

Updated NEXUS Cross-Section Methodology

**WCAP-16045-NP-A, Addendum 2-A
Revision 0**

Updated NEXUS Cross-Section Methodology

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August 2020

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Section A
List of Changes

As part of the NRC review, one change was identified to provide an update to the information in the topical report (TR).

Mini-core calculation results are presented in Table 31 to demonstrate the re-homogenization effect. The initial calculations were performed and the results were presented in an international conference presentation. Subsequent to the conference presentation, the mini-core case was re-modeled at a different condition, which lead to a small change in the reactivity and no change to the assembly power distribution. The final qualification results have been included in the updated Table 31 in this report.

This change is included in this Approved version of the TR as described in the response to RAI-2. The change is listed in the table below along with the section of the report that is modified.

List of Changes

NRC RAI No.	Affected Report Section	Comments
RAI-2	Section 3.2	Referenced in Section 3.2, "MINICORE MODEL CALCULATIONS," Table 31, "Comparison of k_{∞} for 3X3 Mini-Core Case ," has been updated.

Section B
Final Safety Evaluation

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**UNITED STATES
NUCLEAR REGULATORY COMMISSION**
WASHINGTON, D.C. 20555-0001

July 21, 2020

Ms. Camille Zozula, Manager
Infrastructure & Facilities Licensing
Westinghouse Electric Company
1000 Westinghouse Drive
Building 1, Suite 165
Cranberry Township PA 16066

**SUBJECT: FINAL SAFETY EVALUATION FOR WESTINGHOUSE ELECTRIC COMPANY
TOPICAL REPORT WCAP-16045-P-A, ADDENDUM 2, REVISION 0, AND
WCAP-16045-NP-A, ADDENDUM 2, REVISION 0, "UPDATED NEXUS
CROSS-SECTION METHODOLOGY" (EPID: L-2019-TOP-0026)**

Dear Ms. Zozula:

By letter dated June 26, 2019 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML19179A091), Westinghouse Electric Company (Westinghouse) submitted to the U.S. Nuclear Regulatory Commission (NRC) a request for review and approval of Topical Report (TR) WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology." By letter dated May 20, 2020, the NRC issued its draft safety evaluation (SE) for the TR WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0 (ADAMS Accession No. ML20121A306). By letter dated June 18, 2020 (ADAMS Accession No. ML20121A306), Westinghouse provided comments on the draft SE.

The enclosed final SE addresses the applicability of the TR WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology."

The NRC staff has found that WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology," is acceptable for referencing in licensing applications to the extent specified and under the limitations delineated in the TR and the enclosed SE.

According to the guidance provided on the NRC website, we request that Westinghouse publish accepted proprietary and non-proprietary versions of these TRs within three months timeframe.

NOTICE: Enclosure transmitted herewith contains SUNSI. When separated from Enclosure, this transmittal document is decontrolled.

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C. Zozula

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As an alternative to including the RAI questions and RAI responses behind the title page, if changes to the TRs were provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAI questions:

1. The RAI questions and RAI responses can be included as an Appendix to the accepted version.
2. The RAI questions and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TRs. The table should reference the specific RAI questions and RAI responses which resulted in any changes, as shown in the accepted version of the TRs.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, Westinghouse will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing. Licensees referencing this TR would be expected to justify its continued applicability or evaluate their plant using the revised TR.

Sincerely,

/RA – Leslie Perkins for/

Dennis C. Morey, Chief
Licensing Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 99902038

Enclosures:
As stated

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C. Zozula

SUBJECT: FINAL SAFETY EVALUATION FOR WESTINGHOUSE ELECTRIC COMPANY
 TOPICAL REPORT WCAP-16045-P-A, ADDENDUM 2, REVISION 0, AND
 WCAP-16045-NP-A, ADDENDUM 2, REVISION 0, "UPDATED NEXUS
 CROSS-SECTION METHODOLOGY" (EPID: L-2019-TOP-0026)

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ML20196L633 (Non-Prop Comment Resolution Attachment)

***Via e-mail**

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U. S. NUCLEAR REGULATORY COMMISSION
FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION
TOPICAL REPORT WCAP-16045-P-A, AND WCAP-16045-NP-A,
ADDENDUM 2, REVISION 0,
“UPDATED NEXUS CROSS-SECTION METHODOLOGY”
WESTINGHOUSE ELECTRIC COMPANY
EPID L-2019-TOP-0026

1.0 INTRODUCTION

By letter dated June 26, 2019 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML19179A091), Westinghouse Electric Company (Westinghouse) submitted to U.S. Nuclear Regulatory Commission (NRC) WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, “Updated NEXUS Cross-Section Methodology,” for review and approval. The submittal is an addendum to the topical report (TR) which presents an update to the NEXUS cross-section parametrization methodology. The proposed methodology is a reformulation of the methodology described in WCAP-16045-P-A, Addendum 1. The TR addendum is entitled, “Updated NEXUS Cross-Section Methodology,” and can be identified by its document and addendum number, WCAP-16045-P-A, Addendum 2.

The NEXUS methodology is used with the PARAGON and ANC codes. PARAGON is a standalone neutron transport code based on collision probability techniques and approved for use as a standalone lattice physics code and as a cross-section generation tool for core simulators, such as ANC, for uranium-fueled pressurized water reactors (PWRs). ANC is a core simulator code system which performs calculations based on nuclear data supplied by a code such as PARAGON or PHOENIX-P. The NEXUS methodology is a reparameterization of the PARAGON nuclear data output and a new reconstruction approach within the ANC core simulator code to simplify the use of this code system for practical applications. The NEXUS methodology acts as an intermediate step between PARAGON and ANC, establishing a new NEXUS/ANC code system, while still using PARAGON to generate the key cross-section data.

Westinghouse states that the updated NEXUS methodology will advance the ability of the Westinghouse NEXUS/ANC neutronics analysis methodologies to model accident conditions with high local void or core pressure changes, more effectively capture the effect of each individual physics parameter, and consistently and efficiently provide more accurate cross-sections at any core conditions.

2.0 BACKGROUND

The current version of the NEXUS cross-section methodology has been licensed by the NRC since 2007. The current NEXUS methodology has been licensed for uranium-fueled PWRs and as the subject of this evaluation is the second addendum to WCAP-16045-P-A, it will also be evaluated with respect to uranium-fueled PWRs.

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Cross-sections vary with local neutron spectrum. In the 2007 NEXUS cross-section methodology, the local spectrum is characterized by the node-averaged parameters of spectrum index (SI), fuel temperature (T_f), and moderator temperature (T_m). This methodology is somewhat limited in that it cannot account for explicit feedback or perturbation from individual physics parameters because the SI, which represents the overall shape of the neutron spectrum and is affected by physics parameters, is not separable for individual parameters.

[

] A local

spectrum can be represented and parameterized using the physical local state parameters of:

[

] The physical local state parameters provide individual feedback effects in the cross-section representation.

The subject addendum of review, WCAP-16045-P-A, Addendum 2, Revision 0, is intended to replace all existing uses of the currently licensed NEXUS methodology.

3.0 REGULATORY EVALUATION

The current NEXUS methodology, and by extension, the proposed updated NEXUS methodology described in Addendum 2, were developed primarily to satisfy NRC regulatory guidelines to meet the regulatory requirements established in Title 10, "Energy," of the U.S. *Code of Federal Regulations* (CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities," Section 34, "Contents of applications; technical information" to provide safety analysis reports to the NRC detailing the performance of structures, systems, and components provided for the prevention or mitigation of potential accidents. The core physics calculations from the NEXUS/ANC system are used to confirm that key parameters assumed in the safety analysis reports remain bounded by the licensing basis analyses for any given core design.

4.0 TECHNICAL EVALUATION

4.1 Description of Methodology

The NEXUS cross-section methodology provides a linkage between the lattice code PARAGON (WCAP-16045-P-A) and the core simulator ANC (WCAP-10965-P-A). PARAGON is a neutron transport code and is used as a standalone lattice physics code and as a cross-section generation tool for core simulators. ANC is a core simulator code system which performs calculations based on nuclear data supplied by a lattice code such as PARAGON. The NEXUS methodology is a reparameterization of the PARAGON nuclear data output and a reconstruction approach within ANC that simplifies the use of the PARAGON/ANC code system for design use. The currently licensed version of NEXUS characterized the local spectrum using the SI which is the ratio of fast-to-thermal group node average fluxes, T_f , and T_m . During accident conditions when the moderator is no longer in subcooled conditions or the core pressure changes significantly, temperature only representations of the moderator are not precise. The SI represents the overall shape of the neutron spectrum and is affected by any physical state parameter (e.g., boron concentration, moderator density, temperatures, actual fuel history). The SI is a calculated state parameter, so it presents specific challenges when explicit feedback is needed for an individual physics parameter.

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The currently licensed NEXUS uses the following information to develop the lattice code calculations which are referred to in the TR as the calculational matrix:

[

]

Updated NEXUS replaces the SI approach with a new cross-section reformulation methodology.

[

] In addition, a thermal expansion correction will more accurately model the geometric differences between hot and cold reactor conditions. The updated NEXUS methodology will also explicitly include the samarium spectrum effect based on number densities, and a pin-wise spectrum correction that allows for a more accurate representation of the effects on the surrounding environment.

In addition, for the updated NEXUS methodology, the calculational matrix will also include the following:

[

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While currently licensed NEXUS remains an accurate and valid cross-section methodology, updated NEXUS provides a broader range of capabilities and improved computational efficiency.

4.2 Qualification of Single Assembly Model Calculations

The NRC staff reviewed the qualification of the single assembly model calculations in Section 3.1 of the TR. In this section, Westinghouse compared the updated NEXUS results to those of the PARAGON lattice code. The single assemblies were 2D models with infinite boundary conditions. The qualification included six assemblies which containing various uranium enrichments and burnable poison loadings. The following lattices were evaluated:

- Westinghouse-type 17x17 OFA assembly, 5.0 w/o ²³⁵U, 156 1.5x integral fuel burnable absorber (IFBA), 24 wet annular burnable absorber (WABA)
- Westinghouse-type 14x14 assembly, 4.0 w/o ²³⁵U, 64 IFBA

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- Westinghouse-type 15x15 assembly, 4.5 w/o ^{235}U , 116 IFBA
- Combustion Engineering-type 16x16 assembly, 4.2 w/o (average), 16 6 w/o Gd_2O_3 rods
- Westinghouse-type 17x17 standard-size fuel rod assembly, 4.95 w/o ^{235}U , 48 IFBA
- Westinghouse-type 17x17 OFA assembly, 2.6 w/o ^{235}U

Full-power and off-power calculations were completed for power levels between 40 percent and 160 percent. These calculations were completed for the burnup range of 0 to 82000 megawatt-days per metric ton uranium (MWD/MTU) and soluble boron concentrations of 0 to 1800 parts per million (ppm). The k-infinity, measured in percent milli (pcm), values generated from the updated NEXUS methodology were compared to the PARAGON generated k-infinity values.

[

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These conditions which exhibited the deviation from the acceptance criteria Westinghouse used are not typical in an operating reactor, do not depict reality, and therefore, are unnecessary to be met to qualify this application. The updated NEXUS results exhibited reasonable results in comparison to the PARAGON lattice code for single assembly calculations for full and off-power calculations.

The NRC staff also reviewed the results of the calculations at zero-power cold conditions. The same acceptance criteria were used for these calculations [

] The cold temperatures analyzed were 68°F, 300°F, and 500°F and two restart depletions of 0 ppm and 2600 ppm were used. Each of these restart temperatures and depletions were calculated at intervals between 0 MWD/MTU and 82000 MWD/MTU. Each of the above described lattices was first depleted at 0 ppm, 900 ppm, and 1800 ppm soluble boron before the restart conditions. The results of the calculations were within the acceptance criteria except for the [

] The updated NEXUS calculations at the zero-power cold conditions provided reasonable results when compared to the PARAGON lattice code.

The updated NEXUS methodology incorporates cross-section calculations at voided conditions as a new feature. The updated NEXUS methodology has de-coupled the moderator temperature from the moderator density, allowing for calculations during voided conditions. The qualification of this new feature of NEXUS follows the same logic as the single assembly qualification – comparison between values updated NEXUS and PARAGON. The first step in this process is to demonstrate that PARAGON can accurately model the voided conditions. PARAGON was validated against Monte Carlo N-particle Transport Code (MCNP). In the request for additional information (RAI)-3 response, Westinghouse states that MCNP has a

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continuous energy spectrum library. The continuous energy spectrum library means MCNP calculations are not limited by fuel composition. When qualifying updated NEXUS to PARAGON, Westinghouse used the targeted acceptance criteria of [] consistent with the other single assembly validations.

[

]

The qualification calculations were completed at -2 percent, 5 percent, 15 percent, 25 percent, and 40 percent void and for the two soluble boron concentrations of 0 ppm and 2600 ppm. The negative void is an instance of increased pressure above normal operating pressure. The results of most of the calculations up to the 40 percent void were within the acceptance criteria.

[

] The updated NEXUS

methodology demonstrates acceptable results.

The NRC staff reviewed the effect the cross-section re-homogenization has on the pin power distribution. It is noted that the fundamental pin power calculation methodology does not change between versions of NEXUS/ANC, only the cross-section calculations. In this qualification, the Westinghouse-type 17x17 standard-size fuel rod assembly, 4.95 w/o ²³⁵U, 48 IFBA lattice was analyzed. The single assembly pin power calculations were directly compared between the improved NEXUS/ANC and the current NEXUS/ANC. The comparisons included both rodded and unrodded cases. For the unrodded case, calculated at a burnup of 20000 MWD/MTU, the maximum difference between improved NEXUS/ANC and the current NEXUS/ANC is 0.003, i.e. 0.3%, occurring at the edge of the lattice.

Additionally, the NRC staff reviewed two rodded case scenarios presented in the TR. In these calculations, the maximum assembly power and an individual pin power are evaluated. The individual pin chosen was next to a guide thimble which allows for the improved methodology to be evaluated in a scenario which there is a strong impact from the control rod on the pin. The maximum difference in power by using the improved NEXUS/ANC methodology is approximately 1 percent. This minor difference in power confirms the improved NEXUS/ANC methodology is acceptable.

4.3 Qualification of Mini-core Model Calculations

The NRC staff reviewed Section 3.2 of the TR which discusses the performance of a simulated mini-core model. The applicant's mini-core analysis was based on the ANC9 (designated as ANC971R) Re-homogenization Project methodology. The NRC staff reviewed the results of the applicant's verification and validation of ANC9 to confirm that the test adequately captured the re-homogenization effects. The TR accurately describes the applicant's analysis of a NEXUS/ANC mini-core model with reflective boundary conditions which was expected to produce similar eigenvalues when compared to the PARAGON calculation using reflective boundary conditions.

The NRC staff reviewed the TR which describes the process that the applicant used to develop and evaluate a 3x3 UO₂-MOX checker-board mini-core (TR Figure 10 Configuration of 3x3 Mini-

Core) so that they could accurately evaluate the impact of the NEXUS/ANC re-homogenization method. The NEXUS/ANC mini-core model used in the TR included five MOX and four UO₂ fuel assemblies with reflective boundary conditions to evaluate the potential impacts of inter assembly interactions between MOX and UO₂ assemblies in a core. The k_{∞} with and without the re-homogenization correction were evaluated and compared to the PARAGON eigenvalues in Table 31 of the TR. During the closed regulatory audit conducted on October 8-9, 2019, the NRC staff noted that the values in Table 31 of the TR were incorrect as compared to the discussion. The NRC staff requested the Table 31 values to be corrected in RAI-2. The NRC staff reviewed the updated results of the k_{∞} with re-homogenization and determined that the results were very similar to the PARAGON prediction. While the models discussed above used MOX fuel as an extreme example of a neutronically dissimilar fuel assembly, the NRC staff expects that any use of the NEXUS methodology in licensing applications involving MOX fuel would utilize the update process described in the TR and RAI responses.

The NRC staff also reviewed the applicant's comparison of the assembly power distribution in the mini-core model with and without the re-homogenization model (TR Figure 11 Comparison of Assembly Power Comparison for Mini-Core Case). The NRC staff compared the ANC assembly power distribution with and without re-homogenization in the mini-core model with the results of the PARAGON model. The NRC staff determined that the ANC re-homogenization model results were very similar to the PARAGON predicted eigenvalues. Based on the results of the mini-core assembly power distribution comparison the NRC staff believes that NEXUS/ANC will correctly capture the expected interaction effects between dissimilar fuel assemblies.

The NRC staff have reviewed the applicants mini-core re-homogenization model results and conclude that NEXUS/ANC will accurately predict fuel reactivity and pin power distribution in a mini-core model with reflective boundary conditions.

4.4 Qualification of Pressurized Water Reactor Core Calculations

The use of the improved NEXUS methodology to evaluate full-scale applications was assessed through validation studies using five different full-scale cores. Four of the cores represent actual plants for which measured values are available, and the fifth is a theoretical equilibrium core. In some cases, multiple cycles for the same core were simulated as part of the validation of the improved NEXUS methodology. The validation studies included the following core designs:

- Four cycles for a 217-assembly Combustion Engineering (CE) plant with 16x16 fuel utilizing gadolinia as a burnable absorber.
- Five cycles for a 193-assembly Westinghouse PWR plant with 17x17 OFA fuel utilizing IFBA as a burnable absorber.
- Three cycles for a 157-assembly Westinghouse PWR plant with 17x17 standard fuel utilizing IFBA as a burnable absorber.
- The initial cycle for a 157-assembly Westinghouse AP1000® plant with 17x17 fuel utilizing WABA and IFBA as burnable absorbers.
- A theoretical equilibrium cycle for a 193-assembly Westinghouse PWR plant with 17x17 standard fuel.¹

¹ TR states that this is a 4-loop plant, which means 193 assemblies. The specific burnable absorbers used in this cycle design is not specified in the TR, however, the other cores cover the spectrum of

For all cores, key physics parameters were calculated using the improved NEXUS methodology with the ANC code (also known as the improved NEXUS/ANC system), as follows: at-power critical boron concentration curves, at-power axial offset, startup test physics predictions (i.e., cold critical boron concentration and isothermal temperature coefficients), assembly power and radial peaking distributions, control rod worths, and reactivity parameters for several temperatures representing cold conditions (critical boron concentration and rod worth). Representative results are presented in the TR; however, additional results were reviewed during the closed regulatory audit and the NRC staff confirmed that the results included in the TR are consistent with the overall body of validation work performed by the applicant.

The primary intent of the validation studies was to demonstrate that the improved NEXUS methodology provides equivalent or better results relative to the previously approved NEXUS methodology. In some cases, measured data was presented to show how the predictions from the improved NEXUS/ANC system compared to real-world results. Overall, the improved NEXUS/ANC system produces results that are comparable to, or better than, the previously approved NEXUS/ANC system. The NRC staff noted that in certain situations, such as the isothermal temperature coefficient, the improved NEXUS methodology results in an ANC prediction that is about 1 pcm/°F more negative than the previous methodology for the 157-assembly Westinghouse PWR plant. As a result, the measured values are about 0.8-0.9 pcm/°F more positive than the predicted values from the improved NEXUS/ANC system. However, this trend was not observed for the AP1000® plant, and this deviation is within the bounds of acceptable uncertainties.

