Response:

Section 3 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be revised to remove code and library specifics and include guidance on analysis documentation requirements related to code and library version identification and justification of use. Please see the response to RAI 6. Please also refer to the response to RAI 8.d. for PARAGON and library validation.

RAI Response Number: WCAP-17483-RAI-010
Revision: 0

Question:

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.

Westinghouse Response:

PARAGON (Reference 1) is used to generate isotopic number densities of burned fuel assemblies to support burnup credit in spent fuel pool criticality safety calculations. PARAGON performs lattice calculations to deplete fuel as an infinite array in reactor core geometry. [

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The following modeling approaches are followed in PARAGON depletion calculations:

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The neutron (or gamma) flux, obtained from the solution of the transport equation, is a function of three variables: energy, space and angle. For the energy variable, PARAGON uses the multi-group method where the flux is integrated over the energy groups. The standard methodology employs 70 energy groups for the neutron transport calculations. For the spatial variable, the assembly is subdivided into a number of sub-domains or cells and the integral transport equation is solved in the cells using the collision probability method. [

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]^{a,c} The cells of the assembly are then coupled together using the interface current technique. At the interface, the solid angle is discretized into a set of cones where the surface fluxes are assumed constant over each angular cone. Again, consistent with the core design analysis practices, a coupling order of 3 is assigned on all surfaces for azimuthal angle and a coupling order of 1 for polar angle. The resulting algebraic system of equations over the entire assembly is obtained by the response heterogeneous matrix method, which uses current-flux iterations. The convergence criterion on the eigenvalue is 2.0E-5, for the inner (current) iterations 1.0E-3, and for the source iterations 5.0E-5.

The assembly composition changes following neutron irradiation are obtained by calculating the isotopic depletion and buildup in the heterogeneous geometry, using an effective one-group collapsed flux and cross-sections. PARAGON uses the predictor-corrector technique to better account for the flux level variation. [

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References:

1. WCAP-16045-P-A, "Qualification of the Two-Dimensional Transport Code PARAGON," August, 2004.

RAI Response Number: WCAP-17483-RAI-011
Revision: 0

Question:

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.

Westinghouse Response:

Specific guidance for documenting and checking spent fuel pool reactivity calculations (such as those with SCALE) for source convergence, normality testing, warning and error message review, and processing and checking of isotopics (such as from PARAGON) is not given. Westinghouse does not consider these activities as part of a methodology. These activities are important and are considered via the Westinghouse Quality Management System (Reference 1) which requires that personnel authoring and verifying Spent Fuel Pool (SFP) criticality analyses be qualified. Qualification is achieved through demonstration of competence for specific technical topics as outlined in Reference 2.

Reference:

1. QMS, Revision 7, Westinghouse Electric Company Quality Management System, October, 2013.
2. CE-08-643, Revision 2, "CE Criticality Analyst Qualification Definitions and Qualification Guides (CR01/CR02/CR03 and BCR)," December 2013.

RAI Response Number: WCAP-17483-RAI-012
Revision: 0

Question:

The last paragraph in Section 3.2 describes the use of [

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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 8.1 in NUREG/CR-7109 and Table 6.1 in NUREG/CR-6979 may be useful in identifying additional applicable MOX experiments.

Westinghouse Response:

The last paragraph of Section 3.2 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be removed.

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References:

1. NUREG/CR-6979, "Evaluation of the French Haut Taux de Combustion (HTC) Critical Experiment Data," Oak Ridge National Laboratory, September 2008.

2. NUREG/CR-7109, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses - Criticality (k_{eff}) Predictions," Oak Ridge National Laboratory, April 2012.

3. NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," Science Applications International Corporation, January 2001.

RAI Response Number: WCAP-17483-RAI-013
Revision: 0

Question:

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 Ref. 9 used SCALE 4.3 not SCALE 5.1. Furthermore, the text in Ref. 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.

Westinghouse Response:

Westinghouse agrees that there are issues with the use of the 44-group library for conditions such as low-moderator density that are not similar to the LWR conditions. However, a bias developed through proper validation activities will exhibit any non-conservative bias from the library of choice. That being said, in particular for this RAI, Section 3.2 of WCAP-17483-P/WCAP-17483-NP, Revision 0 which contains the discussion about the SCALE code package and cross-section library will be removed. Monte-Carlo code and cross-section version information will be provided in plant-specific submittals.

RAI Response Number: WCAP-17483-RAI-014
Revision: 0

Question:

The second paragraph of Section 3.3.2 states: [

]^{a,c} There are two concerns with this statement. First, it is the responsibility of the analyst to ensure that use of the [

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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.

Westinghouse Response:

The statement in question, namely, [

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RAI Response Number: WCAP-17483-RAI-015
Revision: 0

Question:

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.

Westinghouse Response:

The last paragraph of Section 3.3.2 of WCAP-17483-P/WCAP-17483-NP, Revision 0 reads:

"If a future criticality safety analysis uses the same code system, version, cross-section library, and computing platform, the results of this validation suite may be used directly. If a different code system or computing platform is used in the analysis, then the validation will be re-performed following the same methodology outlined here."

This will be modified to the following:

"If a future criticality safety analysis uses the same code system, version, cross-section library, computing platform, and has the same area of applicability (AoA) of a previously documented validation suite, the results of that previous validation suite may be used directly as long as the responsible analyst assures that the validation suite is applicable to the analysis being performed. Otherwise, the validation will be re-performed using the methodology outlined here. "

RAI Response Number: WCAP-17483-RAI-016
Revision: 0

Question:

Please revise Section 3 to address depletion code validation.

Westinghouse Response:

Section 3 will be revised to include the depletion code validation information provided in the response to RAI 8.d.

RAI Response Number: WCAP-17483-RAI-017
Revision: 0

Question:

Section 3.3.3 notes that the criticality code validation is [

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Westinghouse Response:

All specific validation examples will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0 and determination of the critical experiments to include will be performed on a plant-specific basis according to the methodology in the revised topical report.

In order to cover an expanded temperature range that will be expected in a plant-specific analysis, Westinghouse will include applicable experiments from LEU-COMP-THERM-046 (and other applicable experiments that become available) and determine a temperature dependent bias and bias uncertainty, when applicable.

RAI Response Number: WCAP-17483-RAI-018
Revision: 0

Question:

Section 3.3.3.2 notes that the [ ]^{a,c} Provide a reference for the [ ]^{a,c} 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 [ ]^{a,c} 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 [ ]^{a,c} 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.

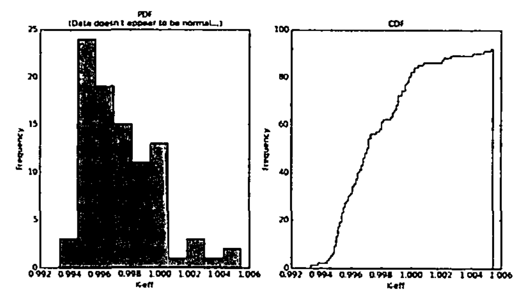

Figure 1: Fresh Fuel, Strong Absorbers k-eff Distribution.

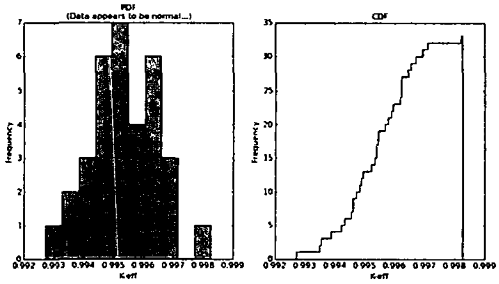

Figure 2: Fresh Fuel, Without Strong Absorbers k-eff Distribution.

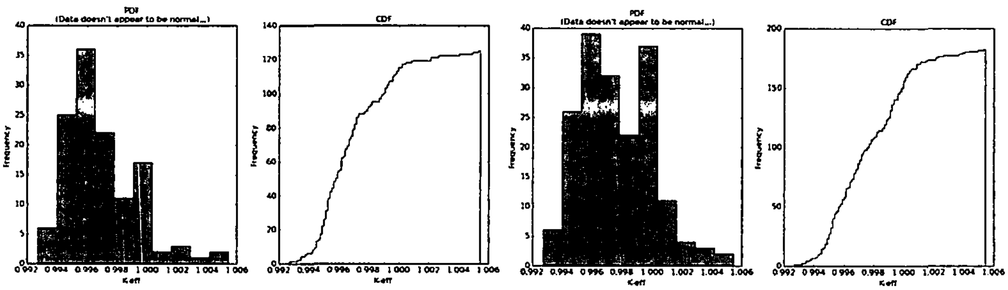

Figure 3: All Fresh Fuel and all HTC Experiments (Phases 1-3) k-eff Distribution (left: w/o HTC; right: w/ HTC).

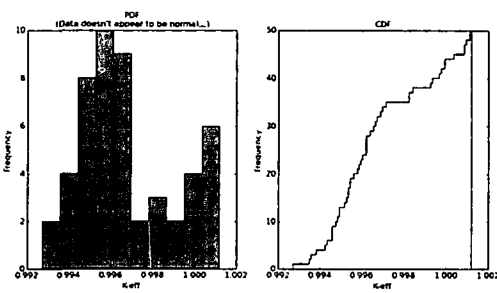

Figure 4: Fresh Fuel and HTC Experiments (Phase 1) Without Strong Absorbers k-eff Distribution.

Westinghouse Response:

Section 3.3.3.2 of WCAP-17483-P/WCAP-17483-NP, Revision 0 notes that the [ ]^{a,c} for the validation suite presented in WCAP-17483-P/WCAP-17483-NP, Revision 0. The [ ]^{a,c} tests for whether or not the provided values as a group are normal around the mean at a 5% significance level with the degree of freedom equal to 4. The test is commonly known as the [ ]^{a,c} "goodness-of-fit" test and described in details in Section 11 of Reference 1. The sample data are sorted into classes, and the [ ]^{a,c} statistic is calculated from the difference between the expected and observed counts. The input for [

]^{a,c}

The validation study provided in WCAP-17483-P/WCAP-17483-NP, Revision 0 was intended to provide a demonstration for performing a Monte-Carlo code validation and bias and bias uncertainty determination. Because plant-specific submittals will include a section on code validation, Sections 3.3.5 through 3.3.8 and Section 3.4 from WCAP-17483-P/WCAP-17483-NP Revision 0 will be removed.

[

]^{a,c}

References:

1. NUREG-1475, Revision 1, "Applying Statistics," U.S. NRC, March 2011.
2. NUREG/CR-6361 "Criticality Benchmark Guide for Light Water Reactor Fuel in Transportation and Storage Packages," ORNL, March 1997.

RAI Response Number: WCAP-17483-RAI-019
Revision: 0

Question:

In equation 3.8, to clarify the equations, replace [ ]a,c

Westinghouse Response:

Westinghouse agrees with the proposed changes. Equation 3.8 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be updated as shown below.

[ ]a,c

RAI Response Number: WCAP-17483-RAI-021
Revision: 0

Question:

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, – [

]a,c 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?

Westinghouse Response:

The example in WCAP-17483-P/WCAP-17483-NP, Revision 0 referred to in this RAI was only intended to be a demonstration of the validation methodology and is now removed from the topical report. Guidance/clarification of Westinghouse standard methodology pertaining to interpolation and extrapolation is described in more detail in responses to RAI questions 32.b. and 32.c. As indicated in RAI 32.c., extrapolation will be performed on an analysis specific basis, including justification and/or the application of any penalty.

RAI Response Number: WCAP-17483-RAI-022
Revision: 0

Question:

In equations 3.13 and 3.14, replace [

]^{a,c}

Westinghouse Response:

The equations 3.13 and 3.14 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be updated as follows, respectively:

[ ]^{a,c}

and

[ ]^{a,c}

RAI Response Number: WCAP-17483-RAI-023
Revision: 0

Question:

In the definitions provided below equation 3.14, change [

]^{a,c} However, only the linear fit is described in the TR.

Westinghouse Response:

The definition of equation 3.14 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be changed and [ ]^{a,c}

RAI Response Number: WCAP-17483-RAI-024
Revision: 0

Question:

In equations 3.20 and 3.21, change [
]a,c to more accurately describe the quantities calculated.

Westinghouse Response:

Equations 3.20 and 3.21 from WCAP-17483-P/WCAP-17483-NP, Revision 0 will be updated as

[ ]a,c

and

[ ]a,c

respectively.

RAI Response Number: WCAP-17483-RAI-025
Revision: 0

Question:

Provide explicit definitions for bias and 95/95 [
]^{a,c}

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

Westinghouse Response:

Section 3 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be revised as follows. Section numbering and equation numbers are representative of this RAI only and will be edited when including into the final WCAP-17483-P/WCAP-17483-NP Revision.

Non-Parametric Single Sided Tolerance Limit

[

]^{a,c}

[

]a,c

[ ]a,c

RAI Response Number: WCAP-17483-RAI-026
Revision: 0

Question:

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 [ ]^{a,c} This may not be appropriate for validating calculations without these materials. Do the k_{eff} values for the subsets with [ ]^{a,c} 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 [ ]^{a,c} While this may be true, it is not enough to simply declare that [ ]^{a,c} will not be modeled. Provide a list of LCEs where [ ]^{a,c} 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: [ ]^{a,c} 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.

Westinghouse Response:

Section 3 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be significantly revised/reformatted, including Section 3.3.5. As a result of reformatting, section and equation numbering may not reflect the original numbering. Responses to this question provide the general basis for updating WCAP-17483-P/WCAP-17483-NP, Revision 0 and may editorially differ from final changes due to formatting edits.

a. The following section will be added as guidance on the selection of critical benchmarks:

"Select Critical Experiment Data

Validation sets should contain experiments which span all of the key parameter(s) associated with an analysis as outlined in Reference 13, which also indicates that

[

]^{a,c}

b. [

]^{a,c}

c. [

]a,c

d. [

]a,c

e. All LCE computer model input files have been documented and independently verified to ensure that they are consistent with the original references. This verification is in accordance with the Westinghouse Quality Management System. Per the Westinghouse Quality Management System, the verification is conducted independently by qualified individuals with experience in various aspects of the work scope. Verification is accomplished using Independent Review of design documentation, alternate calculations, or qualification tests as described in Westinghouse procedures.

RAI Response Number: WCAP-17483-RAI-027
Revision: 0

Question:

Section 3.3.6.2 includes descriptions of [

]^{a,c} Revise the text in Section 3.3.6.2 and Table 3-6 to incorporate the [ ]^{a,c} cases or justify leaving them out.

Westinghouse Response:

The validation study provided in WCAP-17483-P/WCAP-17483-NP, Revision 0 was intended to deliver a demonstration of the Monte-Carlo code validation and bias and bias uncertainty determination methodology employment. Because each plant-specific submittal will include its own Monte Carlo code validation section, this demonstration in the topical report will be removed. As such, Sections 3.3.5 through 3.3.8 and Section 3.4 from WCAP-17483-P/WCAP-17483-NP, Revision 0 will be removed.

[

]^{a,c} The purpose of this limitation was to show an example of the application of the non-parametric treatment.

[ ]^{a,c}

RAI Response Number: WCAP-17483-RAI-028
Revision: 0

Question:

Regarding Section 3.3.7:

a. *[ ]^{a,c} Incorporate this information into the enrichment trending analysis.*

b. *Why doesn't the trending analysis include a [ ]^{a,c} 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 [ ]^{a,c}*

e. *Figure 3-5 shows that there is only [ ]^{a,c}*

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 [ ]^{a,c} Please revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.*

h. *The second set of LCEs includes [ ]^{a,c} 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, [ ]^{a,c} 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 [ ]^{a,c} If so, this is not necessarily appropriate. In some cases, the [ ]^{a,c} Instead, it would be more appropriate to say that the bias and associated uncertainty that yield the [ ]^{a,c} 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 [ ]^{a,c} The text throughout Section 3.3.7.3 indicates that the analysis for this group is for [ ]^{a,c} Other than for enrichment, the results provided in the figures and tables in Section 3.3.7.3 seem to include [ ]^{a,c} (consistent with the group definition provided in Section 3.3.6.2). The enrichment trend analysis appears to include all [ ]^{a,c} 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 [ ]^{a,c} 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 [ ]^{a,c} While it is debatable as to whether or not the [ ]^{a,c} should be included, the text should clearly describe the work, including exclusion or inclusion of the [ ]^{a,c} If the results from enrichment trending analysis for [ ]^{a,c} 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 [ ]^{a,c} Extension of the AoA to [ ]^{a,c} 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.*