The NRC staff also noted that as part of the description for a proposed update process, the applicant presented a set of acceptance criteria in Table 37 (Section 4 of the TR) that are consistent with the uncertainties typically assumed in any safety related applications. The differences between the measured and predicted values for the full PWR core calculations are within the bounds of the acceptance criteria (see next section of this SE for further discussion). However, the bulk of the calculations are intended to demonstrate that the differences between the improved NEXUS methodology and the previously approved NEXUS methodology are acceptable. Based on the small changes in most parameters and clear improvement in other parameters, the NRC staff finds this conclusion to be appropriate.

The NRC staff finds that the full PWR core calculations to be acceptable in demonstrating that the improved NEXUS methodology has similar or better predictive accuracy for ANC compared to the previously approved NEXUS methodology, based on comparison of the calculated data from both methodologies. Furthermore, based on the comparisons between measured and predicted data presented in the TR, the NRC staff finds that the improved NEXUS/ANC system can be expected to provide reasonably accurate predictions of key physics parameters for full PWR cores.

4.5 Evaluation of the Process for Future Code/Methodology Modifications

Section 4 of the TR describes a process that the applicant proposes to use in order to make modifications to the NEXUS code or methodology without requiring prior NRC review and approval. A list of different modifications that are envisioned by the applicant to be appropriate

burnable poisons used in the current fleet of light water reactors, so this was not important to support the NRC staff's findings.

for this process includes “the use of different or additional state parameters in the formulation of the nuclear cross-sections, improved thermal hydraulic modeling, improved fuel rod thermal modeling, and use of an improved multi energy group cross-section structure.” The NRC staff noted that this scope suggests a very broad set of changes. Essentially, the key features of the NEXUS methodology that would not be changed include:

- The use of an approved lattice code (e.g., PARAGON) to generate the data for parametrization.
- The use of selected parameters such as those described in the TR, with a calculational matrix to parametrize the cross-sections from the lattice code.
- The use of the NEXUS methodology with an approved 3D core simulator code (e.g., ANC) to produce predictions.

In order to implement future changes, Westinghouse proposes a benchmarking/validation process with acceptance criteria defined in Table 37. The acceptance criteria cover the key core physics parameters for startup testing and normal operations that confirm key assumptions in the safety analyses continue to be valid for a given core design. The criteria are based on currently licensed uncertainties, or the uncertainties assumed in licensing basis safety analyses. The proposed process would continue to maintain the presence of NRC approved codes to support the lattice and 3D core calculations and would ensure that any changes are confirmed to yield appropriate accuracy relative to measured data.

However, the NRC staff had some concerns about the robustness of the proposed process to ensure that the NEXUS methodology will remain applicable for all its intended applications as described in the TR. As a result, the NRC staff requested further information to clarify how the process would be applied in different situations.

First, the NRC staff requested more information in part 1 of RAI-1 to clarify the area of applicability for any updated NEXUS methodologies when validated using the process described in the TR. The applicant responded (Ref. 2) by clarifying that there are two different kinds of updates that may be made. First, a change may be made to the cross-section representation within the NEXUS methodology, for example, by addition or replacement of state parameters used to reformulate the cross-sections. The goal of the NEXUS methodology is to accurately represent the cross-sections generated by the lattice code. Therefore, the validation of any changes to the NEXUS cross-section representation would be based on a demonstration that calculations executed with the NEXUS/ANC system will lead to the same physics predictions as calculations performed using the lattice code. This validation would be performed using mini-core models which are modeled using both the lattice code and the NEXUS/ANC system. If the key physics parameters are essentially the same, then the NEXUS/ANC system is shown to accurately represent the cross-sections generated by the lattice code.

The other kind of change involves the lattice codes rather than the NEXUS cross-section representation, which may include changes to PARAGON or use of a different lattice code. In this case, not only does the cross-section representation need to be confirmed for accuracy, the overall NEXUS/ANC predictions also need to be benchmarked to ensure that the changes do not invalidate uncertainties assumed in the safety analyses. Table 37 in the LTR lists the relevant uncertainty bands to verify. The response provided for part 1 of RAI-1 provides a summary of the data from different conditions and plant configurations that would be used in this validation.

The proposed validation processes for each of the two types of changes that may affect the predictions made by the NEXUS/ANC methodology are consistent with the expected impacts of these changes. Therefore, the NRC staff finds that the proposed validation processes can reasonably be expected to capture any errors or inappropriate deviations in the accuracy of the NEXUS/ANC predictions, subject to the limitation and condition discussed at the end of this section.

The NRC staff questioned whether the proposed validation process for any updates to the NEXUS methodology would appropriately account for the potential presence of both biases and uncertainties. Treating a systematic bias could yield non-conservative results if treated like an uncertainty. The applicant stated in its response to Part 2 of RAI-1 that the goal of the NEXUS methodology is to produce the same results as the lattice code, therefore, any significant bias would be unacceptable. Section 3 of the TR defines the criteria by which deviations are assessed to be significant or not. However, the lattice code itself could have a bias compared to measured data. Therefore, any updates to the lattice code that propagate forward to the NEXUS/ANC code system must be benchmarked to ensure that the assumptions in the safety analysis codes remain valid. In the RAI response, the applicant stated that the conservative extreme of the tolerance band would be used, ensuring that both the bias and uncertainty are accounted for in the comparison to the acceptance criteria. The NRC staff finds this disposition to be acceptable based on the following findings: (1) any changes to the lattice code would be restricted to those which do not constitute a change to the methodology described in the approved TR associated with that lattice code; (2) any differences between the NEXUS/ANC predictions relative to the lattice code would be restricted to a tight tolerance range; and (3) the bias and uncertainty in the NEXUS/ANC predictions will be verified to be bounded by the values used for key parameters in the safety analyses.

Future applications for the NEXUS/ANC code system may involve novel fuel or structural materials, such as accident tolerant fuel cladding or advanced spacer grid materials. For first-time applications of such materials, measurements may not yet be available. Westinghouse stated in its response to Part 3 of RAI-1 that this information gap will be addressed through benchmarking of the NEXUS/ANC predictions against a high-fidelity transport code that meets certain criteria for acceptance as a state of art code capable of capturing the effects of the materials, geometry, and neutron spectrum on the neutronics of the lattice. First-time applications of new materials that are expected to have a significant impact on the neutronics are generally performed as part of a lead test assembly campaign, in which other controls exist to address the inherent uncertainties due to lack of measured data. This approach to validate the NEXUS/ANC methodology for such applications is consistent with current typical practices for application of neutronics methodologies to novel materials, and therefore, is acceptable.

Finally, the NRC staff noted that the proposed update to the NEXUS methodology would extend the range of applicability to partially voided conditions. Measured data are typically not available for such conditions, so this is not a viable approach for validation of the NEXUS/ANC code system. In response to Part 4 of RAI-1, the applicant stated that the lattice code would need to be approved for use at any off-normal conditions. This approval may occur based on alternative means beyond comparison to measured data at the plant. If the lattice code is qualified for the desired off-normal conditions, then the NEXUS/ANC predictions can be compared to the lattice code in order to confirm that the appropriate cross-sections and reactivities are reproduced by the NEXUS/ANC code system. Since the NRC must review and approve the lattice code for the intended application, and the NEXUS/ANC validation process

will ensure that the predictions from the two code systems are consistent, the NRC staff finds this to be an acceptable approach to validate use of the code system for off-normal conditions.

As discussed above, the NRC staff reviewed the proposed update process for the NEXUS/ANC code and methodology and obtained some additional information from the applicant to clarify how the updated methodology would be validated. The responses provided by Westinghouse were generally satisfactory to describe the application of the validation process. However, the descriptions do not provide a clear definition of the area of applicability for any given validation. Therefore, the NRC staff found it necessary to impose a limitation and condition which requires any application of the NEXUS/ANC predictions that support safety related parameters or controls to have core geometry, compositions, and operating conditions that are reasonably represented or bounded by the mini-cores, operating data, and/or high-fidelity transport calculations, as appropriate. In addition, certain core aspects of the NEXUS parametrization process cannot be modified without undermining the technical basis for approval of the NEXUS methodology and its subsequent validation for use in licensing applications. Therefore, an additional limitation and condition is being imposed to ensure that these aspects of the NEXUS methodology are not modified through the update process.

5.0 LIMITATIONS AND CONDITIONS

The following limitations and conditions apply to any use of the updated NEXUS methodology, as updated through the update process described in Section 4 of the TR, for licensing applications.

1. For any specific licensing application of the NEXUS methodology to support safety related parameters or controls, the mini-cores, measured datasets, and/or high-fidelity transport calculations used to validate the NEXUS code being used must be sufficiently representative, or bound, all compositions, geometries, and operating conditions associated with the licensing application in question.
2. Certain features of the NEXUS methodology cannot be updated or changed using the process described in Section 4 of the TR. The features are as follows:
 - a. The lattice code must be consistent with the methodology described in an NRC approved TR;
 - b. The parametrization must be performed based on cross-sections generated by the lattice code within an appropriate calculational matrix that covers the range of expected operating conditions, as described in the TR; and
 - c. The resulting use of NEXUS with an NRC approved 3D core simulator code must be independently validated through comparison to mini-core calculations, measured plant data, and/or high-fidelity transport calculations, as described in the TR and RAI responses.

6.0 CONCLUSIONS

In WCAP-16045-P-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology," Westinghouse presented a reparameterization of the PARAGON nuclear data output and a new reconstruction approach within the ANC core simulator code to simplify the use of this code system for practical applications.

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The NRC staff finds that the methodology, as described in Addendum 2 and responses to the NRC staff RAI questions, adequately demonstrates that NEXUS accurately predicts cross-sections under a wide range of core conditions. In addition, the NRC staff finds that the procedure described for modification of the methodology is adequate with the addition of the limitations and conditions as described in Section 5.0 of this SE. As such, NRC staff approval of WCAP-16045-P-A, Addendum 2, Revision 0, is contingent on adherence to the limitations and conditions.

7.0 REFERENCES

1. Letter from K. L. Hosack, Manager, Product Line Regulatory Support, Westinghouse, to NRC Document Control Desk, "Submittal of WCAP-16045-P-A Addendum 2/ WCAP-16045-NP-A Addendum 2, 'Updated NEXUS Cross-Section Methodology,' Revision 0 (Proprietary/Non-Proprietary)," dated June 26, 2019 (ADAMS Accession No. ML19179A091).
2. Letter from K. L. Hosack, Manager, Product Line Regulatory Support, Westinghouse, to NRC Document Control Desk, "Responses to NRC Request for Additional Information for Westinghouse Topical Report WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, 'Updated NEXUS Cross-Section Methodology,'" dated March 3, 2020 (ADAMS Accession No. ML20066G642).
3. Letter from B. F. Mauer, Acting Manager, Regulatory Compliance and Plant Licensing, Westinghouse, to NRC Document Control Desk, "Submittal of WCAP-16045-P-A, Addendum 1/WCAP-16045-NP-A, Addendum 1, 'Qualification of the NEXUS Nuclear Data Methodology,' for NRC Review and Approval (Proprietary/Non-Proprietary)," dated November 29, 2005 (ADAMS Accession No. ML053460154).
4. Letter from J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse, to NRC Document Control Desk, "Submittal of Approved Versions of WCAP-16045-P-A Addendum 1-A/WCAP-16045-NP-A Addendum 1-A, 'Qualification of the NEXUS Nuclear Data Methodology' (TAC No. MC9606); WCAP-16523-P-A/ WCAP-16523-NP-A, 'Westinghouse Correlations WSSV and WSSV-T for Predicting Critical Heat Flux in Rod Bundles with Side-Supported Mixing Vanes' (TAC No. MID0561); and CENPD-132-P-A Supplement 4-P-A Addendum 1-P-A/CENPD-132-NP-A Supplement 4-NP-A Addendum 1-NP-A, 'Calculative Methods for the CE Nuclear Power Large Break LOCA Evaluation Model: Improvement to 1999 Large Break LOCA EM – Steam Cooling Model for Less Than 1 in/sec Core Reflood' (TAC No. MD2161) (Proprietary/Non-proprietary)," dated September 7, 2007 (ADAMS Accession No. ML072570325).

Attachment: Comment Resolution

Principal Contributors: Diana Woodyatt
Scott Krepel

Date: July 21, 2020

RESOLUTION OF COMMENTS ON DRAFT SAFETY EVALUATION FOR

TOPICAL REPORT WCAP-16045-P-A, AND WCAP-16045-NP-A,

ADDENDUM 2, REVISION 0,

“UPDATED NEXUS CROSS-SECTION METHODOLOGY”

WESTINGHOUSE ELECTRIC COMPANY

EPID L-2019-TOP-0026

WESTINGHOUSE ELECTRIC COMPANY

By letter dated June 18, 2020 (Agencywide Documents Access and Management System Accession No. ML20121A306), Westinghouse Electric Company (Westinghouse) provided comments on the draft safety evaluation (SE) for Topical Report (TR) WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, “Updated NEXUS Cross-Section Methodology.” Westinghouse stated that there is proprietary information in the draft SE. The following is the U.S. Nuclear Regulatory Commission (NRC) staff’s resolution of these comments:

Draft SE comments for TR WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0:

1. Fifth sentence of the first paragraph of Section 4.2, “Qualification of Single Assembly Model Calculations,” reads in the draft SE:

The following lattices were evaluated:

- Westinghouse-type 17x17 OFA assembly, 5.0 w/o ²³⁵U, 156 1.5x integral fuel burnable absorber (IFBA), 24 wet annual burnable absorber (WABA)
- Westinghouse-type 14x14 assembly, 4.0 w/o ²³⁵U, 64 IFBA
- Westinghouse-type 15x15 assembly, 4.5 w/o ²³⁵U, 116 IFBA
- Combustion Engineering-type 16x16 assembly, 4.2 w/o (average), 16 6 w/o Gd₂O₃ rods
- Westinghouse-type 17x17 standard-size fuel rod assembly, 4.95 w/o ²³⁵U, 48 IFBA
- Westinghouse-type 17x17 OFA assembly, 2.6 w/o ²³⁵U

Westinghouse proposed to replace “annual” with “annular,” so the sentence would read:

The following lattices were evaluated:

- Westinghouse-type 17x17 OFA assembly, 5.0 w/o ²³⁵U, 156 1.5x integral fuel burnable absorber (IFBA), 24 wet annular burnable absorber (WABA)
- Westinghouse-type 14x14 assembly, 4.0 w/o ²³⁵U, 64 IFBA
- Westinghouse-type 15x15 assembly, 4.5 w/o ²³⁵U, 116 IFBA
- Combustion Engineering-type 16x16 assembly, 4.2 w/o (average), 16 6 w/o Gd₂O₃ rods
- Westinghouse-type 17x17 standard-size fuel rod assembly, 4.95 w/o ²³⁵U, 48 IFBA
- Westinghouse-type 17x17 OFA assembly, 2.6 w/o ²³⁵U

NRC Resolution for Comment 1 on Draft SE

The NRC staff has reviewed the Westinghouse comment and agrees that proposed wording provides additional clarification. The NRC staff has updated the second sentence of the first paragraph of Section 4.2, “Qualification of Single Assembly Model Calculations.”

2. Westinghouse suggested replacing “pcm” with “, i.e. 0.3%,” in the fifth sentence of the sixth paragraph in Section 4.2, “Qualification of Single Assembly Model Calculations.”

NRC Resolution for Comment 2 on Draft SE

The NRC staff has reviewed Westinghouse comment and agrees that proposed wording provides additional clarification. The NRC staff has replaced “pcm” with “, i.e. 0.3%,” in the fifth sentence of the sixth paragraph in Section 4.2, “Qualification of Single Assembly Model Calculations.”

Fifth sentence of the sixth paragraph in Section 4.2, “Qualification of Single Assembly Model Calculations,” now reads:

The comparisons included both rodded and unrodded cases. For the unrodded case, calculated at a burnup of 20000 MWD/MTU, the maximum difference between improved NEXUS/ANC and the current NEXUS/ANC is 0.003, i.e. 0.3%, occurring at the edge of the lattice.

3. Last sentence of the second paragraph of Section 4.3, “Qualification of Minicore Model Calculations,” reads:

In the absence of actual plant data, NEXUS/ANC has not been approved for MOX or non UO₂ fueled reactors.

Westinghouse suggested to re-word the sentence to clarify it.

NRC Resolution for Comment 3 on Draft SE

The NRC staff agrees that clarification is needed. The NRC staff re-worded last sentence of the second paragraph of Section 4.3, "Qualification of Minicore Model Calculations," which now reads:

While the models discussed above used MOX fuel as an extreme example of a neutronically dissimilar fuel assembly, the NRC staff expects that any use of the NEXUS methodology in licensing applications involving MOX fuel would utilize the update process described in the TR and RAI responses.

4. Westinghouse provided proprietary markings on the draft SE.

NRC Resolution for Comment 4 on Draft SE:

The NRC staff reviewed the Westinghouse markings and incorporated them into the final SE.

5. Westinghouse provided editorial comments.

NRC Resolution for Comment 5 on Draft SE:

The NRC staff reviewed editorial comments provided by Westinghouse and finds them acceptable because the changes are editorial in nature.

Section C
Submittal of Topical Report



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LTR-NRC-19-34

June 26, 2019

Subject: Submittal of WCAP-16045-P-A Addendum 2/WCAP-16045-NP-A Addendum 2, "Updated NEXUS Cross-Section Methodology," Revision 0 (Proprietary/Non-Proprietary)

Enclosed are the proprietary and non-proprietary approved versions of WCAP-16045-P-A Addendum 2/WCAP-16045-NP-A Addendum 2, "Updated NEXUS Cross-Section Methodology," Revision 0, dated June 2019.

This submittal contains proprietary information of Westinghouse Electric Company LLC ("Westinghouse"). In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Nuclear Regulatory Commission's ("Commission's") regulations, we are enclosing with this submittal an Application for Withholding Proprietary Information from Public Disclosure and an Affidavit. The Affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the proprietary aspects of the Application for Withholding or the Westinghouse Affidavit should reference AW-19-4908 and should be addressed to Camille T. Zozula, Manager, Infrastructure & Facilities Licensing, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Suite 165, Cranberry Township, Pennsylvania 16066.



Korey L. Hosack, Manager
Product Line Regulatory Support

cc: Ekatrina Lenning
Dennis Morey

Enclosures:

1. Westinghouse Affidavit AW-19-4908
2. Proprietary Information Notice and Copyright Notice
3. WCAP-16045-P-A Addendum 2, "Updated NEXUS Cross-Section Methodology," Revision 0 (Proprietary)
4. WCAP-16045-NP-A Addendum 2, "Updated NEXUS Cross-Section Methodology," Revision 0 (Non-Proprietary)

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

COUNTY OF BUTLER:

- (1) I, Korey L. Hosack, have been specifically delegated and authorized to apply for withholding and execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse).
- (2) I am requesting the proprietary portions of LTR-NRC-19-34 be withheld from public disclosure under 10 CFR 2.390.
- (3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged, or as confidential commercial or financial information.
- (4) Pursuant to 10 CFR 2.390, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.
 - (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse and is not customarily disclosed to the public.
 - (ii) Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.
- (5) Westinghouse has policies in place to identify proprietary information. Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

AFFIDAVIT

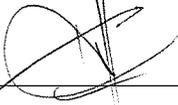
- (a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.
 - (b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage (e.g., by optimization or improved marketability).
 - (c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.
 - (d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.
 - (e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.
 - (f) It contains patentable ideas, for which patent protection may be desirable.
- (6) The attached documents are bracketed and marked to indicate the bases for withholding. The justification for withholding is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (5)(a) through (f) of this Affidavit.