Westinghouse Response:

a. It would not be appropriate to include [ ]^{a,c} in the enrichment trend analysis for the following reasons:

[

]^{a,c} are not included in the enrichment trending considering either fresh or as depleted enrichments.

b. Please see the response to RAI 12.

c. Please see the response to RAI 17.

d. A plant-specific analysis validation study will include available data suitable for the storage configurations in that particular plant. An appropriate justification will be provided for the Area of Applicability (AoA) definition including sufficiency of bounding values of the validation data. Please note that Sections 3.3.5 through 3.3.8 and Section 3.4, including Figures 3-1 through 3-16 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be removed.

e. Please see the response to Item d. A plant-specific analysis validation study will include additional LCEs to extend the AoA up to a necessary value of soluble boron concentration.

f. Untrended bias and bias uncertainty were provided in Tables 3-3 to 3-6 of WCAP-17483/WCAP-17483-NP, Revision 0, however these tables will be removed. A plant-specific analysis validation study will include an updated statistical analysis technique like the single-sided tolerance limit.

g. Westinghouse agrees with the reviewer. In Table 3-8 the k_{fit} values are shifted down. However, Section 3.3.7 including Table 3-8 from WCAP-17483/WCAP-17483-NP, Revision 0 will be removed.

h. Please see response to Item d above. A plant-specific analysis validation study will include revised sets of data applicable to the plant specific submittal.

i. See the response to RAI 20.

j. Please see the response to items a and d. The basis for not including HTC experiments for enrichment trending analyses is given in the response to Item a.

k. Please see the response to item d above. A plant-specific analysis validation study will include updated normality tests as described in the RAI 18 response. Westinghouse agrees with the reviewer that for subgroups of data used to develop each separate bias and bias uncertainty in the trending analyses, an applicable normality test described in the response to RAI 18 will be performed.

References:

1. NUREG/CR-6979, "Evaluation of the French Haut Taux de Combustion (HTC) Critical Experiment Data," Oak Ridge National Laboratory, September 2008.

2. NUREG/CR-7109, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses - Criticality (k_{eff}) Predictions," Oak Ridge National Laboratory, April 2012.

3. NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," Science Applications International Corporation, January 2001.

RAI Response Number: WCAP-17483-RAI-029
Revision: 0

The text in the 2nd paragraph of TR's Section 3.4 implies that the validation supports credit for [ ]^{a,c} The Westinghouse [ ]^{a,c} The LCEs used in the validation study do not include any configurations with [ ]^{a,c} Additional validation work would be required to support validation of [ ]^{a,c} Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, to make this clear.

Question:

Westinghouse Response:

While integral absorber credit is not part of the standard methodology, justification for Integral Burnable Absorber (IFBA) credit validation is provided herein. No critical benchmarks with IFBA zirconium diboride (ZrB_2) geometry are available, however, the validation of ^{10}B as a strong neutron absorber and its ability to hold down reactivity is performed by considering the critical benchmarks with different physical forms such as boric acid solutions, B_4C and Borated stainless steel compounds. This approach is in agreement with the recommendations provided in Table 2.3 of Reference 1. The validation study includes LCEs with borated plates located close to the fuel rods. The physical location of boron absorber near fuel rods impacts the local distribution of thermal neutrons in a similar manner as ZrB_2 in the IFBA coating. The local suppression of the thermal neutron distribution "seen" by the fuel rod located near borated plate reduces the overall reactivity, changes the neutron spectrum at the surface of the fuel rod, and impacts the fission rate in a similar manner as the ZrB_2 in IFBA does. The validation study of the LCEs with strong neutron absorber does not show any statistical evidence that the k_{eff} is a function of physical form of ^{10}B as a strong neutron absorber. The validation of ^{10}B as a strong neutron absorber shows that the energy dependent boron cross-sections are acceptable for use in nuclear safety related calculations. [ ]^{a,c}

References:

1. NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," Science Applications International Corporation, January 2001.
2. WCAP-17094-P, Revision 3, "Turkey Point Units 3 and 4 New Fuel Storage Rack and Spent Fuel Pool Criticality Analysis," February 2011.
3. J. Paige (NRC) to M. Nazar (FPL), "Turkey Point Units 3 and 4 - "Issuance of Amendments Regarding Fuel Criticality Analysis (TAC Nos. ME4470 and ME4471)," Accession No. ML1 1216A057, October 31, 2011.

RAI Response Number: WCAP-17483-RAI-030
Revision: 0

Question:

Regarding Table 3-20:

a. *The fourth column in the table is listed as [ ]^{a,c} While the text claimed to be evaluating this category, the LCE set used was instead [ ]^{a,c} Revise the table or update the analysis.*

b. *In the row labeled "Fissionable Material," list [ ]^{a,c} 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 [ ]^{a,c} This is not appropriate because there is only [ ]^{a,c} Revise the table to reflect a maximum of [ ]^{a,c} Extrapolation up to [ ]^{a,c} 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 [ ]^{a,c} to claim they are adequately validated. No trending analysis was performed to identify biases and uncertainties as a function of [ ]^{a,c} content. Revise the entries to remove [ ]^{a,c}*

e. *In the row labeled "Physical Form of Absorbers," remove [ ]^{a,c} 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 [ ]^{a,c} upper boundary to [ ]^{a,c} because there is only one point above [ ]^{a,c} and this is not enough data to justify extension from [ ]^{a,c}*

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 [ ]^{a,c} 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.*

Westinghouse Response:

a. Westinghouse agrees with the reviewer, the fourth column in Table 3-20 should be listed as [ ]^{a,c} However, Section 3.4 from WCAP-17483-P/WCAP-17483-NP, Revision 0 including this table, will be removed.

b. The [ ]^{a,c} isotopes will be listed in a plant-specific analysis table with a summary of Area of Applicability (AoA). However, Section 3.4 including Table 3-20 from WCAP-17483-P/WCAP-17483-NP, Revision 0 will be removed.

c. The NUREG/CR-6361 Case 166 which has a fuel enrichment of [ ]^{a,c} was removed from the topical report because of the presence of the Ag-In-Cd absorber (See the response to the RAI 26.b.). However, Section 3.4 including Table 3-20 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0. In a plant-specific analysis validation study, all discussions related to the extension of the AoA will be conducted in a separate section from the area of applicability determination. The extrapolation of any key physical parameter, if needed, will be based on allowable ranges of experiments, tolerances, and other critical experiment requirements provided in Table 2.3 of NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," Science Applications International Corporation, January 2001. See the response to RAI 32 for more information.

d. The LCEs containing Ag-In-Cd, Cadmium and Gadolinium will be removed (See the response to RAI 26.b). Section 3.4 including Table 3-20 from WCAP-17483-P/WCAP-17483-NP, Revision 0 will be removed.

e. Please see response to the Item d above.

f. Plant-specific analysis submittals will list the appropriate soluble boron concentration range in the AoA table or justify the extension. Section 3.4 including Table 3-20 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0.

g. Plant-specific analysis submittals will list an acceptable EALF range in the AoA table. Section 3.4 including Table 3-20 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0.

h. Plant-specific analysis submittals will use an appropriate label for AEG appropriate to the number of energy groups used in the cross-section library. Section 3.4 including Table 3-20 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0.

RAI Response Number: WCAP-17483-RAI-032
Revision: 0

Question:

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 [

]a,c

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.

Westinghouse Response:

Section 3 of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be revised to incorporate guidance on the following:

- Comparison of safety analysis models and validation studies
- Identification of validation gaps and deficiencies
- The need to address validation gaps and deficiencies in plant specific analysis

WCAP-17483-P/WCAP-17483-NP will be updated as follows:

a. As detailed in Reference 13 of WCAP-17483-P/WCAP-17483-NP, Revision 0 (NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology", Science Applications International Organization, January 2001), a comparison of the parameters in the validation suite and in the system to be evaluated shall be developed in the form of a table with parameter ranges for the validation suite and the system to be analyzed.

b. Validation gaps exist where data is clustered with distinct lack of data between clusters. Deficiencies such as poor fission product validation, no fuel composition calculation validation, poor or no validation of criticality calculations with some reactivity control devices and extrapolation of key parameters, etc. also ultimately stem from a lack of data, similarly to validation gaps. If Westinghouse identifies gaps/deficiencies, they will be acknowledged formally as indicated in the item c response.

c. [

]a,c

RAI Response Number: WCAP-17483-RAI-034
Revision: 0

Question:

Consider adding guidance in Section 4.1 reminding analysts that it is necessary to identify and address design variations such as [ ]a,c 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.

Westinghouse Response:

[ ]a,c are considered as part of the normal conditions evaluations. LTAs shall be identified and addressed if present. The following text will be added to the end of the first paragraph in Section 4.1.1:

[ ]a,c

RAI Response Number: WCAP-17483-RAI-035
Revision: 0

Question:

The text below Table 4-1 states:

[

]^{a,c}

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 [ ]^{a,c} to document that it was considered, evaluated, and is equivalent. Revise WCAP-17483-P/WCAP-17483-NP, Revision 0, accordingly.

Westinghouse Response:

The text below Table 4-1 will be revised as follows:

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-036
Revision: 0

Question:

The last paragraph in Section 4.1.1.1 provides justification for [ ]^{a,c} when determining the bounding assembly designs. Augment the discussion to clarify that it may be necessary to reconsider [ ]^{a,c} changes significantly.

Westinghouse Response:

The last paragraph in Section 4.1.1.1 will be modified as follows:

[ ]^{a,c}

RAI Response Number: WCAP-17483-RAI-037
Revision: 0

Question:

Section 4.1.1.5, addressing [ ]a,c cites NUREG/CR-6760 as supporting that it is [ ]a,c NUREG/CR-6760 is not clear on this subject. The studies with [ ]a,c 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 [ ]a,c is always conservative. The impact of these [ ]a,c 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.

Westinghouse Response:

See the response to RAI 57.b.

RAI Response Number: WCAP-17483-RAI-038
Revision: 0

Question:

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.

Westinghouse Response:

[

]a,c

RAI Response Number: WCAP-17483-RAI-039
Revision: 0

Question:

Section 4.1.2.1 claims that it is acceptable to use [$]^{a,c}$ This is not appropriate. It is necessary to evaluate the bounding assembly using [$]^{a,c}$ 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 [$]^{a,c}$ is bounding due to its more optimal H/U ratio. Then at some higher burnup the [$]^{a,c}$ 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 [$]^{a,c}$ that are used in the safety analysis.

Westinghouse Response:

[$]^{a,c}$

Section 4.1.2.1 is being modified to the following:

[$]^{a,c}$

RAI Response Number: WCAP-17483-RAI-040
Revision: 0

Question:

The last paragraph in Section 4.1.2.1 includes the following statement: [

]a,c

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.

Westinghouse Response:

Please see the response to RAI 39.

RAI Response Number: WCAP-17483-RAI-041
Revision: 0

Question:

Sections 4.2.2 and 4.2.4 discuss the simplified top and bottom nozzle models. This model is said to include at least [ ]^{a,c} above and below the active fuel length. No studies or other justification is provided for this model. Why is [ ]^{a,c} used and what is the distance between the ends of the active fuel and the [ ]^{a,c} 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.

Westinghouse Response:

Section 4.2.2 will be revised as follows:

[

]^{a,c}

Section 4.2.4 will be revised as follows:

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-042
Revision: 0

Question:

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 [ ]^{a,c} 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, 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 [ ]^{a,c} 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: [*

   ]^{a,c}

   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.

Westinghouse Response:

a.

i. Depletion calculations with grids were performed the same way as common practice lattice-physics calculations are performed for core design studies. For each assembly type modeled in this analysis, the total grid volume was smeared uniformly over the moderator region in the assembly. Only grids in the active fuel region, including the bottom grid were homogenized. As a result, the top grid was not modeled in the depletion calculations since it is not present in the active fuel.

Sleeves are physically located only in guide tube cells; therefore, sleeve material was not homogenized, but the effect was accounted for by calculating an effective guide tube thickness that preserved the sleeve volume.

With grids and sleeves accounted for in the depletion calculations, isotopic number densities for the depleted fuel were calculated and used in the subsequent k-effective calculations.

In the criticality calculations using KENO, the axial span of each grid was preserved, and the volume of the grid was homogenized over the moderator in that axial span. The approach for modeling grids in KENO was as follows:

[

]^{a,c}

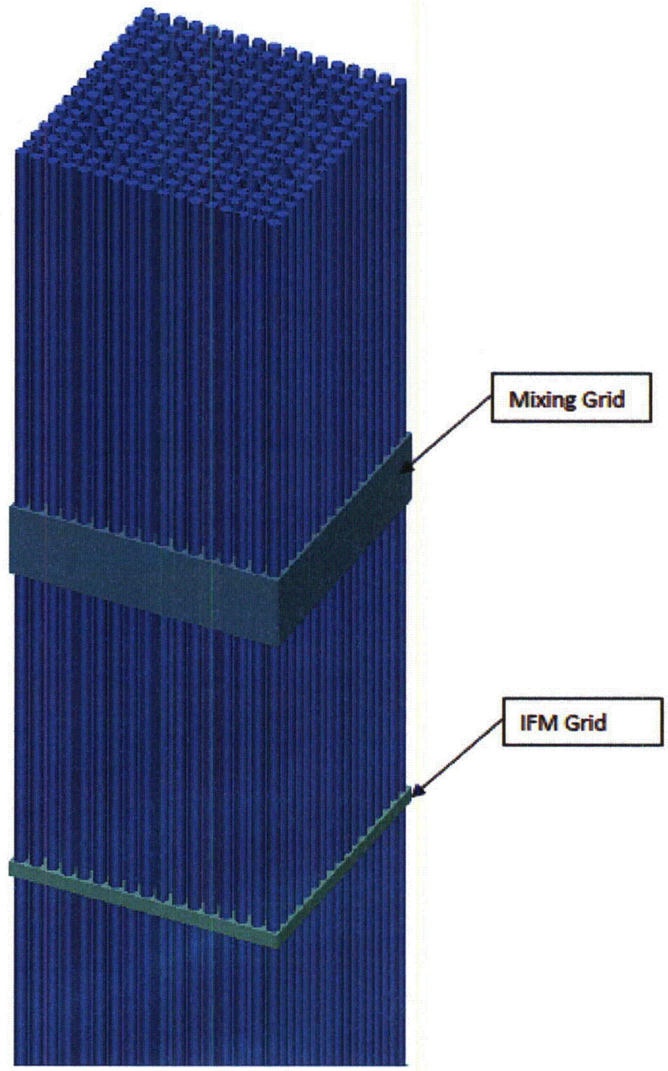

Figure 1: KENO model of a fuel assembly with grids

ii. Local burnup depressions created by the grids are not modeled in legacy core design studies. Modern methods, however capture these effects, which are inherently reflected within the plant-specific power and temperature profiles used in the criticality safety analysis.

iii. [

]a,c

but will have negligible impact on the sensitivity of the grid effects. Other factors such as those listed in the question will not change the conclusions of this study for the following reasons:

- Axial blankets, which are low-enriched and have annular pellets will remove the 'end-effect'; essentially moving the most reactive region to the fully enriched middle sections of the fuel. Therefore, if a grid is located near the blanket region, its effect will diminish also. The analysis has already shown that grids near the fully enriched fuel have minimal impact on the results.
- Fuel assemblies with radial enrichment zoning are modeled using an average enrichment with additional conservatism. Consequently, such analysis is covered by the conclusion of this grid study.

iv. Other assembly designs need not be considered because the analysis has been performed in a bounding manner. The CE and Westinghouse assembly designs were chosen [

]^{a,c}

v. Without identification and detailed review of these alternative analyses, it is not possible to understand the differences between these studies and the study performed by Westinghouse. Assumptions can be made that will considerably overestimate the reactivity impact of grids. Examples of such assumptions are modeling the material as void and/or over estimating grid volumes during depletion.

b. The node 3 data for Profile 1 in Table 4-6 was modeled as shown in WCAP-17483-P/WCAP-17483-NP Revision 0. The intent was to use the DOE shapes. The value of 1.028 was inadvertently used for node 3. The value was kept as it is immaterial to the conclusions and validity of the study. The assembly burnup ranges have been indicated. Table 4-6 will be revised as follows:

Table 4-6 [ ]^{a,c}

a,c

c. "Statistical significance" in this context was intended to mean that a calculated reactivity increase was smaller than the associated Monte Carlo uncertainty. This last paragraph will be revised for clarification as follows:

"As seen from the figure, the conclusions do not change in the presence of racks: the results of the criticality calculations without consideration for grids are conservative or the reactivity impact of the grids is within the Monte Carlo uncertainty."