AFFIDAVIT

I declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: 20190624



Korey L. Hosack, Manager
Product Line Regulatory Support

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1 INTRODUCTION

The NEXUS methodology is a reparameterization of the PARAGON (Reference 4) nuclear data output and a new reconstruction approach within the ANC core simulator code (Reference 1) to simplify the use of this code system for design use. The current version of the NEXUS methodology (Reference 2) has been licensed by the NRC for uranium-fueled pressurized water reactors (PWRs).

The NEXUS methodology provides a linkage between the lattice code PARAGON and ANC. PARAGON is a stand-alone neutron transport code based on collision probability techniques and approved for use as a stand-alone lattice physics code and as a cross-section generation tool for core simulators, such as ANC, for uranium-fueled PWRs. ANC is a core simulator code system which performs calculations based on nuclear data supplied by a code such as PARAGON or PHOENIX-P.

Westinghouse has developed an improved version of the NEXUS cross-section methodology, referred to in this report as Updated NEXUS. This updated methodology will enable NEXUS to:

- Model accident conditions with high local void or core pressure change
- More effectively capture the effect of each individual physics parameter
- Consistently and efficiently provide more accurate cross-sections at any core condition

The improved NEXUS cross-section methodology, i.e., reformulation and rehomogenization methodology, has been developed and qualified. Westinghouse is seeking an approval of the updated NEXUS methodology to be used in the NEXUS/ANC code system, as a direct replacement of all existing uses of the currently licensed NEXUS methodology in References 2 and 3 for both normal operating and accident conditions.

2 METHODOLOGY

2.1 CROSS-SECTION DATA REFORMULATION

2.1.1 Currently Licensed NEXUS Methodology

NEXUS adopts a once-through cross-section representation methodology to generate node-wise two-group assembly nuclear data for Westinghouse nodal code ANC (Reference 1). These assembly average nuclear data, e.g., cross-sections, vary with the local neutron spectrum. The current licensed cross-section methodology (Reference 2) characterizes the local spectrum using three node-average state parameters: (1) spectrum index (SI), the ratio of fast-to-thermal group node-average fluxes, (2) fuel temperature (T_f), and (3) moderator temperature (T_m). This methodology has been successfully applied to pressurized water reactor core design and safety analysis and provides accurate predictions in steady-state operation conditions. However, it is desirable to expand the current NEXUS capability to be able to precisely model an accident condition with high local void or core pressure change (Reference 5). This will enable elimination of overly conservative cross-section calculations.

The SI represents the overall shape of the neutron spectrum and is affected by any physical state parameter (e.g., boron concentration, moderator density, temperatures, actual fuel history). Since the spectrum index is not separable, the current methodology has a significant challenge for the advanced application of NEXUS methodology, especially when the explicit feedback or perturbation is needed from an individual physics parameter. Moreover, the spectrum index is a calculated state parameter rather than a physical one that can be controlled by the user. Consequently, the nodal code is required to perform extra feedback iterations to calculate an updated spectrum index in order to reconstruct nodal nuclear data so as to match the actual local conditions, which reduces the code calculation efficiency.

2.1.2 Updated NEXUS Cross-Section Methodology

[

]^{a,c} Extensive studies (Reference 5) have shown that the local spectrum, even at highly voided conditions, can be represented and parameterized using the following four physical local state parameters:

1) [

]^{a,c}

In order to capture the individual feedback effects of these physical state parameters and avoid double-counting these feedback effects in the simulator cross-section representations, the so-called feedback-free macroscopic cross-sections are adopted using a process similar to currently licensed NEXUS. These feedback-free cross-sections along with microscopic cross-sections of the actinides, fission-products, burnable absorbers, and other explicitly modeled isotopes, are a function of the local neutron spectrum. The local spectrum is determined by the above four local state parameters.

The nodal macroscopic cross-section is deconstructed into a feedback-free cross-section and a number of additive feedback correction terms. The feedback-free cross-section and the fundamental components of the feedback correction terms are all given as the product of a reference cross-section and a spectrum correction factor, which is represented in terms of the above four state parameters and fuel exposure.

When modeled in the nodal code, the feedback-included macroscopic cross-sections for each node are reconstructed by correcting the reference feedback-free macroscopic cross-section using the actual conditions of the node.

Additional feedback corrections are added to this cross-section to account for the composition difference from the feedback-free contents. These feedbacks include []^{a,c} using spectral and history corrected microscopic cross-sections and the corresponding isotopic number densities which are tracked individually for each node in the nodal code. All burnable absorbers are tracked explicitly, and corrections are made to the macroscopic cross-sections for their presence. Macroscopic cross-sections are also corrected for spacer grids and inserted control rods. Finally, the macroscopic cross-section is corrected for the spectral history of the node. All feedback-included macroscopic cross-sections (absorption, fission, etc.) are corrected in this way. The fast and thermal diffusion coefficients are also reconstructed in the same manner.

The fundamental feedback corrections are the microscopic cross-sections representative of the feedback material (i.e., []^{a,c}). Analogous to the macroscopic cross-sections, these microscopic cross-sections are corrected from the reference microscopic cross-sections. The corrections to the microscopic cross-sections include a spectral correction based on the []^{a,c}. Corrections are also made to the microscopic cross-sections based on the presence of a spacer grid and/or absorber inserts (e.g., control rod), and/or removal of discrete burnable absorber rods.

Due to thermal expansion, there is a geometry difference between hot and cold conditions; therefore, []^{a,c} is introduced to the macroscopic cross-sections based on the temperature difference between the reference and actual conditions. With all of the above feedback corrections, the reconstructed macroscopic cross-sections will represent the fuel node at the local conditions at hot dimensions.

As in the currently licensed NEXUS, the corrections for these models are calculated from data generated by the lattice code through the execution of a standardized set of lattice code calculations called the calculational matrix. This matrix includes:

1) [

] ^{a,c}

In addition, for the Updated NEXUS methodology, the calculational matrix also includes:

8) [

] ^{a,c}

All cases are performed over the exposure range of the reference depletion.

Cross-section data are prepared for the core simulator by performing multivariable least squares fits at each exposure point from the lattice code data. The fit for each correction term is calculated using the data from the appropriate branch cases which calculate the effect of that correction. All corrections are made using the reference depletion data as the base.

Depletion history effects are captured in the nodal simulator by explicitly tracking the number densities of actinides and fission products, as well as all burnable absorber nuclides on a node basis. The macroscopic cross-sections for every node in the nodal simulator are adjusted for these feedback effects by using the differences in the node-wise tracked nuclides from their corresponding reference values at the same fuel burnup and the microscopic cross-sections adjusted to the node conditions. A full set of microscopic data including the microscopic cross-section corrections described above is provided for each fission product and actinide isotope tracked by the simulator.

The reconstruction of the cross-sections in NEXUS/ANC is performed using exactly the same fitting formulations that were used in generating the fitting data from the calculational matrix lattice code data. A significant fraction of the qualification effort involves confirming that the lattice code data is accurately reconstructed by ANC. The results of k-infinity comparisons of ANC single assembly calculations against PARAGON calculations performed at identical conditions are presented for several assembly types and configurations in Section 3 of this report. These calculations demonstrate the accuracy of the NEXUS methodology in reproducing the PARAGON results over a wide range of feedback conditions.

2.2 CROSS-SECTION DATA RE-HOMOGENIZATION

As a standard process, reflective boundary conditions are normally used in lattice calculations. With all the feedback data generated from the standard lattice calculations, the reconstructed cross-sections of NEXUS/ANC represent the fuel assembly at a reflective boundary. When there is a strong interaction between the fuel assembly and its surroundings, the reconstructed nodal average cross-sections in NEXUS/ANC do not account for the environmental effect since the interaction impacts both neutron spectrum and flux distribution in the node. The accuracy of the reconstructed cross-sections has been enhanced by the adoption of a re-homogenization methodology.

Theoretically, the nodal homogenous cross-section (Σ_x) is the flux-volume averaged cross-section from the actual fine mesh cross-sections (Σ_x^i) and fluxes (ϕ^i) as:

$$\Sigma_x = \frac{\sum_i \Sigma_x^i \phi^i V^i}{\sum_i \phi^i V^i}$$

[

] a,c

A 3x3 mini-core model is simulated in Section 3.2 to demonstrate the effect and improved accuracy of the cross-section re-homogenization methodology by comparing k-infinity values and assembly power distributions between ANC and PARAGON calculations.

3 QUALIFICATION

3.1 SINGLE ASSEMBLY MODEL CALCULATIONS

The fundamental methodology of updated NEXUS was validated and qualified through single-assembly calculations and directly comparing the results against references that were generated by the PARAGON lattice code. Single-assembly 2D models, assuming reflective boundary conditions, were created using both ANC (using the new NEXUS methodology) and PARAGON. The following fuel lattices were modeled and analyzed in this report:

- Lattice 1: Westinghouse-type 17x17 OFA assembly
Enrichment: 5.0 w/o ^{235}U
Burnable absorber: 156 1.5x IFBA, 24 WABA
Reason for inclusion: 17x17 OFA fuel assembly, high enrichment, very high burnable poison loading
- Lattice 2: Westinghouse-type 14x14 assembly
Enrichment: 4.0 w/o ^{235}U
Burnable absorber: 64 IFBA
Reasons for inclusion: Even lattice Westinghouse assembly with moderate enrichment and burnable absorber loading
- Lattice 3: Westinghouse-type 15x15 assembly
Enrichment: 4.5 w/o
Burnable absorber: 116 IFBA
Reasons for inclusion: 15x15, high power density, high enrichment, high BA loading
- Lattice 4: Combustion Engineering-type 16x16 assembly
Enrichment: 4.2 w/o (average)
Burnable absorber: 16 6w/o Gd_2O_3 rods
Reasons for inclusion: CE assembly, heavy Gd_2O_3 burnable absorber loading
- Lattice 5: Westinghouse-type 17x17 standard-size fuel rod assembly
Enrichment: 4.95 w/o ^{235}U
Burnable absorber: 48 IFBA
Reasons for inclusion: 17x17 standard rod with high enrichment and light/moderate IFBA loading
- Lattice 6: Westinghouse-type 17x17 OFA assembly
Enrichment: 2.6 w/o ^{235}U
Burnable absorber: None
Reasons for inclusion: low enrichment (often used as axial blanket enrichment)

3.1.1 Full Power and Off-Power Depletions

The fuel lattices were depleted at power conditions equivalent to typical reactor operation with various reactor coolant system (RCS) soluble boron levels. The capability of NEXUS to correct the cross-sections for spectral differences permits accurate calculations, at powers other than full power. This is especially true if the depletion at the off-power condition occurs over a long exposure period. To demonstrate this capability, single assembly ANC depletion calculations were performed for each of the six lattice types at six power levels from 40% to 160% power. The k-infinity values from these calculations were compared to PARAGON assembly depletions performed at the corresponding power levels. The comparisons are presented as described below:

Tables 1-6: Full power depletions at different boron levels for each of the six fuel lattices

Tables 7-13: Off-power depletions for lattice type 1 (including restart full power depletion results)

Tables 14-18: Summary results of off-power depletions for lattice types 2 to 6

The burnup values for these tables were chosen so that, with the exception of the 0, 150, and 82000 MWD/MTU burnup points, they would be different from the burnup values used in the calculation matrix. For off-power depletions, the k-infinity comparisons for the 17x17 OFA assembly with 156 IFBA and 24 WABA are shown in detail in Tables 7 to 13. Summaries of the k-infinity results (i.e., the average difference and the maximum difference) are presented for the other assemblies in Tables 14 through 18. Note that both the average difference and the maximum difference are calculated using the absolute magnitude of the differences. [

] ^{a,c}

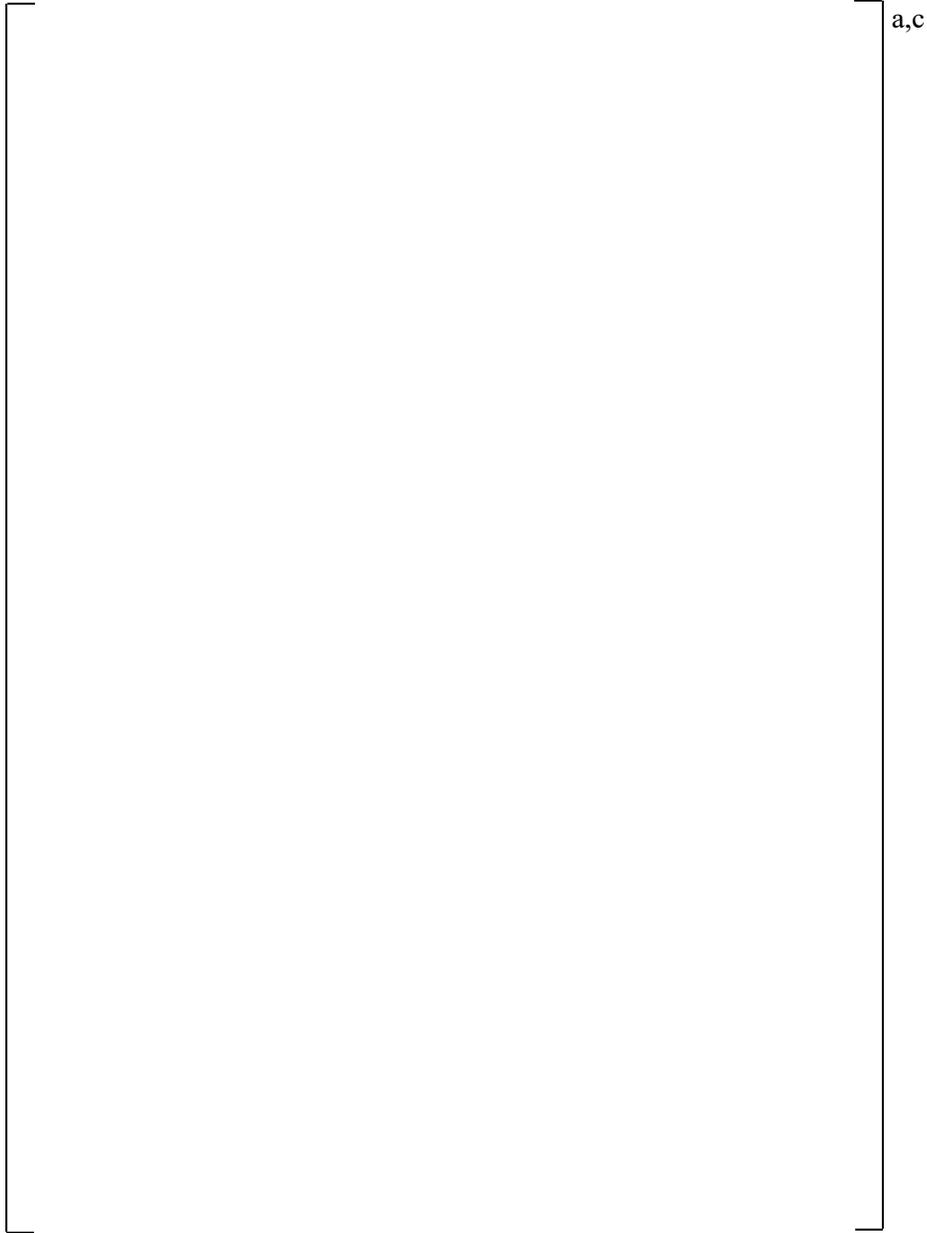
[

] ^{a,c}

Therefore, the results are acceptable for all lattice types at all boron concentrations, power levels and burnup steps.

**Table 1 Westinghouse-type 17x17 OFA Assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Full Power Depletions**

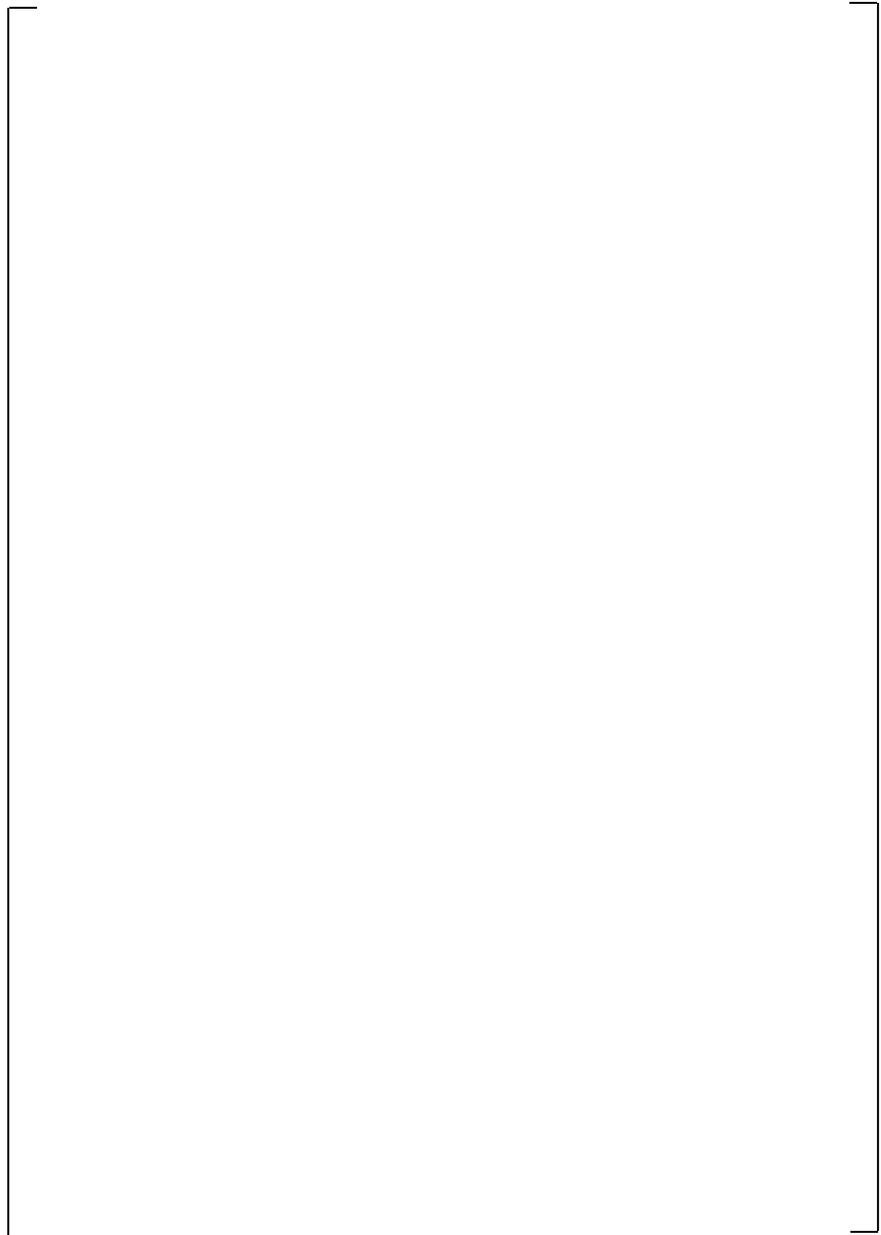
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 2 Westinghouse-type 14x14 Assembly 4.0 w/o ²³⁵U 64 IFBA
Full Power Depletions**