RAI Response Number: WCAP-17483-RAI-043
Revision: 0

Question:

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: [ ]^{a,c} Clearly, it is not assumed that a [ ]^{a,c} 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.

Westinghouse Response:

Section 4.3 will be updated as follows:

4.3 MODELING SIMPLIFICATIONS AND APPROXIMATIONS

A number of conservative modeling simplifications and approximations which pertain to depletion and criticality calculations are listed below.

4.3.1 Depletion Modeling

[

]a,c

4.3.2 Criticality Modeling

[

]a,c

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-044
Revision: 0

Question:

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.

Westinghouse Response:

The standard methodology does not credit the presence of residual neutron absorber. There may be instances in plant-specific analysis in which a peak reactivity determination and residual neutron absorber credit may be needed for early-discharged fuel assemblies with burnable absorbers. Those cases are outside the scope of this topical report and will be handled on a plant-specific basis. The third bullet in Section 4.3.1 WCAP-17483-P/WCAP-17483-NP, Revision 0 is modified as follows:

- [

]^{a,c}

RAI Response Number: WCAP-17483-RAI-045
Revision: 0

Question:

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:*

   [ ]a,c

   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 [ ]a,c In some cases, replacing the [ ]a,c 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 [ ]^{a,c} 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 [ ]^{a,c} to provide a conservative model of the assembly [ ]^{a,c} 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: [ ]^{a,c}*

Westinghouse Response:

a. Please see the response to RAI question 8.c. Post-depletion calculation processing of burned fuel composition is discussed in response to RAI question 10.

b. Fresh fuel designs that the plant will be temporarily storing before loading in the core are modeled in the new fuel storage rack calculations. The analysis will account for the current fuel design(s) as previous designs will not be relocated to the fresh fuel storage racks. Please see bullet 8 of Section 4.3.2 in response to RAI question 43.

c. [

]^{a,c} Nevertheless, these details are plant-specific and this bullet does not necessarily pertain to modeling simplifications. As such, it will be removed from this section. Please see the response to RAI question 43.

d. [

]^{a,c}

e. This bullet pertains to boron loading only. Other parameters related to the location and length of the absorber panels are addressed in Section 6.1.18. The bullet will be modified as shown in the response to RAI question 43.

f. Please see the response to RAI question 43.

g. Please see response to RAI question 41.

h. This bullet is now considered misleading and redundant to Section 6.1. As such, it will be removed.

i. Please see the response to RAI question 43.

j. Modeling simplifications for the items in question are discussed below:

i. [

]^{a,c}

[

]^{a,c}

ii. [

]^{a,c}

iii. Small physical changes, such as fuel rod growth and clad creep during reactor operation are not considered in criticality safety analysis. This is justified in a Westinghouse study presented in References 2 and 3.

iv. In the standard methodology, depletion calculations are performed using pin-by-pin neutron transport calculations and resulting isotopics are averaged over the fuel assembly to be used in reactivity determinations in the pool. The fuel assemblies in the pool are modeled in 3-D and pin-by-pin, each pin with the same average material composition determined from the depletion calculations. [

]^{a,c}

Radial variations in the neutron flux, which are mainly due to leakage at the core periphery, may result in a non-uniform horizontal burnup distribution over the radial extent of the reactor core. As the reactor operates, the radial flux shape flattens due to fuel depletion and fission product poisoning near the core center. However, because of the high leakage from the core, burnup drops off rapidly near the periphery. Ultimately, at the end of a cycle, the individual assemblies located near the center of the core will have a relatively uniform horizontal burnup distribution, while the assemblies near the core periphery may have a significant radial variation in burnup. Thus, it is possible for fuel rods on one side of an assembly to have experienced notably less burnup than fuel rods on the opposite side of the same assembly. It is important to note that that with modern fuel management strategies, only highly depleted fuel is put on the periphery, and the burnup accumulated in the last cycle is less than that accumulated in the previous cycles. It should also be noted that the 'tilt' will be more pronounced towards the axial mid-plane of the fuel assemblies. To enhance fuel utilization, assemblies are typically relocated within the reactor core between cycle operations. These fuel management practices tend to effectively reduce the radial burnup gradient in normal discharged fuel. However, a periphery assembly discharged after a single irradiation cycle may exhibit a significant horizontal burnup gradient and in the event that two or more assemblies are placed in a configuration such that their low-burnup zones are adjacent, an increase in reactivity may occur. [

]a,c

Reference:

1. "Review of Fuel Failures in Water Cooled Reactors," IAEA Nuclear Energy Series, ISSN 1995–7807; no. NF-T-2.1.
2. WCAP-17094-P, Revision 3, "Turkey Point Units 3 and 4 New Fuel Storage Rack and Spent Fuel Pool Criticality Analysis," February 2011.
3. J. Paige (NRC) to M. Nazar (FPL), "Turkey Point Units 3 and 4 - "Issuance of Amendments Regarding Fuel Criticality Analysis (TAC Nos. ME4470 and ME4471)," Accession No. ML1 1216A057, October 31, 2011.

RAI Response Number: WCAP-17483-RAI-046
Revision: 0

Question:

The first paragraph in Section 5.1 includes a statement that [ ]^{a,c} 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.

Westinghouse Response:

Credit for residual integral absorber is not part of the standard methodology. If residual integral absorber is credited for an analysis, the details will be provided in that plant-specific criticality safety analysis report.

RAI Response Number: WCAP-17483-RAI-047
Revision: 0

Question:

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: [ ]^{a,c} 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 [ ]^{a,c} Revise the text or Figure 5-1 to more completely describe the potential inputs.*

Westinghouse Response:

a. There is no special treatment for blanket material; its irradiation is handled in the same manner as regular, fully enriched fuel.

b. [

]^{a,c}

Figure 5-1 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0 to eliminate inconsistency with the text.

c. The following table provides a list of fission products credited in the analysis:

[ ]^{a,c}

d. Figure 5-1 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0 to eliminate inconsistency with the text.

RAI Response Number: WCAP-17483-RAI-048
Revision: 0

Question:

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.

Westinghouse Response:

Section 5.3 of WCAP-17483-P Revision 0 states:

[

]a,c

RAI Response Number: WCAP-17483-RAI-049
Revision: 0

Question:

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.

Westinghouse Response:

Plant data and core design analyses are not typically directly compared; either is considered appropriate for use in developing limiting axial burnup profiles, because the data sets are representative of planned or actual operation. Plant data models are generally created based on core follow data where core design data assumptions may vary depending on the organization that developed the model and the purpose of the model. The typical core design assumption is hot full power (HFP) all rods out (ARO).

[

]a,c

RAI Response Number: WCAP-17483-RAI-050
Revision: 0

Question:

The Westinghouse [

]^{a,c} 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.

Westinghouse Response:

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-051
Revision: 0

Question:

Section 5.3.5 provides the demonstration that the [

]a,c 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 [

]a,c The comparison does not appear to be comprehensive and presupposes that the axial profiles identified by the [*]a,c 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.*

Westinghouse Response:

[

]a,c

RAI Response Number: WCAP-17483-RAI-053
Revision: 0

Question:

A clear and complete statement of how the [ ]^{a,c} 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 [ ]^{a,c} How will future cycles be compared to the [ ]^{a,c} profiles? How will exceptions be identified and handled?

Westinghouse Response:

Profiles from Table 5-2 have been provided to demonstrate [ ]^{a,c} Plant-specific bounding profiles determined using [ ]^{a,c} will be used in the analysis.

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-054
Revision: 0

Question:

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 [ ]^{a,c}*

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

Westinghouse Response:

a. [ ]^{a,c}

b. [ ]^{a,c}

c. Please see response to b.

d. [ ]^{a,c}

[

]a,c

e. The following guidance will be added to WCAP-17483-P/WCAP-17483-NP, Revision 0, in Section 5.3 to ensure that the appropriate burnup profiles are selected for future analysis.

"Analyses using this method will reference this topical for description of the specifics of the approach and will describe the generation of the axial burnup profile database being used for the specific analysis in question."