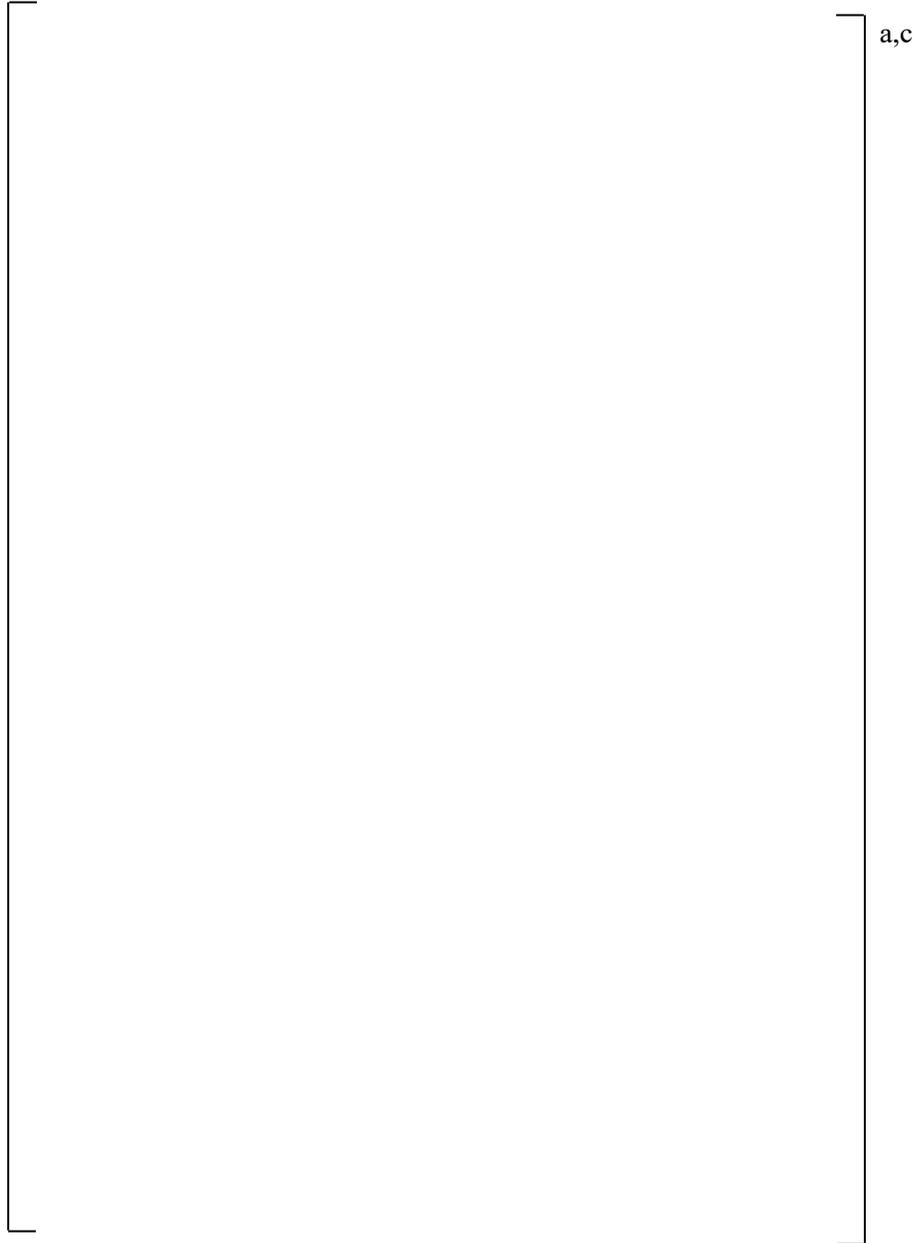
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 3 Westinghouse-type 15x15 Assembly 4.5 w/o 235U 116 IFBA
Full Power Depletions**

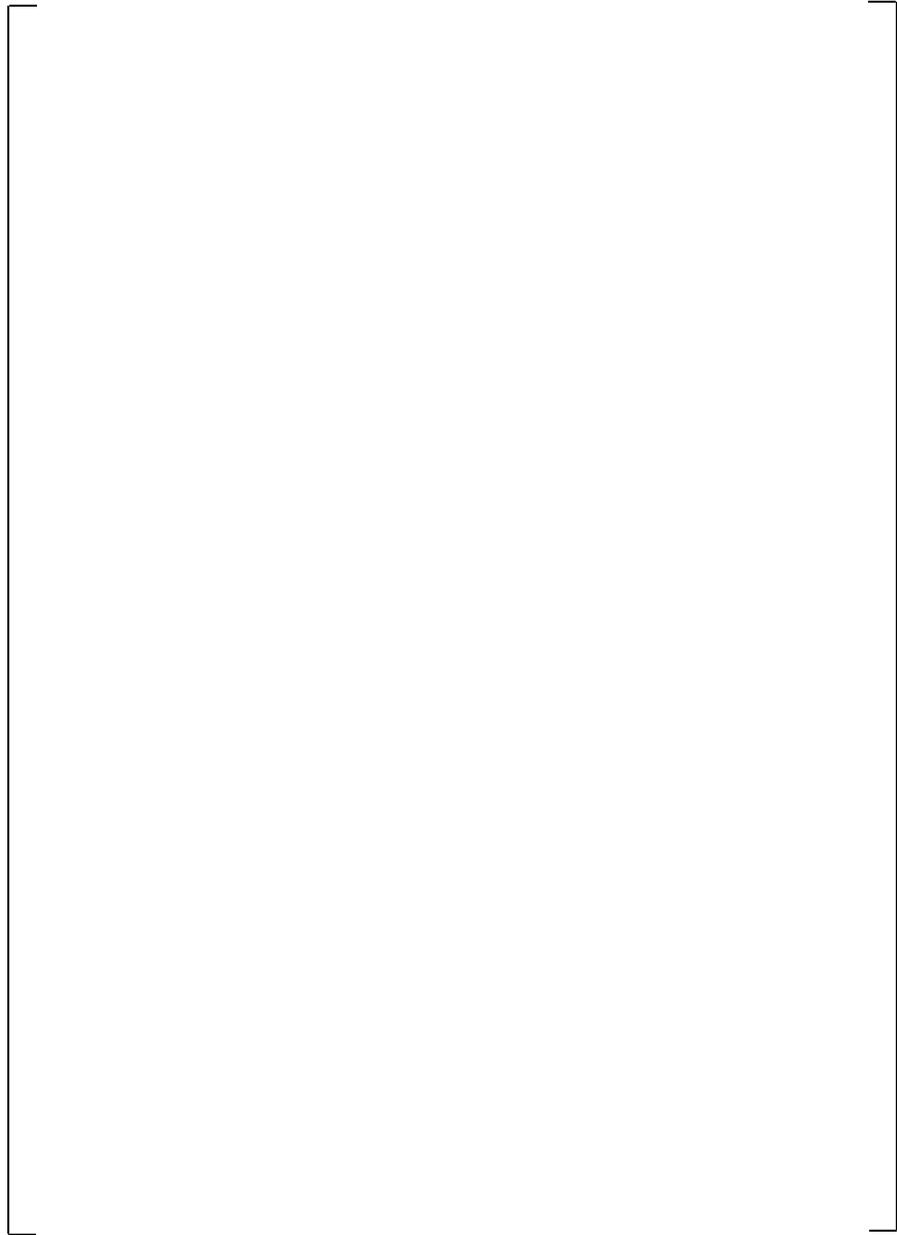
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 4 CE-type 16x16 Assembly 4.2 w/o 235U with 16 Gd2O3 Burnable Absorbers
Full Power Depletions**

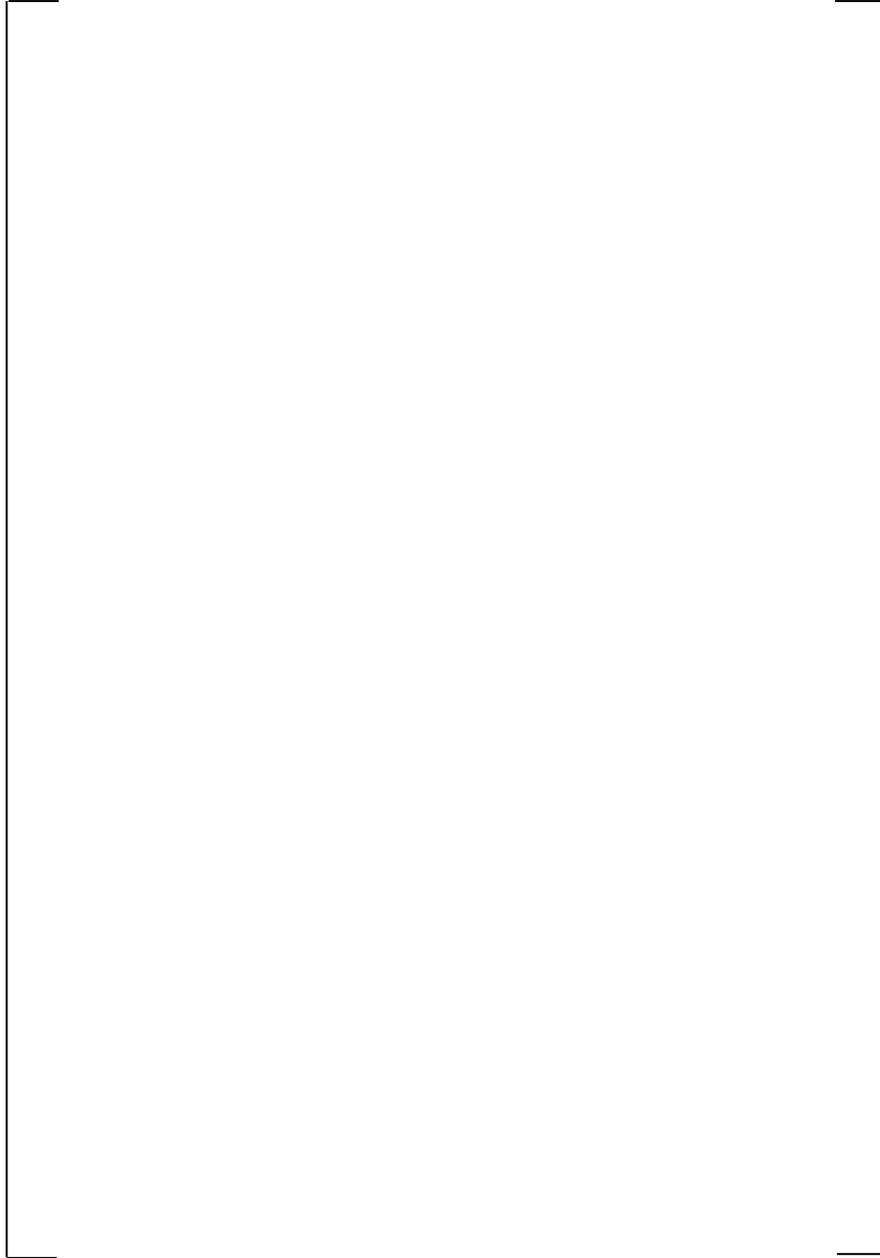
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 5 Westinghouse-type 17x17 Standard Assembly 4.95 w/o 235U 48 IFBA
Full Power Depletions**

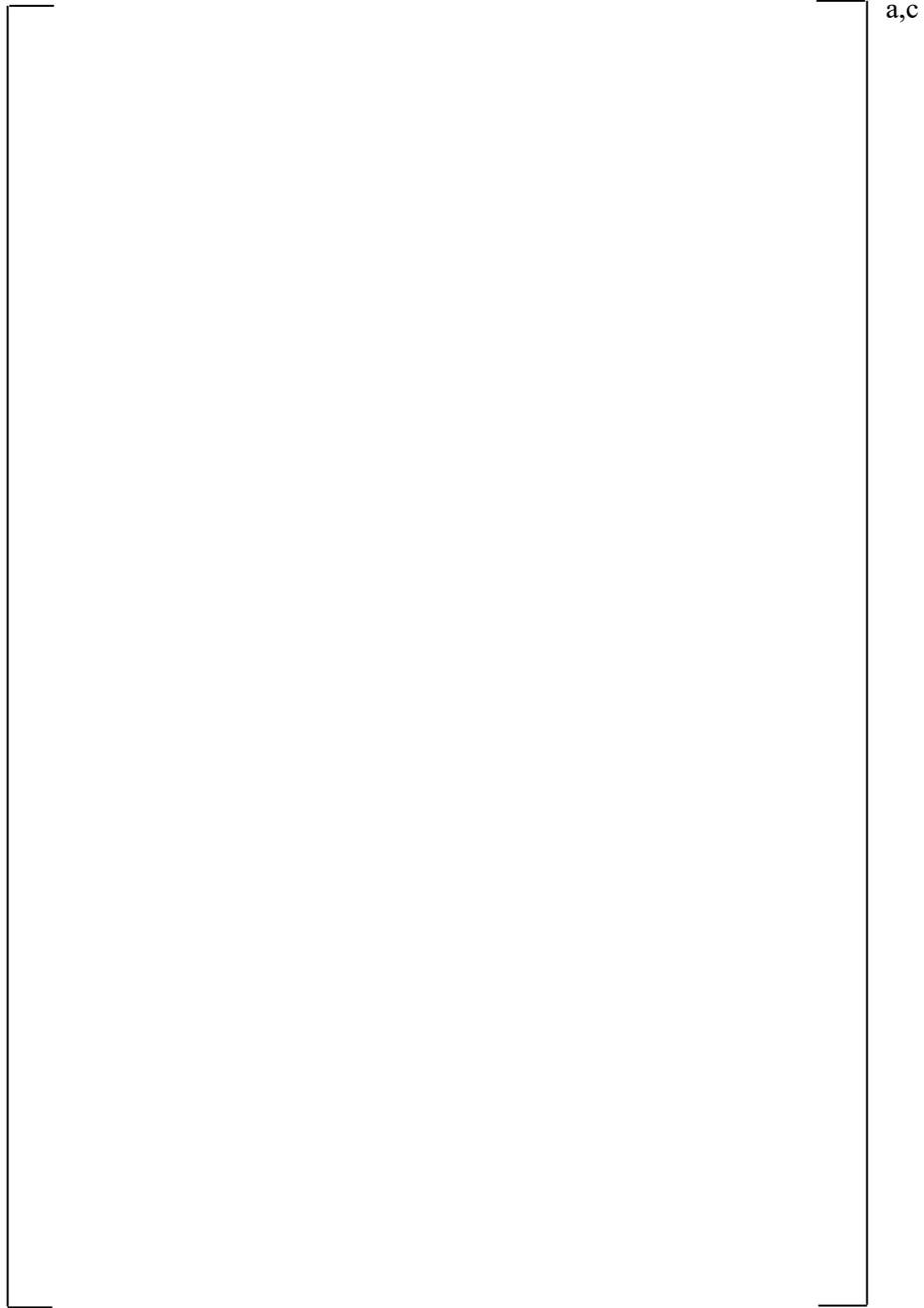
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 6 Westinghouse-type 17x17 OFA Assembly 2.6 w/o 235U No Burnable Absorbers
Full Power Depletions**

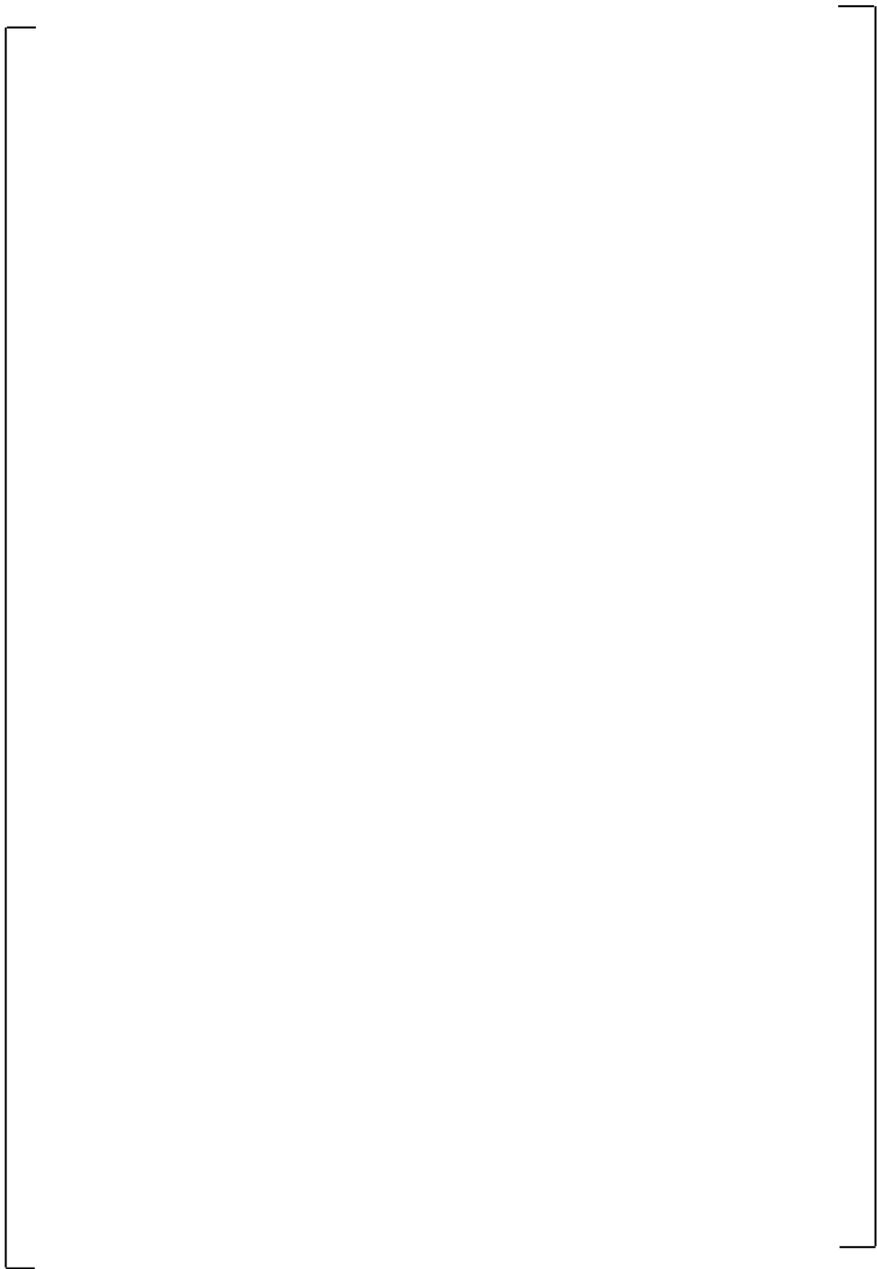
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 7 Westinghouse-type 17x17 OFA Assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Depletions at 40% Power**