RAI Response Number: WCAP-17483-RAI-055
Revision: 0

Question:

Regarding Section 5.4.2:

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

]a,c 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.*

Westinghouse Response:

a. The 1st paragraph in Section 5.4.2 will be revised to remove the statement in question as follows:

[

]a,c

b. The 2nd paragraph in Section 5.4.2 will be revised to make it clearer that the sensitivities discussed are of the k-effective of the storage configurations in the pool:

[

]a,c

c. The 3rd paragraph in Section 5.4.2 will be revised to clarify the standard method for determining a conservative moderator temperature for use in depletion calculations:

[

]a,c

RAI Response Number: WCAP-17483-RAI-057
Revision: 0

Question:

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 [ ]^{a,c} Typically, NUREG/CR-6760 is cited as the reference supporting this assertion. However, the [ ]^{a,c} 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 [ ]^{a,c} 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 [ ]^{a,c} 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.

Westinghouse Response:

a. Section 5.4.6.3 of WCAP-17483-P/WCAP-17483-NP, Revision 0 discusses the use of burnable absorbers in depletion calculations. The section will be modified to include the following:

[

]a,c

b. The NRC has requested additional information regarding the conservatism of ignoring the presence of gadolinia and erbia. There are two previous RAI responses which provide information directly applicable to this question:

1. WCAP-17483-P Rev. 0 Request for supplemental information #4, ML12171A205.
2. WCAP-17400-P Rev. 0 Request for Additional Information Round 2 Question 1 Enclosure 3 of ML12249A069.

[

]a,c

RAI Response Number: WCAP-17483-RAI-058
Revision: 0

Question:

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

Westinghouse Response:

The following text will be added to a new subsection (5.4.9) at the end of Section 5.4:

"Section 5.4.9 Post-Irradiation Cooling Time

[

]a,c

RAI Response Number: WCAP-17483-RAI-059
Revision: 0

Question:

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, [

]a,c 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 [ ]a,c 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.

Westinghouse Response:

Table T-11b of "Applying Statistics" (Reference 1) shows that Single Sided Tolerance Factor for $n = \infty$, $\gamma = 0.95$ and $\pi = 0.95$ is 1.645. [

]a,c

$$Uncertainty = k_{perturbed} - k_{nominal} + 2.0 * \sqrt{\sigma_{nominal}^2 + \sigma_{perturbed}^2} \tag{6.1}$$

$$Depl. Unc. = 0.05 * \left[k_{fresh} - k_{depleted} + 2.0 * \sqrt{\sigma_{fresh}^2 + \sigma_{depleted}^2}\right] \tag{6.3}$$

$$FPMA\ worth\ bias. = 0.02 * \left[k_{nominal} - k_{perturbed} + 2.0 * \sqrt{\sigma_{nominal}^2 + \sigma_{perturbed}^2}\right] \tag{6.4}$$

Furthermore, text in Section 6.2 will be modified as follows:

"The Monte Carlo uncertainty term for each individual bias and uncertainty calculation is already included in the total. The Monte Carlo uncertainty for each individual burnup credit calculation must still be accounted for. Two acceptable ways to account for the Monte Carlo uncertainty in the individual burnup credit calculations are to:

[ ]a,c

Here, σ is the Monte Carlo uncertainty from the individual calculations and σ_{max} is the maximum of all the individual σ values."

Reference:

1. NUREG-1475, Revision 1, "Applying Statistics," March 2011.

RAI Response Number: WCAP-17483-RAI-060
Revision: 0

Question:

The last paragraph on page 6-1 and equation 6.2 discuss the subject of "statistical significance". The idea of [ ]^{a,c} 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".

Westinghouse Response:

Westinghouse agrees with the reviewer that the term "statistical significance" was not appropriate due to the explicit technical meaning of the term in statistics. The Westinghouse standard methodology will not exclude uncertainties on the basis of statistical insignificance. The last paragraph on page 6-1 of WCAP 17483-P/WCAP 17483-NP, Revision 0 is revised as follows:

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-061
Revision: 0

Question:

The second paragraph in Section 6.1 states: [

]a,c Provide a study or references supporting this assertion. The last sentence in the third paragraph goes on to say, [ ]a,c 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.

Westinghouse Response:

[

]a,c

[

]^{a,c}

Table 1 Fuel Rack Specifications for Plant A

a,c

Table 2 Fuel Assembly Specifications for Plant A

a,c

Table 3 Fuel Rack Specifications for Plant B

a,c

Table 4 Fuel Assembly Specifications for Plant B

a,c

Table 5 Fuel Storage Array Descriptions

a,c

RAI Response Number: WCAP-17483-RAI-062
Revision: 0

Question:

The first paragraph of Section 6.1.2 suggests that it may be acceptable to [ ]^{a,c} 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.

Westinghouse Response:

Credit of integral burnable absorbers in fresh fuel is not part of the standard methodology. As such, the last sentence in the first paragraph of Section 6.1.2 will be removed. The resulting paragraph is as follows:

[ ]^{a,c}

RAI Response Number: WCAP-17483-RAI-063
Revision: 0

Question:

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:

[

]a,c

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.

Westinghouse Response:

[

]a,c

RAI Response Number: WCAP-17483-RAI-064
Revision: 0

Question:

Section 6.1.6 covers quantification of the [ ]^a,c 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 [ ]^a,c Revise TR accordingly.
c. The logic for calculating the [ ]^a,c seems pretty clear. However, the [ ]^a,c could be limiting for some lattices in some conditions. For example, how does [ ]^a,c affect k-effective at optimum moderation conditions in the new fuel storage racks? Provide guidance for calculating [ ]^a,c in systems where [ ]^a,c yields a reactivity increase.

Westinghouse Response:

a. Section 6.1.6 is re-written as follows:

[

]^a,c

b. Please see the response to item a.

c. Please see the response to item a. [

]^a,c

RAI Response Number: WCAP-17483-RAI-065
Revision: 0

Question:

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, B4C rods, rack inserts)*
e. *Material compositions*

Westinghouse Response:

Poison panel and reactivity control device reactivity uncertainties from manufacturing are not explicitly addressed in section 6.1. In general, guidance given in section 6.1.11 is applicable. Material compositions and the specific details of tolerances taken into account as well as their treatment method will be explicitly included in each site-specific analysis in which poison panels are present.

RAI Response Number: WCAP-17483-RAI-066
Revision: 0

Question:

The last sentence in Section 6.1.11 states: [

]a,c 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.

Westinghouse Response:

Any engineer who performs a criticality safety analysis has been qualified under Westinghouse's Quality Management System. As part of this qualification, the engineer receives training in the methodology used for SFP analyses and is confirmed, by fully qualified criticality engineers and management, to be sufficiently knowledgeable to perform analyses unsupervised. Note that all Westinghouse SFP calculations and evaluations are both performed and reviewed by qualified personnel so concurrence on expectation of 'no significant effect' must be reached by both the qualified author and verifier. Additionally, Section 6.1.11 will be modified to state the following:

[

]a,c

RAI Response Number: WCAP-17483-RAI-067
Revision: 0

Question:

Section 6.1.12 describes calculation of an uncertainty to cover poor validation of [ ]^{a,c} This appears to be the [ ]^{a,c} 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.

Westinghouse Response:

[

]^{a,c} The section will be modified as follows:

"6.1.13 Fission Product and Actinide Worth Bias

The fission product and actinide worth bias is calculated using Equation 6.4:

[ ]a,c

[

]a,c

References

1. NUREG/CR-7108, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Isotopic Composition Predictions," Adams Accession: ML12116A124, April, 2012.
2. NUREG/CR-7109, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Criticality (k_{eff}) Predictions," Adams Accession:ML12116A128, April, 2012.
3. Kord Smith, Shaun Tarves, et al., "Benchmarks for Quantifying Fuel Reactivity Depletion Uncertainty," EPRI, Palo Alto, CA, 1022909 (2011).
4. Dale Lancaster, "Utilization of the EPRI Depletion Benchmarks for Burnup Credit Validation," EPRI, Palo Alto, CA, 1025203 (2012).
5. Kucukboyaci, V. N. "EPRI Depletion Benchmark Calculations Using PARAGON," Proceedings of the ANS NCSD 2013 - Criticality Safety in the Modern Era: Raising the Bar, Wilmington, NC, October 1, 2013.

RAI Response Number: WCAP-17483-RAI-068
Revision: 0

Question:

Section 6.1.13 includes a list of nuclides that will be retained in the perturbed case when calculating the [ ]a,c This list of nuclides is not consistent with those listed in Figure 5-1, which appears to track only [ ]a,c The list in Section 6.1.13 also includes [ ]a,c It is not clear why it is acceptable to include [ ]a,c 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.

Westinghouse Response:

Figure 5-1 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0 to eliminate inconsistency with the text. Please also see response to RAI 47.c. for the list of credited fission products as well as major and minor actinides. [

]a,c

Section 6.1.13 will be revised to correct the list of isotopes simulated in the fuel in the perturbation cases and is given in the response to RAI 67.

RAI Response Number: WCAP-17483-RAI-069
Revision: 0

Question:

Section 6.1.14 describes calculation of an uncertainty in the [ ]^{a,c} Since equation 6.5 does not appear to include Monte Carlo calculation uncertainty, it appears as though the [ ]^{a,c} Provide more details on how the [ ]^{a,c} 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 [ ]^{a,c} To avoid confusion during the implementation, revise the WCAP-17483-P/ WCAP-17483-NP, Revision 0, text to require the analyst confirm and address [ ]^{a,c} treatment explicitly in the criticality analysis report.

Westinghouse Response:

The value of δk/δBU is determined from analysis of Monte Carlo calculation results. Equation 6.5 is revised as follows:

[ ]^{a,c}

where:

[ ]^{a,c}

The last paragraph of Section 6.1.14 is revised as follows:

[ ]^{a,c}

RAI Response Number: WCAP-17483-RAI-070
Revision: 0

Question:

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

]^{a,c} 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 [ ]^{a,c} determination. Is this done for each and every initial enrichment/burnup point? If not, describe and justify the more limited set of calculations.

Westinghouse Response:

The sentence starting at the bottom of page 6-14 and ending on 6-15 of WCAP-17483-P/WCAP-17483-NP, Revision 0 was replaced by the following text:
[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-076
Revision: 0

Question:

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.

Westinghouse Response:

Because the data in Tables 6-1 through 6-3 have already been depicted in Figures 6-1 through 6-21, these tables are redundant and will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0, along with Section 6.4 which refers to them. Figures 6-1 through 6-21 will be retained as those figures support the individual sections on bias and uncertainties in explaining how they relate to assembly burnup and enrichment. Details of the data presented in these figures are provided in response to RAI 61.

Section 6.1 of WCAP-17483-P/ WCAP-17483-NP, Revision 0 will be modified as follows to provide sufficient information about the configurations used in Figures 6-1 through 6-21:

[

]a,c

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-077
Revision: 0

Question:

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 [

]a,c

Westinghouse Response:

[

]a,c

RAI Response Number: WCAP-17483-RAI-078
Revision: 0

Question:

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.

Westinghouse Response:

Westinghouse agrees with the reviewer(s), however as discussed in the response to RAI 76, Tables 6-1, 6-2, and 6-3 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0.

RAI Response Number: WCAP-17483-RAI-081
Revision: 0

Question:

The second paragraph of Section 6.6.1 of the TR states: [

]a,c 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 [

]a,c is to be implemented in the standard analysis.

Furthermore, it is proposed that it would be appropriate to reduce [
]a,c as a modeling simplification to bound the effect of both depletion and manufacturing tolerances. The manufacturing tolerances on [
]a,c may yield a larger effect on k-effective than a [
]a,c 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.

Westinghouse Response:

Section 6.6 of the TR will be revised for clarification to address fresh and exposed discrete absorbers. Validation of ^{10}B based fixed and discrete absorbers follow the same justification in response to RAI 29. [

]a,c

"6.6 DETERMINATION OF MINIMUM ABSORBER REQUIREMENTS

This section discusses neutron absorber credit and how the absorbers are treated in criticality safety calculations. The assumptions used in the criticality calculations will necessarily be different from the assumptions used when considering absorbers as depletion parameters, which are discussed in Section 5.4.

[

]a,c

[

]a,c

6.6.1 Credit for Discrete and Fixed Absorbers

[

]a,c

RAI Response Number: WCAP-17483-RAI-082
Revision: 0

Question:

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

Westinghouse Response:

As stated in the response to RAI 81, credit for fresh burnable absorbers is no longer part of the standard methodology. As such, Section 6.2 will be removed from WCAP-17483-P/WCAP-17483-NP, Revision 0.

RAI Response Number: WCAP-17483-RAI-084
Revision: 0

Question:

In 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?*

Westinghouse Response:

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-085
Revision: 0

Question:

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.

Westinghouse Response:

WCAP-17483-P/WCAP-17483-NP, Revision 0, Section 6.7.1 is intending to provide potential modeling strategies that have not been discussed, which are acceptable as part of the accident or interface modeling. Accident analysis modeling approaches are described in Section 6.7.2, while Section 7.3 and its subsections describe postulated accident scenarios. Section 6.7.2 will be modified to include the following:

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-086
Revision: 0

Question:

The last sentence in Section 6.7.1 indicates that a [

]a,c

Westinghouse Response:

The following will be added to the end of Section 6.7.1 of WCAP 17483-P/WCAP-17483-NP, Revision 0:

[

]a,c

RAI Response Number: WCAP-17483-RAI-088
Revision: 0

Question:

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 [*

   ]^{a,c}

b. *As per the first sentence in Section 6.7.3.1, [*

   ]^{a,c} 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.*

Westinghouse Response:

a. It is not Westinghouse's intent to indicate any required minimum or maximum size for any array. All arrays to be used on a site specific analysis will be fully detailed in that analysis.

b. A review of Figure 6-28 has determined that the figure is correct as it is presented in WCAP-17483-P/ WCAP-17483-NP, Revision 0. When considering each stored assembly, it should be part of acceptable arrays with all of its adjacent assemblies.

   In this example Array 1 only requires that all Fresh fuel have a face adjacent empty cell. This requirement has been met as the figure is currently laid out. Note that a 'Med. BU' assembly can be stored in any location that would store a 'Fresh' assembly. The interface between Array 2 and Array 3 all qualify as Array 2. While some of the fuel assemblies are labelled as Array 3, they also meet the burnup requirements for Array 2.

RAI Response Number: WCAP-17483-RAI-089
Revision: 0

Question:

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

]^{a,c}

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 [*

   ]^{a,c} 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 [*

   ]^{a,c} 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.*

Westinghouse Response:

a. The text in Section 6.7.3 will be modified as follows:

   [

   ]^{a,c}

[

]a,c

b. See Response c.

c. Section 6.7.3.2 will be revised as shown below to more appropriately describe the standard method. [

]a,c

[

]a,c

A new example will replace that provided in Table 6-16. The new example will be as follows:

Table 6-16: [ ]a,c

a,c

d. [

]a,c

RAI Response Number: WCAP-17483-RAI-090
Revision: 0

Question:

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.

Westinghouse Response:

The quoted text in the first paragraph of Section 7 will be updated to match the text in 10 CFR 50.68(b)(4) as follows:

"If no credit for soluble boron is taken, the k-effective of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity must not exceed 0.95, at a 95 percent probability, 95 percent confidence level, if flooded with unborated water. If credit is taken for soluble boron, the k-effective of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity must not exceed 0.95, at a 95 percent probability, 95 percent confidence level, if flooded with borated water, and the k-effective must remain below 1.0 (subcritical), at a 95 percent probability, 95 percent confidence level, if flooded with unborated water."

RAI Response Number: WCAP-17483-RAI-091
Revision: 0

Question:

In Section 7.2:

a. *In the first paragraph, revise the text to describe the modeling of [ ]^{a,c} more completely. Is this [ ]^{a,c} 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 [ ]^{a,c} 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.*

Westinghouse Response:

a. The first paragraph in Section 7.2 will be revised as follows:

"Each storage configuration shall be defined such that $k_{eff} < 1.0$ including all applicable biases and uncertainties in the unborated condition. Then, the amount of soluble boron required such that k_{eff} is no greater than 0.95 including all applicable biases and uncertainties in the borated condition shall be determined. [ ]^{a,c}

[

]^{a,c}

Please see the response to RAI 41 for additional information.

b. The second paragraph in Section 7.2 will be revised as follows:

"The amount of soluble boron required to ensure k_{eff} is no greater than 0.95 including all applicable biases and uncertainties will be determined by direct Monte Carlo simulation. [

]^{a,c}

c. All configurations are designed to meet the requirement that k_{eff} is less than 1.0, including all applicable biases and uncertainties, and administrative margin. The last paragraph in Section 7.2 is not meant to impose restrictions on determination of soluble boron requirement for normal conditions. [

]^{a,c}

d. Please see the modified paragraph in response to item b.