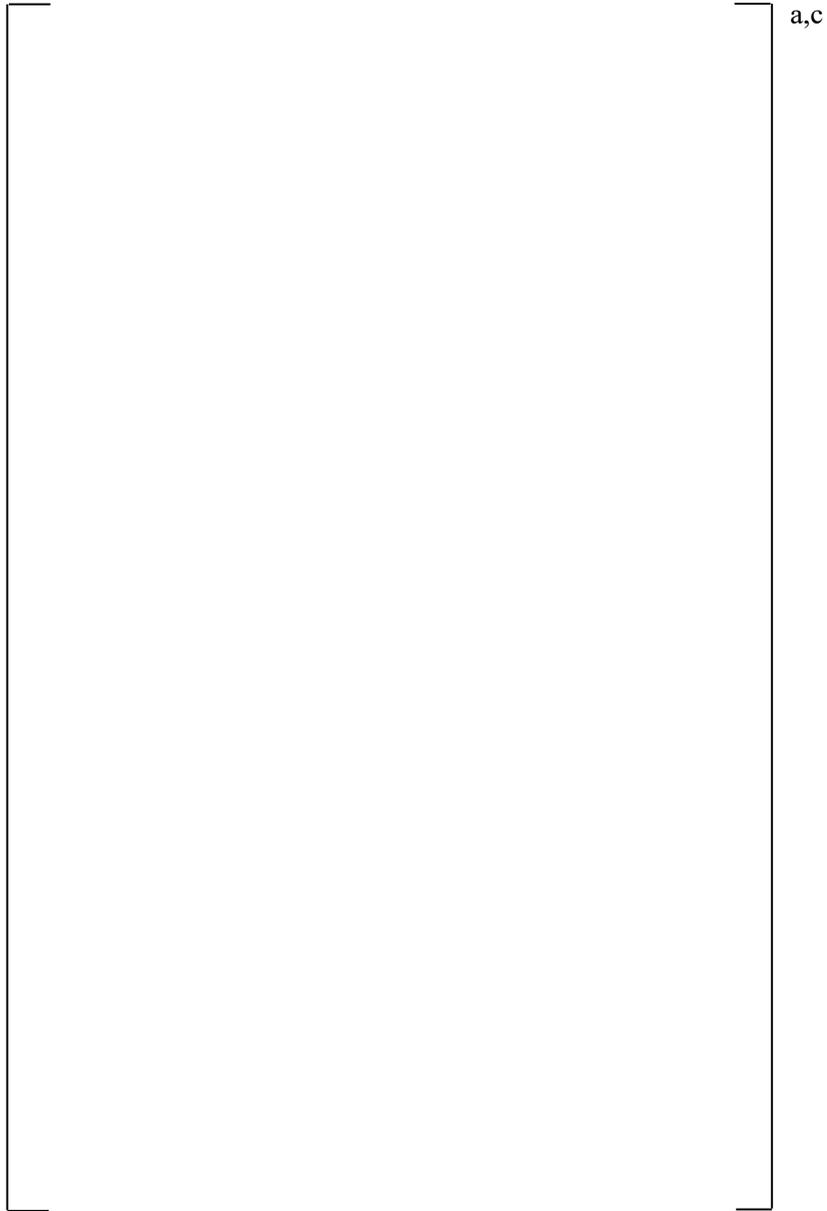
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 8 Westinghouse-type 17x17 OFA Assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Depletions at 60% Power**

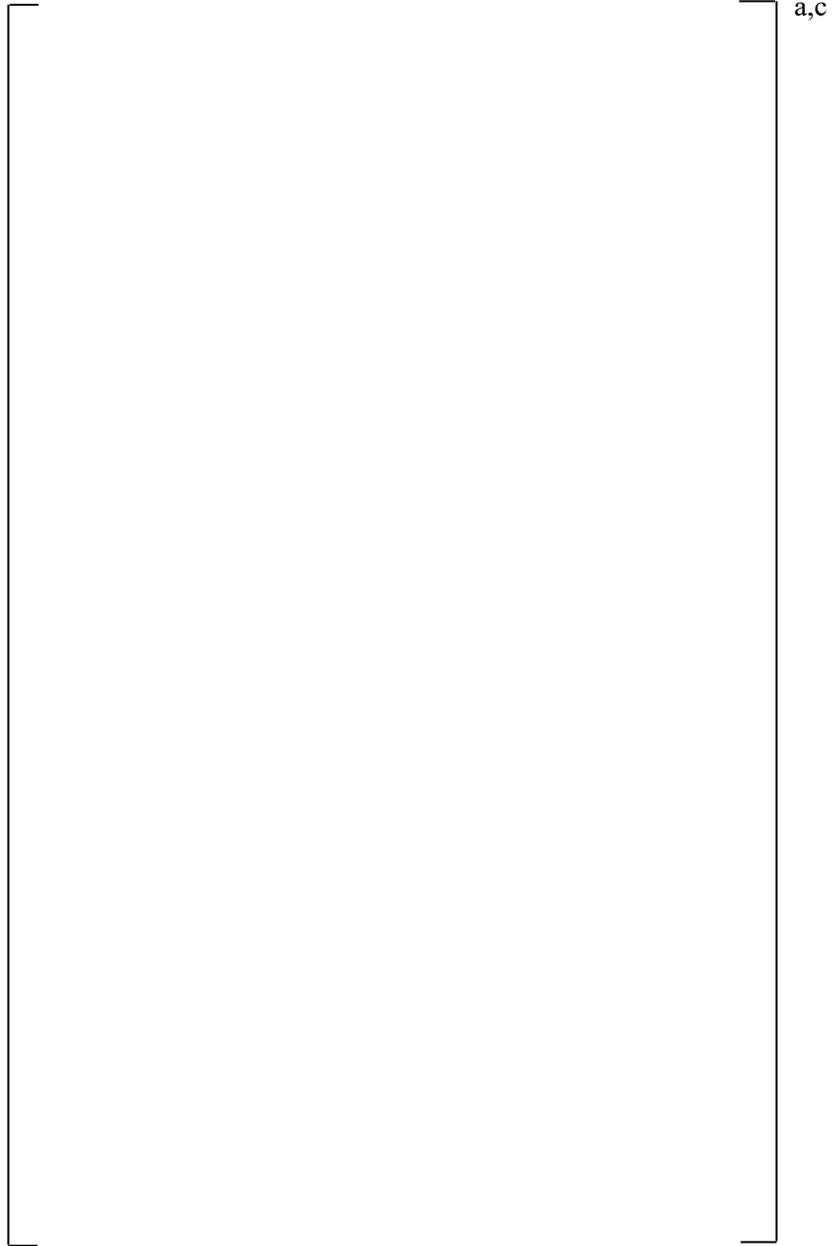
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 9 Westinghouse-type 17x17 OFA Assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Depletions at 80% Power**

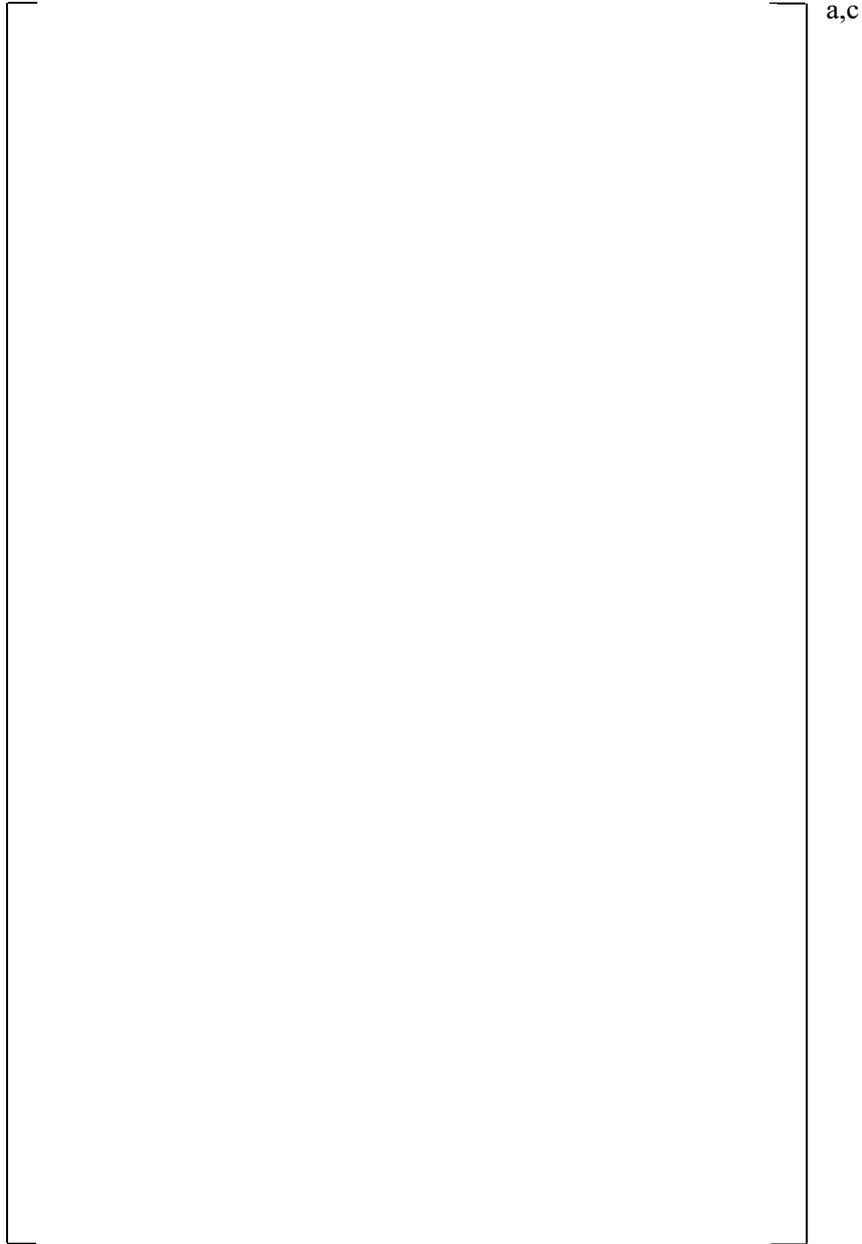
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 10 Westinghouse-type 17x17 OFA Assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Depletions at 100% Power**

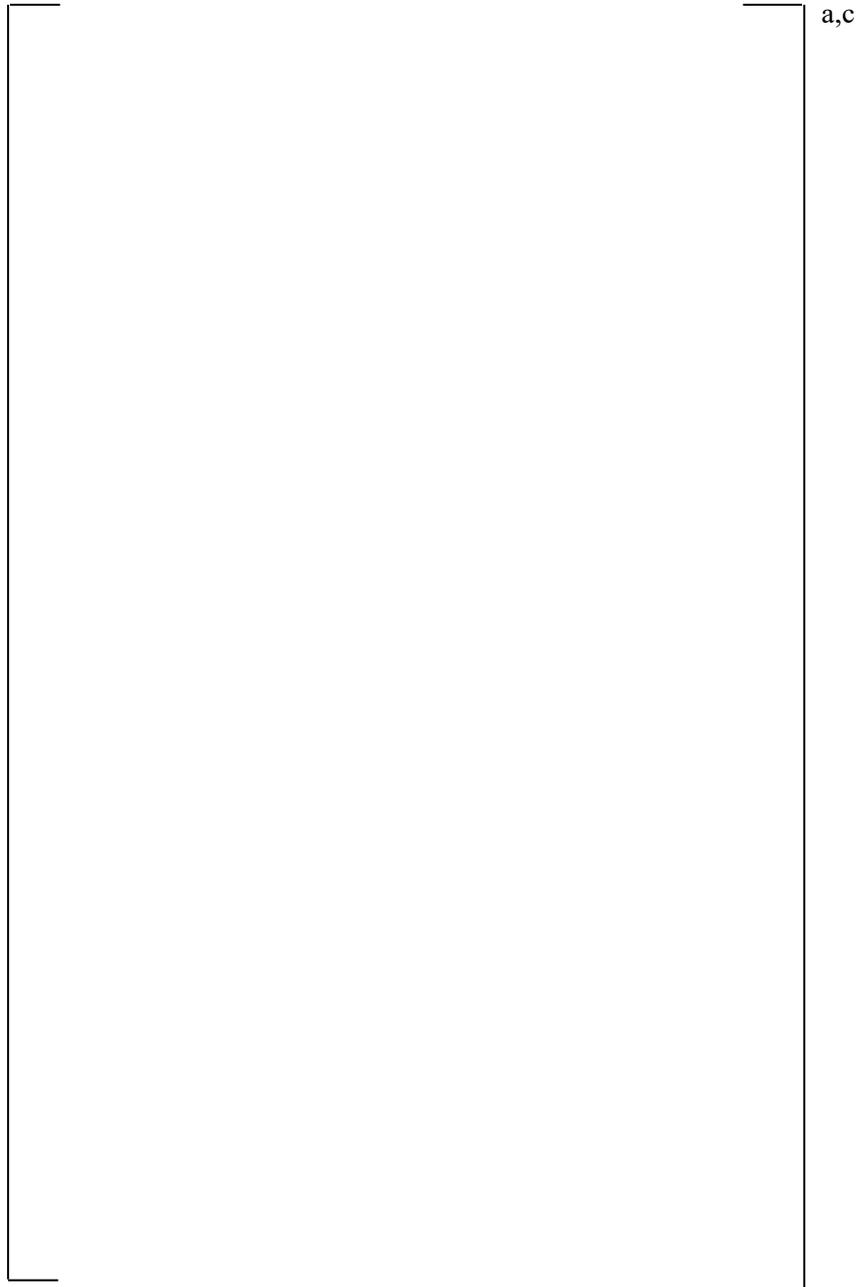
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

Table 11 Westinghouse-type 17x17 OFA Assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA Depletions at 120% Power

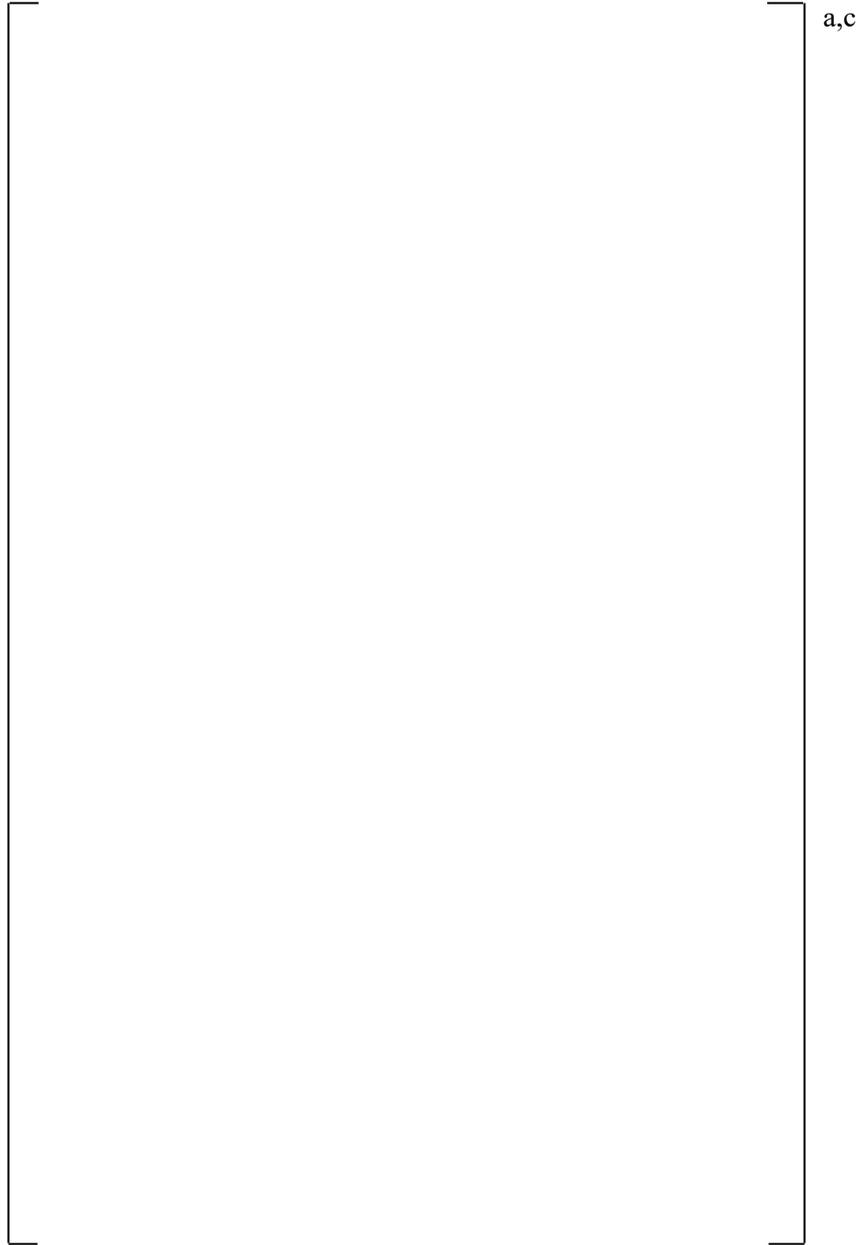
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 12 Westinghouse-type 17x17 OFA assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Depletions at 140% Power**

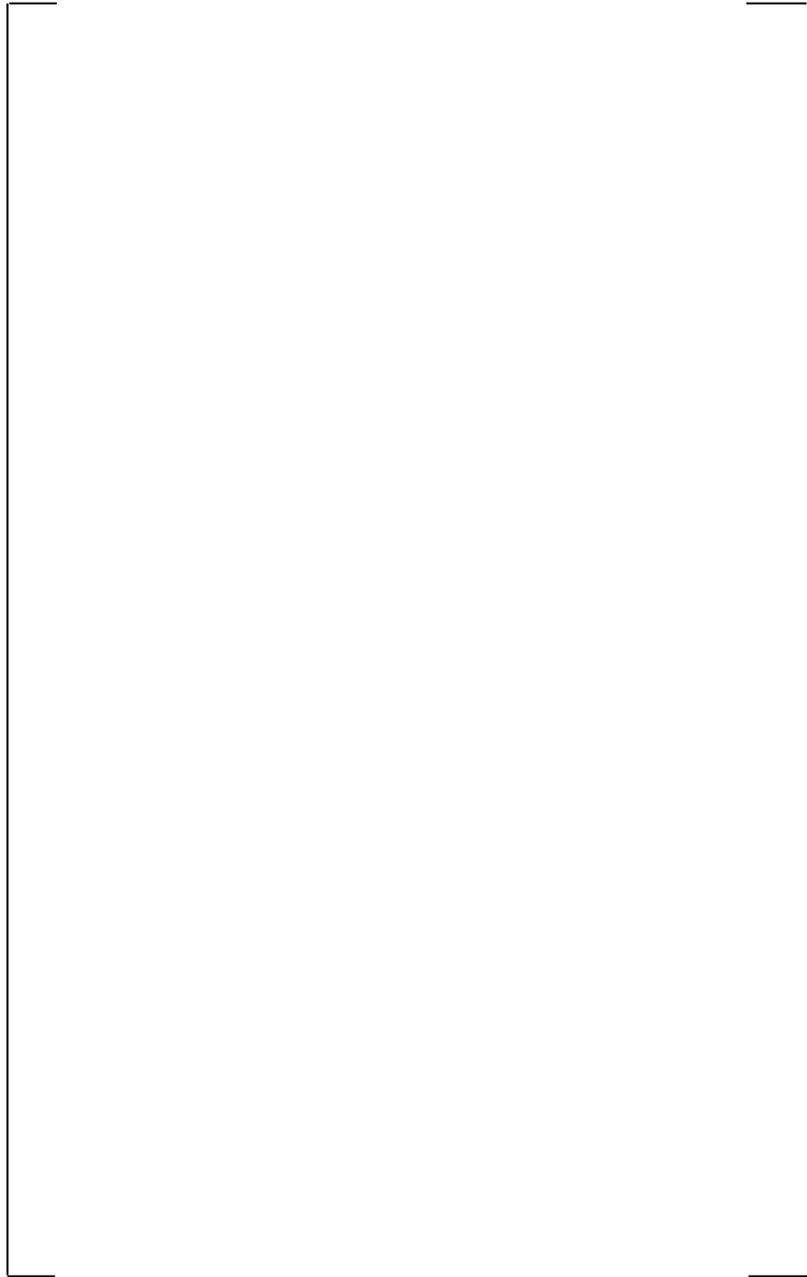
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 13 Westinghouse-type 17x17 OFA assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Depletions at 160% Power**

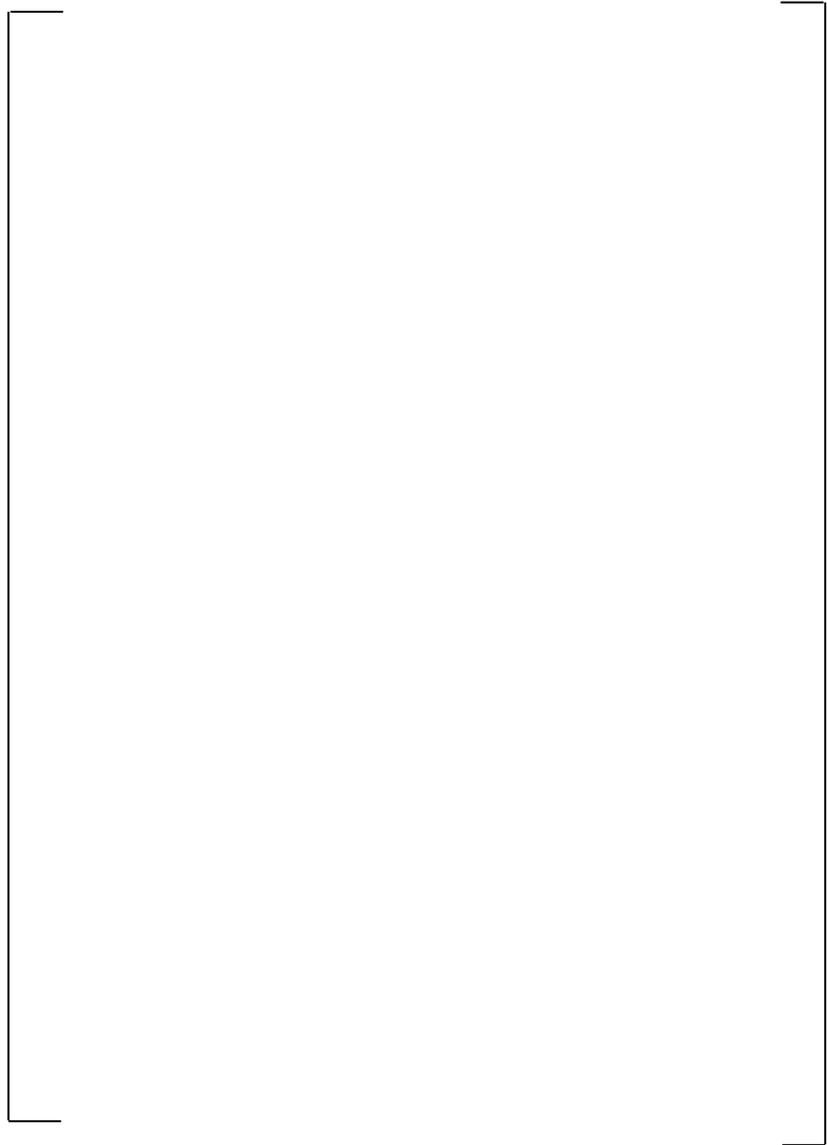
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 14 Westinghouse-type 14x14 Assembly 4.0 w/o ²³⁵U with 64 IFBA
Summary of Differences: Depletions at Powers from 40% to 160%**

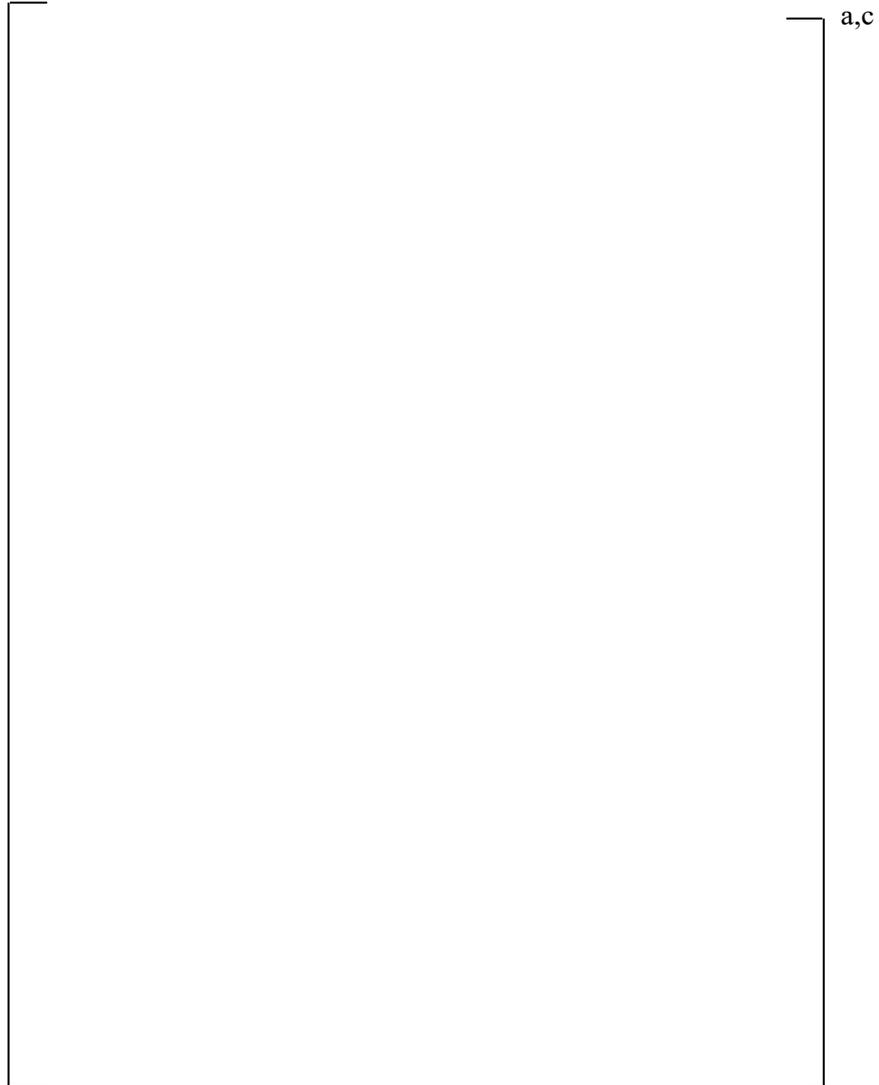
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 15 Westinghouse-type 15x15 Assembly 4.5 w/o ²³⁵U with 116 IFBA
Summary of Differences: Depletions at Powers from 40% to 160%**

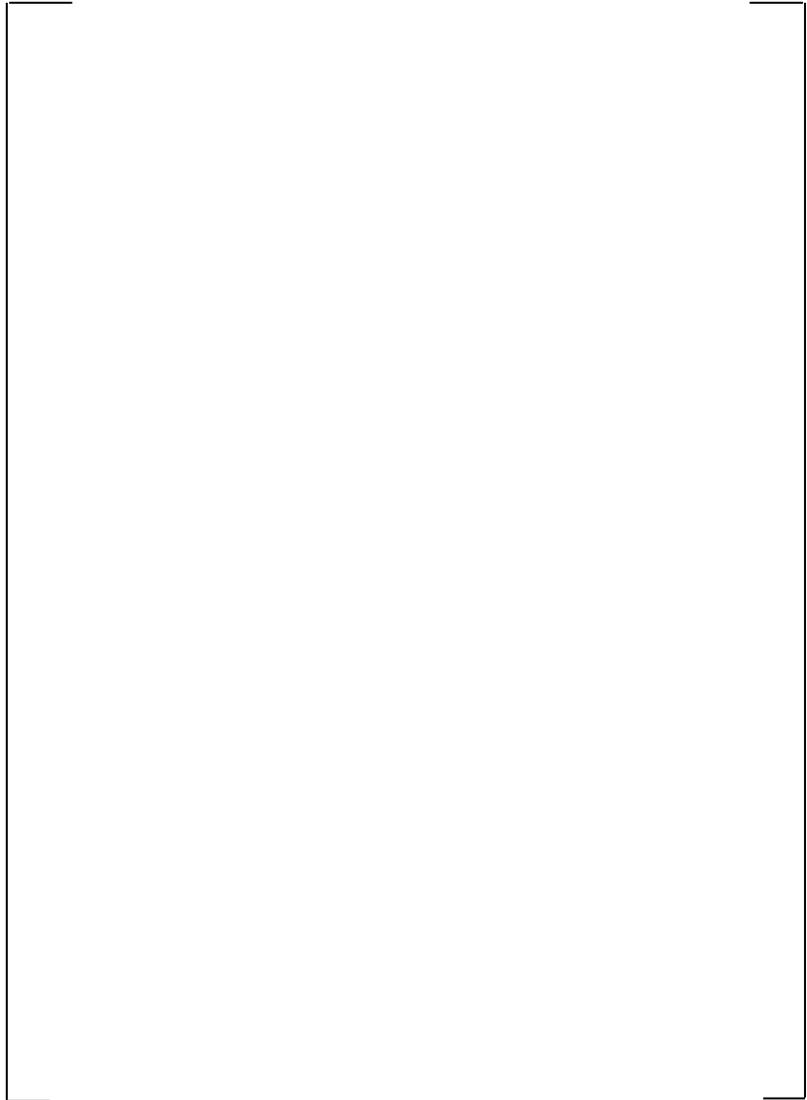
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 16 CE-type 16x16 Assembly 4.2 w/o ^{235}U with 16 Gd_2O_3 Burnable Absorbers
Summary of Differences: Depletions at Powers from 40% to 160%**

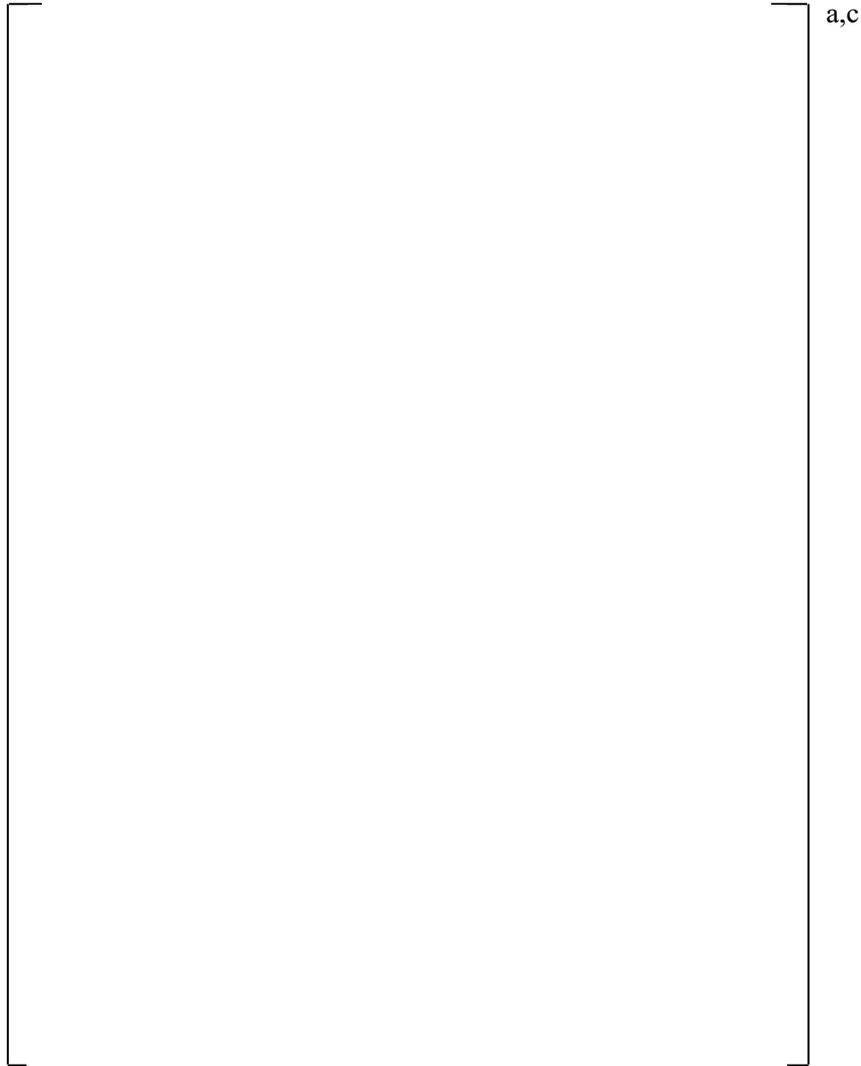
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 17 Westinghouse-type 17x17 Standard Assembly 4.95 w/o ²³⁵U with 48 IFBA
Summary of Differences: Depletions at Powers from 40% to 160%**

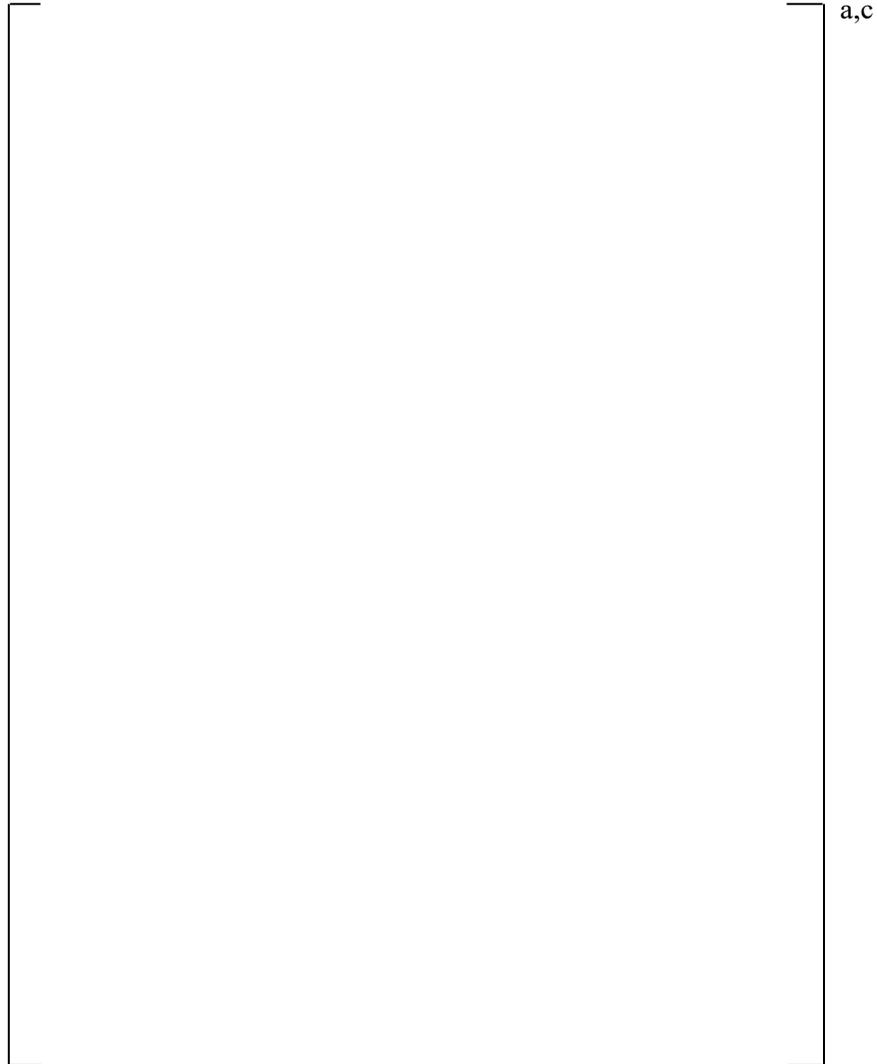
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 18 Westinghouse-type 17x17 OFA Assembly 2.6 w/o ²³⁵U No Burnable Absorbers
Summary of Differences: Depletions at Powers from 40% to 160%**

Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

3.1.2 Zero-Power Cold Calculations

To evaluate the accuracy of calculations at zero-power cold conditions, each of the six lattice types (described in Section 3.1) were first depleted at three different RCS boron concentrations (0, 900 and 1800 ppm), then were restarted at regular depletion step intervals from 0 to 82,000 GWD/MTU, at three “cold” temperatures (68, 300, 500 °F) and two RCS boron concentrations (0 ppm and 2600 ppm). The k-infinity results for the re-converged cold calculations are presented in Tables 19-24.