RAI Response Number: WCAP-17483-RAI-092
Revision: 0

Question:

The first two sentences in Section 7.3 state: [

]^{a,c} 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.

Westinghouse Response:

The first paragraph of the introduction to Section 7.3 will be reworded as follows:

"The spent fuel pool is required to maintain a $k_{eff} \leq 0.95$ under both normal and accident scenarios. The double contingency principle outlined in Section 4.2.2 of Reference 1 indicates that it should take two independent, unlikely, and concurrent events for a criticality to occur. [

]^{a,c}

[

]a,c

Reference:

1. ANSI/ANS-8.1-1998; R2007, "Nuclear Criticality Safety in Operations with Fissionable Materials outside Reactors."

RAI Response Number: WCAP-17483-RAI-093
Revision: 0

Question:

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,c

a. *From the text, [*

]a,c Specify the criteria used in determining the value of "much less".

b. *Revise the text to clarify the mechanics of how the [*
]a,c 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. *[ ]a,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. *[ ]a,c may not be appropriate since there is an associated variation in water density. Consequently, boron worth will vary with water density. [ ]a,c 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.*

Westinghouse Response:

a.) The extrapolation approach within Section 7.3.2 will be removed. This section of WCAP-17483-P/WCAP-17483-NP, Revision 0 will be rewritten as follows:

[

]a,c

b.) Please see the response to a.

c.) Please see the response to a.

d.) Please see the response to a.

RAI Response Number: WCAP-17483-RAI-094
Revision: 0

Question:

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 [ ]^{a,c} 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.

Westinghouse Response:

All of the subsections in Section 7.3 relate to postulated accidents. Section 7.3.3 specifically deals with the placement or travel of an assembly through an area which is not intended to have an assembly. Such incidents are considered accident conditions.

For the cases where an assembly is intended to be placed in a position different than the 'standard' static storage locations then this operation is considered as part of the normal conditions evàluations performed and submitted for review in plant-specific analyses.

RAI Response Number: WCAP-17483-RAI-095
Revision: 0

Question:

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.

Westinghouse Response:

This is already addressed in Section 6.1.11 of WCAP-17483-P/WCAP-17483-NP, Revision 0 in the statement:

"Each analysis will contain a description of the rack design and the manufacturing tolerances associated with that rack."

The statement aligns with Westinghouse's practice of obtaining and reviewing the design of SFP racks for an analysis. This is standard practice regardless of the presence of neutron absorbing material in the racks. While this is not clearly outlined elsewhere in the WCAP, the process of obtaining accurate inputs must be part of developing any safety analysis. The process of ensuring accurate and appropriate input is requested is controlled under Westinghouse's Quality Management System.

RAI Response Number: WCAP-17483-RAI-096
Revision: 0

Question:

In Section 7.3.3 and 7.3.4, it is stated that [

]^{a,c} 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.

Westinghouse Response:

The first sentence in Sections 7.3.3 and 7.3.4 will be modified to the following:

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-097
Revision: 0

Question:

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

Westinghouse Response:

Addressing a multiple misload accident is not part of the standard methodology because generic guidance cannot be given to cover the event. Treatment of a multiple misload will depend on plant specific information including spent fuel management processes, the physical layout of the SFP racks and modules, and the plant specific configurations being developed.

[ ]a,c

As a part of every analysis, the qualified analysts review plant conditions and operations and determine which accidents are relevant at the plant. [

]a,c

RAI Response Number: WCAP-17483-RAI-098
Revision: 0

Question:

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.

Westinghouse Response:

This is a potential accident which depends on specific plant normal operations and is addressed by the response to RAI 104.

RAI Response Number: WCAP-17483-RAI-099
Revision: 0

Question:

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 [ ]^{a,c} 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.

Westinghouse Response:

The guidance does not suggest that it may be appropriate to limit the evaluation to a single missing reactivity control device. An accident incorporating a single control rod being removed was provided as an example of one potential credible accident. The guidance specifically states:

[

]^{a,c}

Note that the evaluation of the accidents to be considered in a plant-specific analysis will be performed by an engineer with the appropriate level of qualification under Westinghouse's quality program which meets the requirements of Chapter 10 of the Code of Federal Regulations Part 50 Appendix B.

RAI Response Number: WCAP-17483-RAI-100
Revision: 0

Question:

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.

Westinghouse Response:

A paragraph will be added to Section 7.2 of WCAP-17483-P/WCAP-17483-NP, Revision 0 to address a boron dilution accident as follows:

[

]^{a,c}

RAI Response Number: WCAP-17483-RAI-101
Revision: 0

Question:

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.

Westinghouse Response:

A paragraph will be added to the end of Section 7.4 of WCAP-17483-P/WCAP-17483-NP, Revision 0 to include consideration of the boron worth with moderator temperature/density variation:

[

]a,c

RAI Response Number: WCAP-17483-RAI-102
Revision: 0

Question:

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.

Westinghouse Response:

Westinghouse agrees that while the physics of the New Fuel Rack (NFR) as compared to the SFP can be different, the methodology associated with performing a NFR analysis is similar to that of the spent fuel pool storage rack analysis.

Requirements

The information on requirements is provided in Section 8 of WCAP-17483-P/WCAP-17483-NP, Revision 0.

Analytical Methods

The details on the codes used for a plant specific analysis of the NFR will be provided in the analysis-specific application package together with the validation suite supporting use of the code for the specific application. Modeling methods are described in Section 4.3.2.

Validation

The validation suite supporting the NFR analysis is governed by the guidance provided in Section 3 of WCAP-17483-P/WCAP-17483-NP, Revision 0, as modified by the RAI responses provided. The validation suite will involve:

1. determining the appropriate area of applicability (AoA) for the validation suite;
2. selecting and modeling an appropriate set of critical experiments;
3. performing trending analyses as necessary; and
4. addressing any gaps between the validation suite and the application-specific AoA.

Bounding Assembly Design

The process for determining a bounding fuel assembly design is outlined in Section 4.1 and is followed considering the analysis-specific conditions associated with fuel in the NFR.

Modeling of Normal and Abnormal Conditions

There is no regulatory requirement to model the NFR in its unmoderated state because there are no criticality concerns with moderator excluded. Because of this normal conditions are not analyzed as part of NFR analyses. The requirements of Chapter 10 of the Code of Federal Regulations, Part 50.68 relate to abnormal conditions identified for fresh fuel storage in the NFR. The conditions analyzed are the fully flooded and optimum moderation cases. Additionally, any other abnormal condition which shares a common cause as the fully flooded or optimum moderation cases will be evaluated and documented.

Determination of Maximum k_{eff}

The maximum k_{eff} is determined in the same manner for the NFR and the SFP. The uncertainties and biases to be considered are the same as those for fresh fuel configurations in the spent fuel pool and the total sum of biases and uncertainties is calculated and applied in the same manner.

RAI Response Number: WCAP-17483-RAI-104
Revision: 0

Question:

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.

Westinghouse Response:

Section 7.3 of WCAP-17483-P/WCAP-17483-NP, Revision 0 deals with postulated accident scenarios, which are departures from normal conditions. As such, the second paragraph of Section 7.3 will be modified to include a statement as follows:

> "Accidents that are a consequence of normal SFP operations besides static storage shall also be evaluated and documented. [
>
>]^{a,c}

RAI Response Number: WCAP-17483-RAI-108
Revision: 0

Question:

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

Westinghouse Response:

Reference 10 will be corrected as follows:

10. C.E. Sanders and J.C. Wagner, "Study of the Effect of Integral Burnable Absorbers for PWR Burnup Credit" NUREG/CR-6760, March 2002.

RAI Response Number: WCAP-17483-RAI-109
Revision: 0

Question:

Correct Reference 29 to indicate "Nucl. Tech." rather than "Nuclear."

Westinghouse Response:

Reference 29 will be corrected as follows:

11. J. C. Wagner and C. E. Sanders, "Investigation of the Effect of Fixed Absorbers on the Reactivity of PWR Spent Nuclear Fuel for Burnup Credit," Nucl. Tech.; Volume 139; Issue 2; pages 91-126, August 2002.