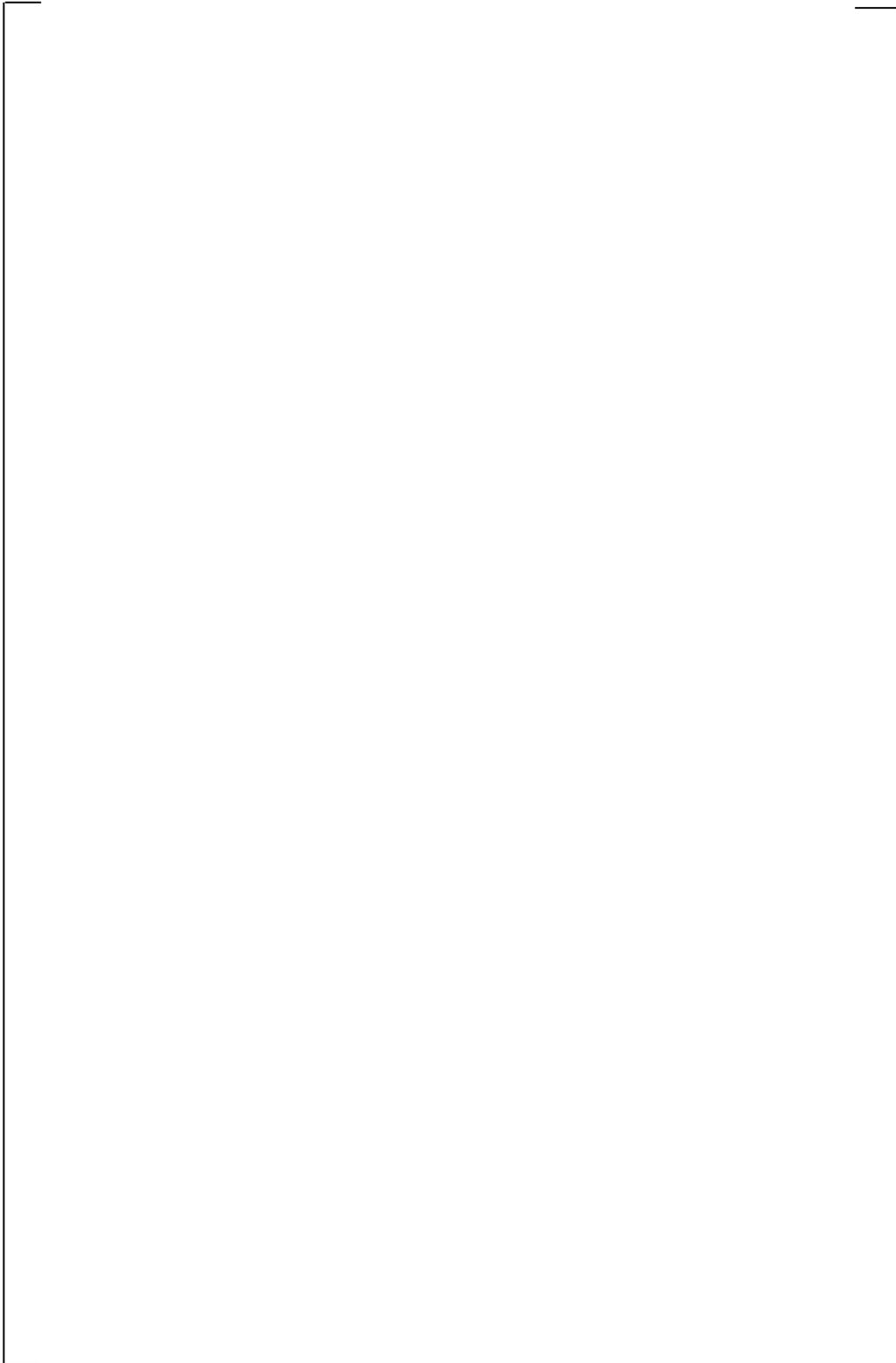
The ability to predict the eigenvalue over a wide variation in restart RCS boron concentrations and temperatures over a wide range of exposures demonstrates that the Updated NEXUS cross-section reformulation methodology is accurate for any condition that could be expected in a PWR core calculation.

The results for these cases are accurate. [

] ^{a,c}

**Table 19 Westinghouse-type 17x17 OFA assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Cold Restart Reactivity Points**

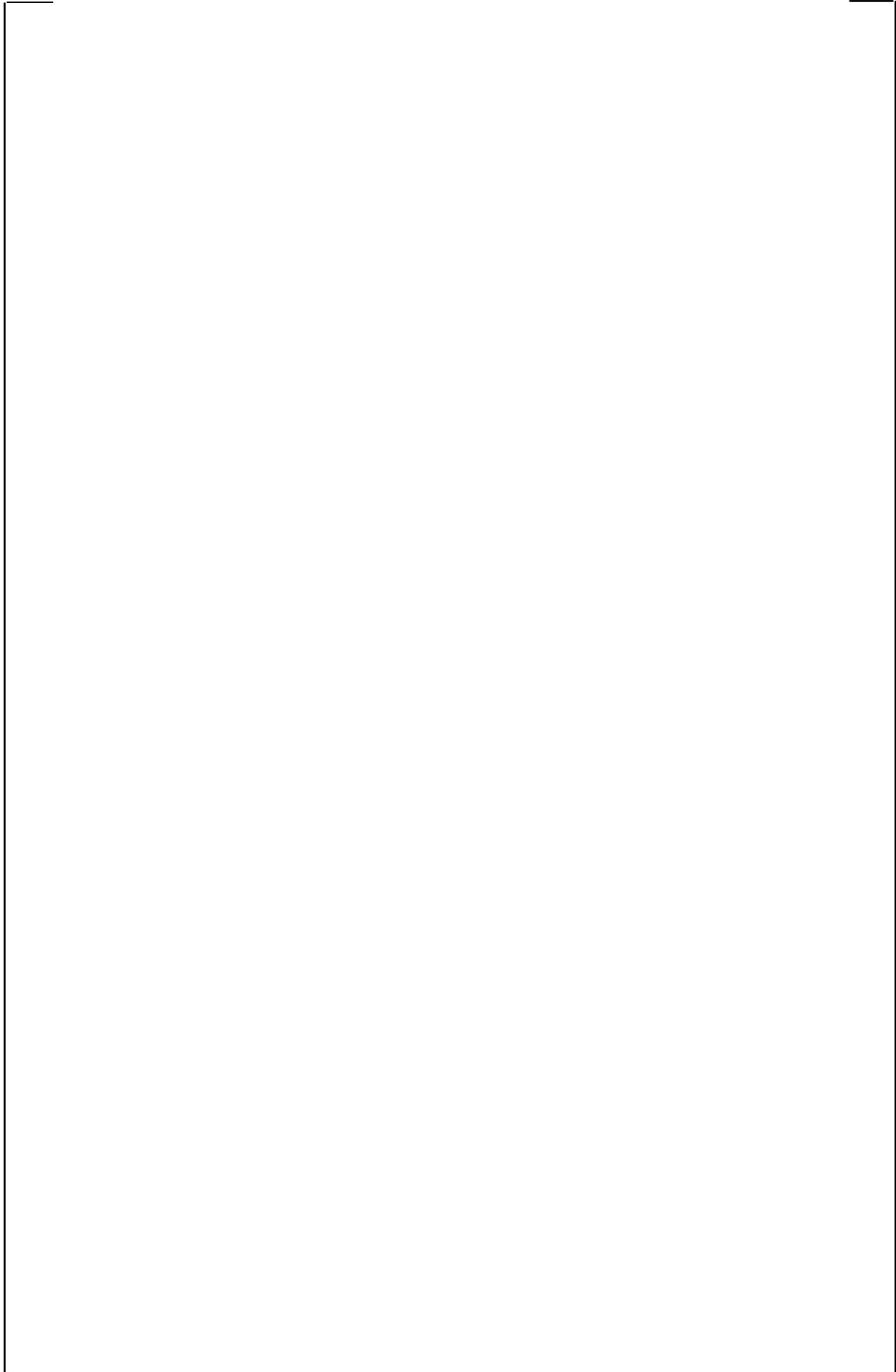
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 20 Westinghouse-type 14x14 Assembly 4.0 w/o ²³⁵U 64 1.5x IFBA Burnable Absorber
Summary of Differences: Depletions and Cold Restart Reactivity Points**

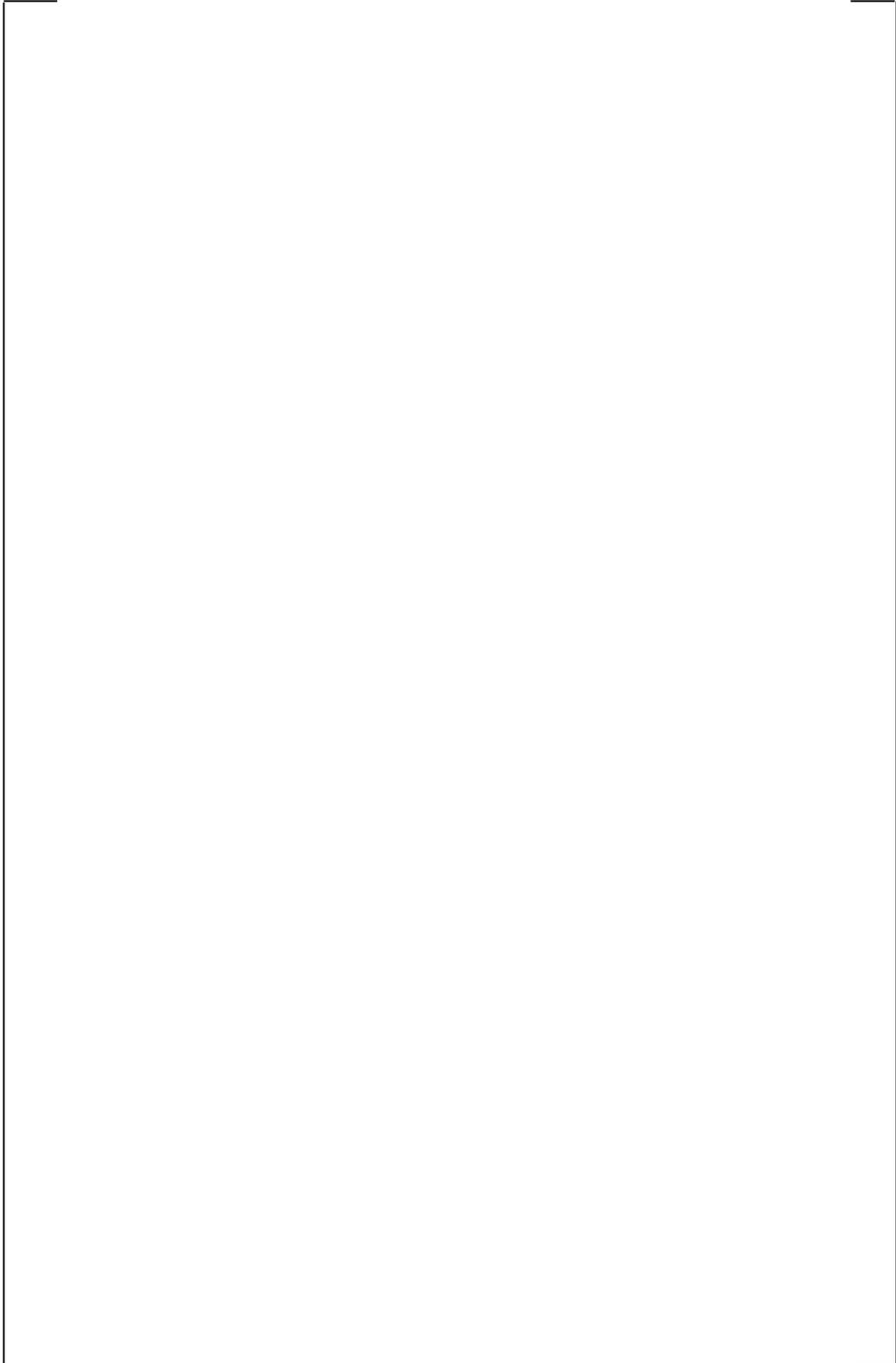
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 21 Westinghouse-type 15x15 Assembly 4.5 w/o ²³⁵U 116 1.5x IFBA
Summary of Differences: Depletions and Cold Restart Reactivity Points**

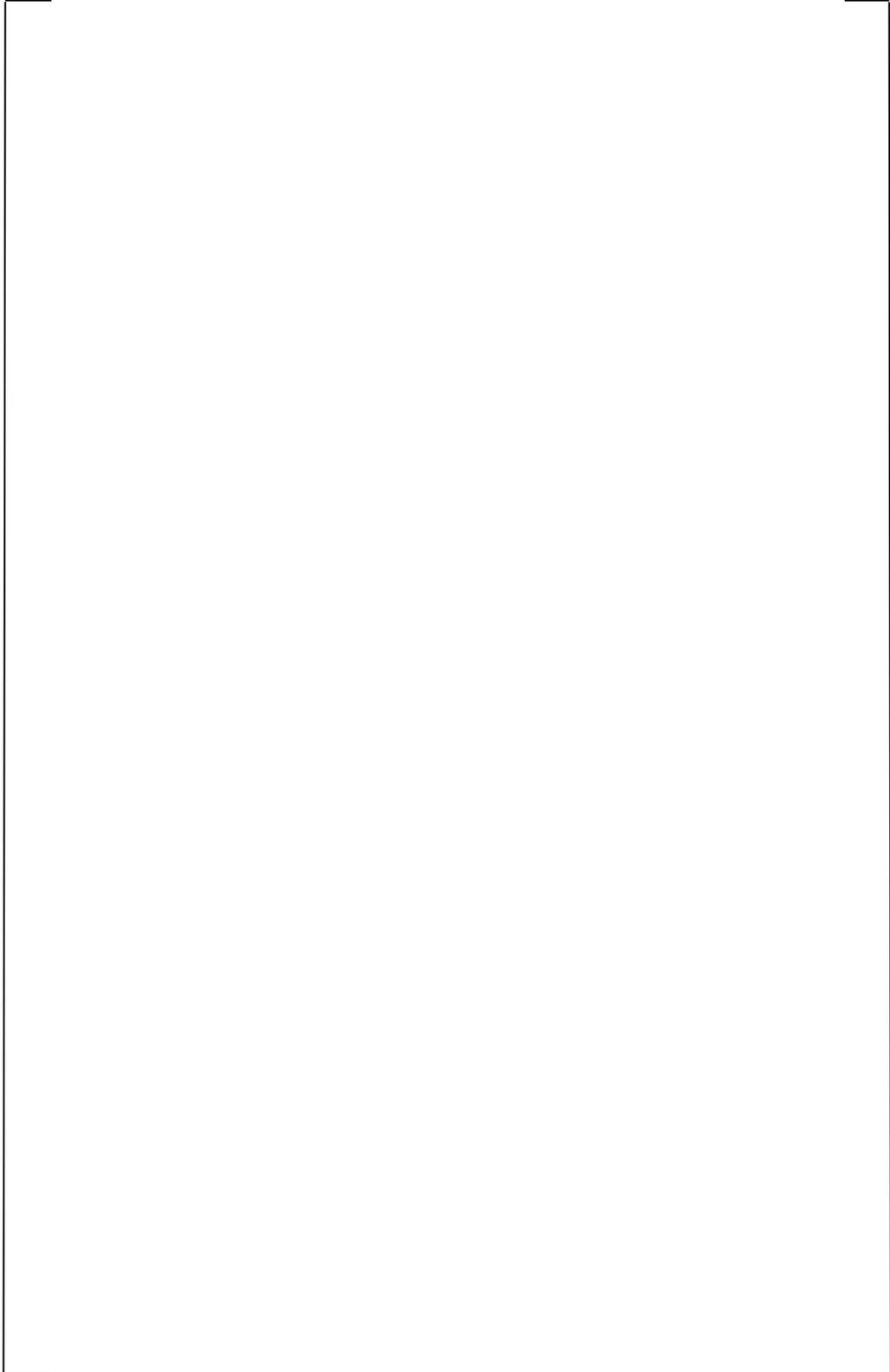
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 22 CE-type 16x16 Assembly with 16 6w/o Gd₂O₃ Burnable Absorbers
Summary of Differences: Depletions and Cold Restart Reactivity Points**

Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 23 Westinghouse-type 17x17 standard assembly – 4.95 w/o ²³⁵U 48 1.5x IFBA
Summary of Differences: Depletions and Cold Restart Reactivity Points**

Comparison of NEXUS/ANC to PARAGON, differences in pcm

a,c

**Table 24 Westinghouse-type 17x17 OFA assembly – 2.6 w/o ²³⁵U No Burnable Absorber
Summary of Differences: Depletions and Cold Restart Reactivity Points**

Comparison of NEXUS/ANC to PARAGON, differences in pcm

a,c

3.1.3 Calculations at Voided Conditions

The new reformulation method decouples the relationship between moderator temperature and moderator density, giving excellent results at off-nominal voided conditions where local moderator density is changed due potentially to a combination of system depressurization and high local power (similar to conditions present during a steamline break event). To demonstrate the efficacy of this decoupling, the fuel assembly depletions at the three RCS boron concentrations described in Section 3.1.2 were re-converged at multiple depletion steps with a wide range of void fractions (-2%, 5%, 15%, 25%, and 40%), each at two soluble boron concentrations (0 and 2600 ppm). Negative void fraction represents the case with the condition of core pressure increment. Table 25 presents the k-infinity comparisons in detail for the 17x17 OFA assembly with 156 IFBA and 24 WABA, while Tables 26 to 30 summarize the comparisons for the other five fuel lattice types described in Section 3.1.

The results for these cases are accurate over the range of void fraction analyzed. [

] ^{a,c} The accuracy of the k-infinity prediction is maintained, even with the increment of void fraction.

**Table 25 Westinghouse-type 17x17 OFA assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA
Restart Reactivity Points for Voided Conditions**

Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

Table 25: Westinghouse-type 17x17 OFA assembly 5.0 w/o ²³⁵U 156 IFBA and 24 WABA Restart Reactivity Points for Voided Conditions (cont.)

Comparison of NEXUS/ANC to PARAGON, differences in pcm

	a,c
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**Table 26 Westinghouse-type 14x14 Assembly with 64 IFBA Burnable Absorbers
Summary of Differences: Restart Reactivity Points for Voided Conditions**

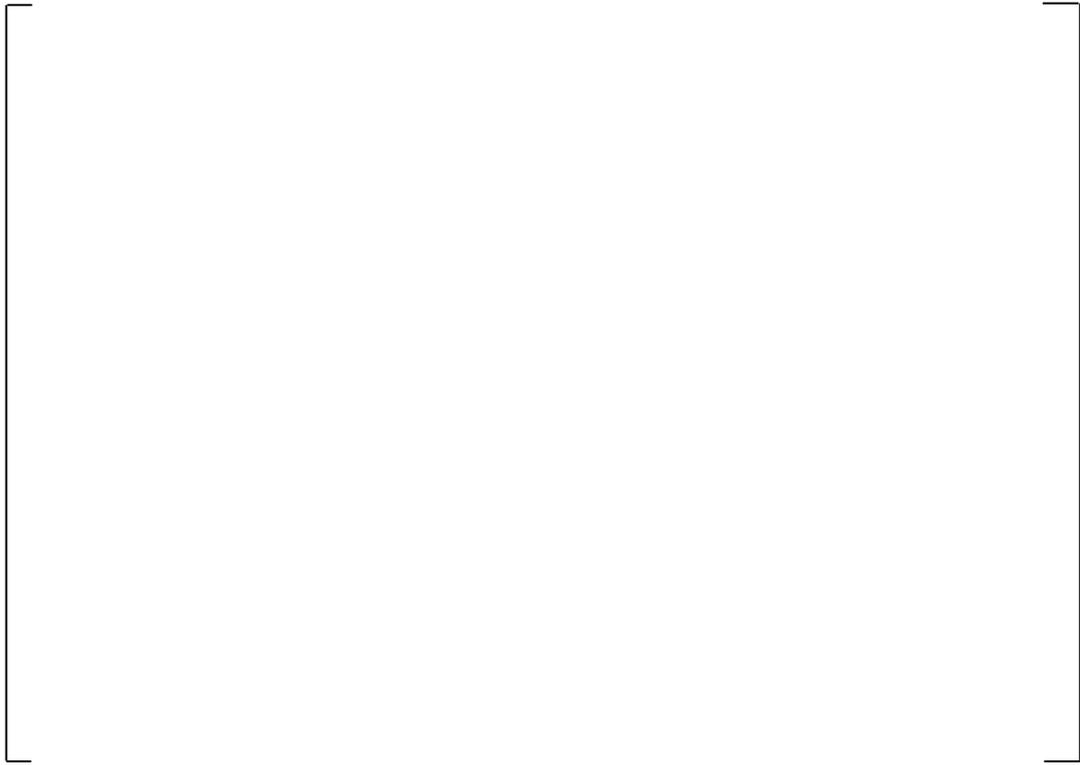
Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 27 Westinghouse-type 15x15 Assembly with 116 IFBA Burnable Absorbers
Summary of Differences: Restart Reactivity Points for Voided Conditions**

Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 28 CE-type 16x16 Assembly with 16 6w/o Gd₂O₃ Burnable Absorbers
Summary of Differences: Restart Reactivity Points for Voided Conditions**

Comparison of NEXUS/ANC to PARAGON, differences in pcm



a,c

**Table 29 Westinghouse-type 17x17 Standard Assembly – 4.95 w/o ²³⁵U 48 IFBA
Summary of Differences: Restart Reactivity Points for Voided Conditions**

Comparison of NEXUS/ANC to PARAGON, differences in pcm

	a,c
--	-----

**Table 30 Westinghouse-type 17x17 OFA assembly – 2.6 w/o ²³⁵U No Burnable Absorber
Summary of Differences: Restart Reactivity Points for Voided Conditions**

Comparison of NEXUS/ANC to PARAGON, differences in pcm



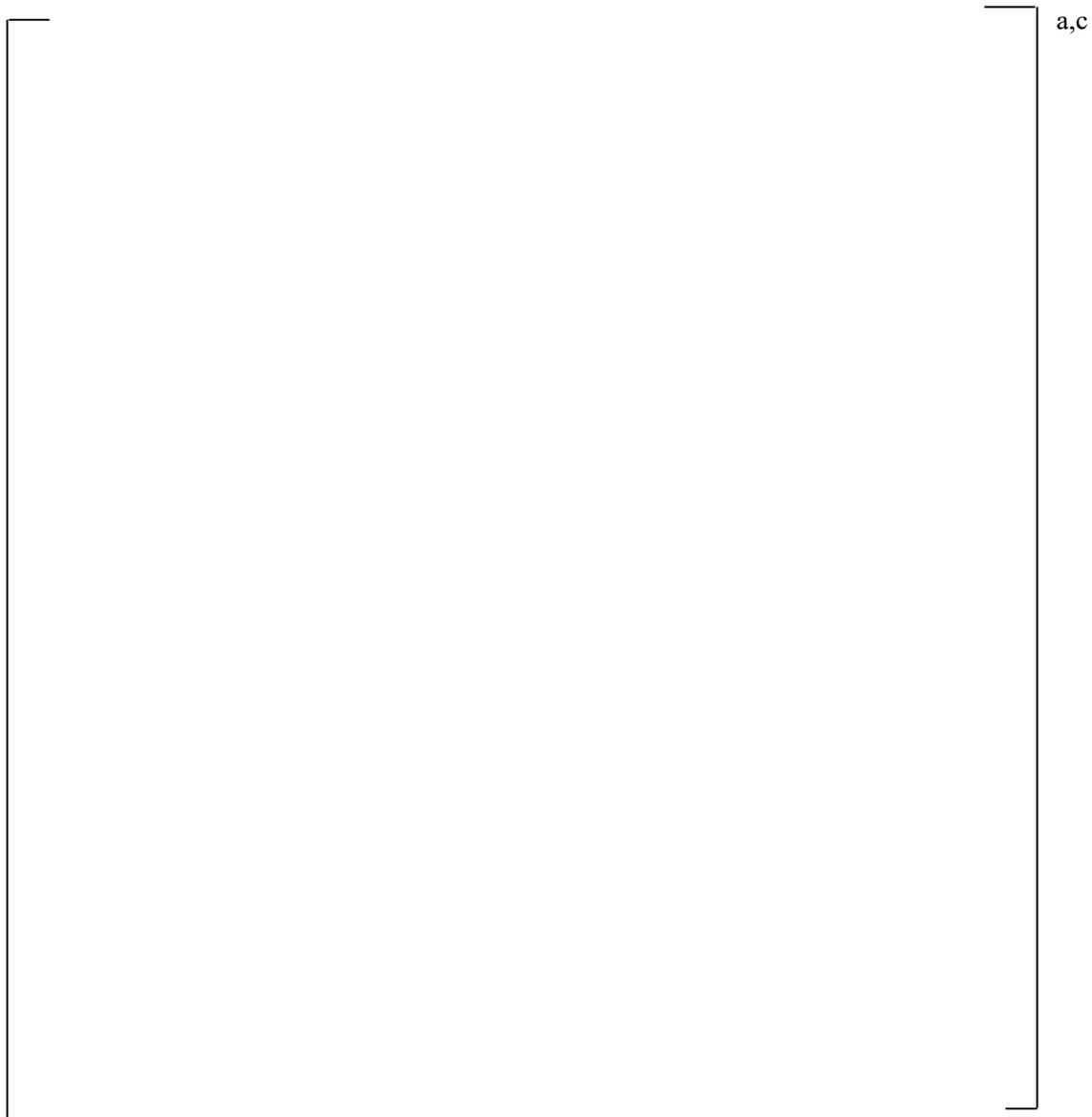
a,c

3.1.4 Evaluation of New Cross-Section Reformulation Methods on Pin Power Distribution

In Reference 3, Westinghouse developed an advanced pin power calculation methodology which was implemented in the NEXUS/ANC code system. The fundamental pin power calculation methodology remains the same for the updated NEXUS/ANC methodology except for the pin cell cross-sections, which will use the new cross-section reformulation instead.

The impact of the pin cell cross-section model on pin power calculation results was analyzed by performing single assembly pin power calculations and directly comparing the results between the new cross-section reformulation and the currently licensed NEXUS/ANC. The lattice type 5, illustrated in Figure 1, was modeled and analyzed in this report.

Figure 1 Map of Westinghouse 17x17 Standard Rod Size Assembly – 4.95 w/o 235U 48 IFBA



The fuel assembly was depleted at both unrodded and rodded conditions. For the unrodded case, Figure 2 shows the pin power distribution difference for the up-left quadrant of the assembly at 20,000 MWD/MTU. The difference is defined as the new cross-section reformulation value minus the value using the current NEXUS/ANC methodology.

Figure 2 Pin Power Difference at 20,000 MWD/MTU for Unrodded Case

0.003	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001
0.002	0.002	0.001	0.000	0.000	-0.001	0.000	0.000	-0.001
0.003	0.001	0.000	-0.001	-0.002		0.000	-0.001	
0.001	0.000	0.000		-0.002	-0.001	0.000	0.000	0.000
0.001	0.000	-0.002	-0.002	0.000	-0.002	0.000	0.000	-0.001
0.001	-0.001		-0.001	-0.002		0.000	-0.001	
0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
0.001	0.000	-0.001	0.000	0.000	-0.001	0.001	0.001	0.000
0.001	-0.001		0.000	-0.001		0.000	0.000	

For the rodded case, two insertion scenarios for the Ag-In-Cd black control rods as shown in Figure 3, in which the control rods are fully inserted and withdrawn at various depletion intervals.

Figure 3 Illustration of Control Rods Insertion Scenarios



Throughout the depletion history, both the assembly maximum power (F_Q) and pin (5,4) power were evaluated. Fuel pin (5,4) was chosen because it is next to a guide thimble where the control rod strongly impacts the power of that pin. Figures 4 to 7 show the impact of the cross-section methodology change on F_Q and pin (5,4) power for both control rod insertion scenarios. Figures 8 and 9 show the detailed comparison of the pin power distribution at 12000 MWD/MTU.

The results demonstrate that adopting the new cross-section reformulation in the pin-cell cross-section calculation has no impact on the pin power calculation, as desired. The maximum change of the pin power is approximately 1%. Therefore, the licensed ANC pin power reconstruction methodology [Reference 3] continues to function appropriately with the new cross-section methodology.

Figure 4 Impact of Cross-Section Model on Fq for CR Sequence 1

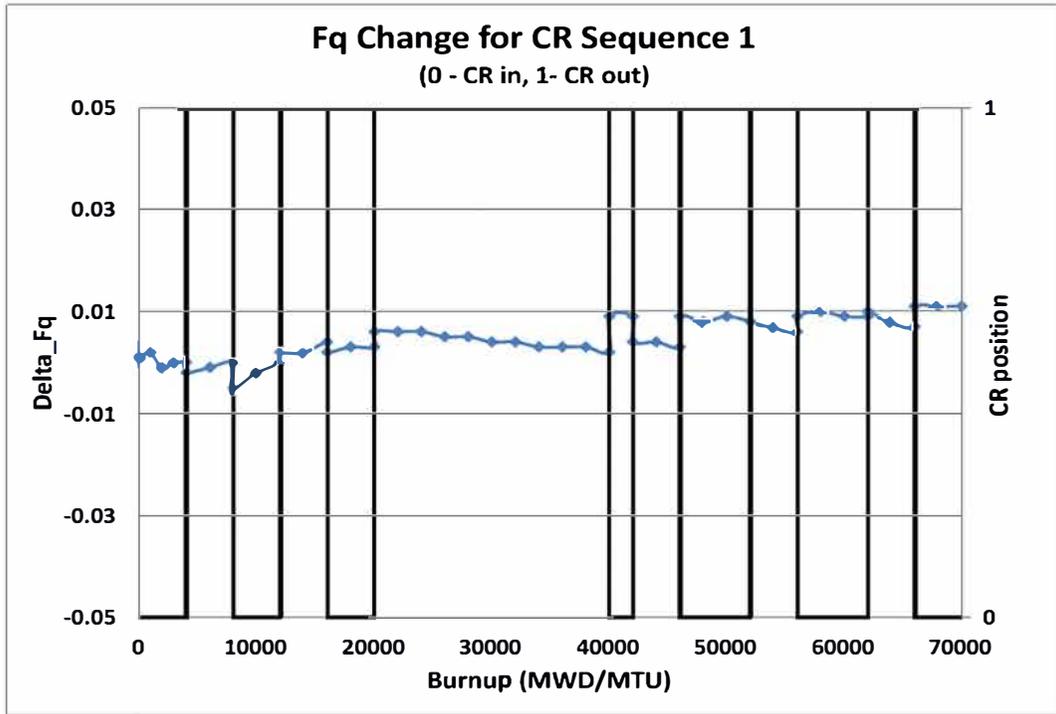


Figure 5 Impact of Cross-Section Model on Power Distribution of Pin (5,4) for Sequence 1

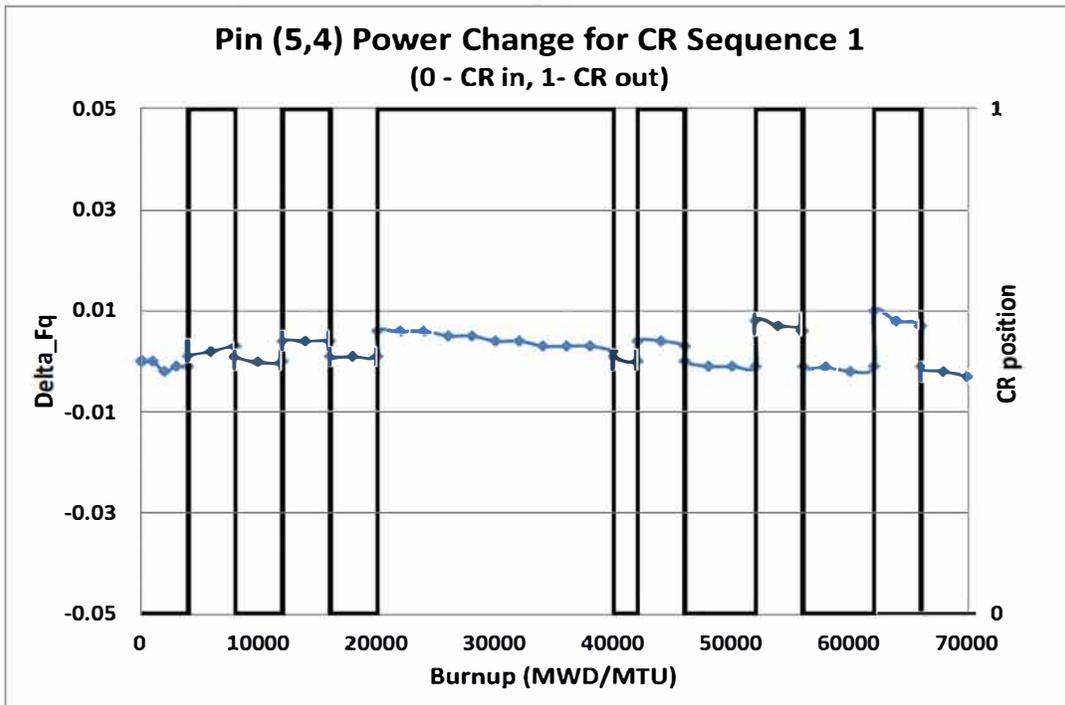


Figure 6 Impact of Cross-Section Model on FQ or CR Sequence 2

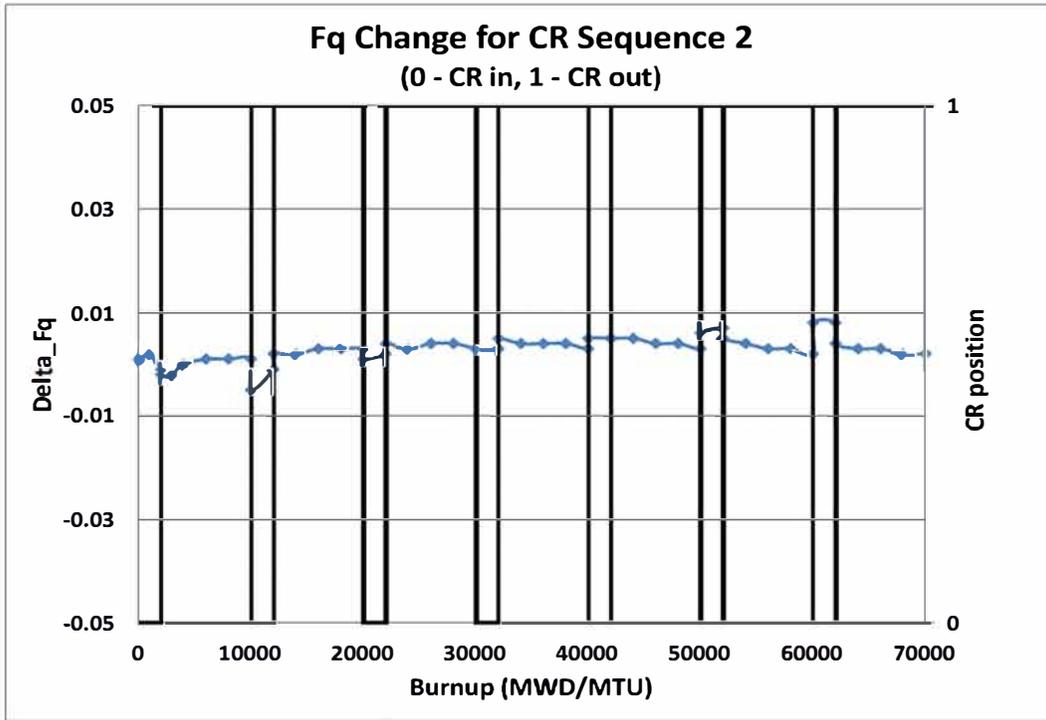


Figure 7 Impact of Cross-Section Model on Power Distribution of Pin (5,4) for Sequence 2

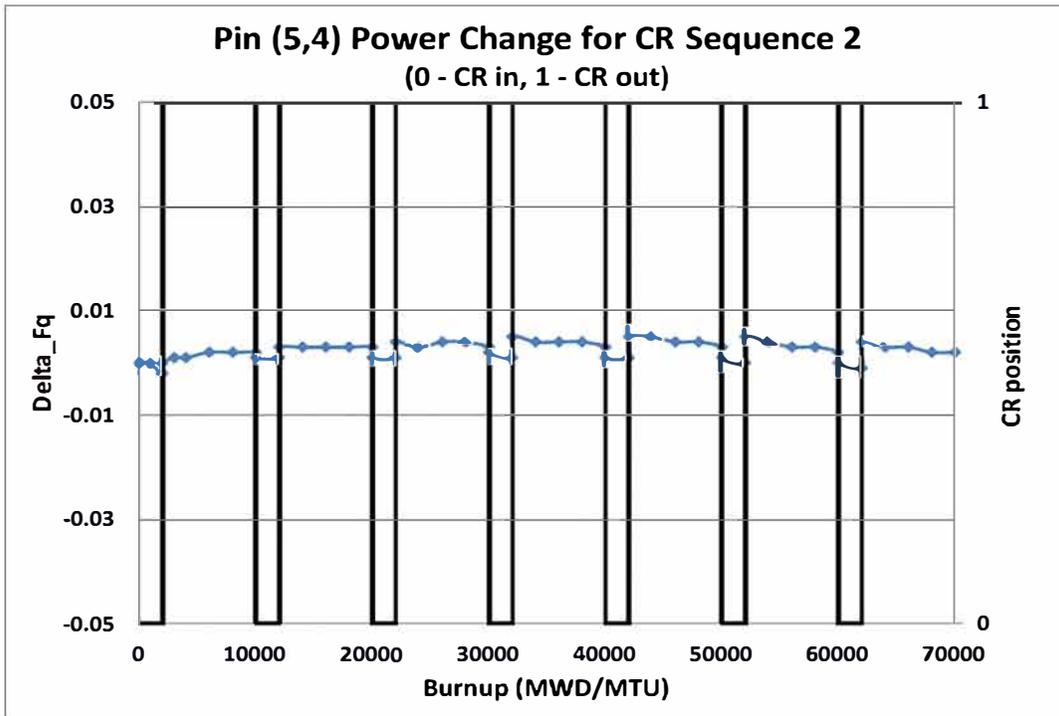


Figure 8 Pin Power Difference at 12000 MWD/MTU for Scenario 1

0.000	0.001	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	0.000
0.001	0.000	-0.001	-0.001	-0.001	0.000	-0.001	0.000	0.000
0.000	-0.001	-0.001	0.000	-0.001		0.000	-0.001	
-0.001	-0.001	0.000		0.000	0.001	0.001	0.001	0.001
-0.001	-0.001	-0.001	0.000	0.001	0.000	0.001	0.001	0.001
-0.001	0.000		0.001	0.000		0.002	0.000	
-0.001	-0.001	0.000	0.001	0.001	0.002	0.000	0.000	0.000
-0.001	0.000	-0.001	0.001	0.001	0.000	0.000	0.000	-0.002
0.000	0.000		0.001	0.001		0.000	-0.002	

Figure 9 Pin Power Difference at 12000 MWD/MTU for Scenario 2

0.001	0.002	0.000	0.000	-0.001	0.000	0.000	0.000	0.000
0.002	0.000	0.000	-0.001	-0.001	-0.001	-0.001	0.000	0.000
0.000	0.000	-0.001	0.000	-0.001		0.000	-0.001	
0.000	-0.001	0.000		-0.001	0.001	0.001	0.000	0.001
-0.001	-0.001	-0.001	-0.001	0.000	0.000	0.001	0.001	0.001
0.000	-0.001		0.001	0.000		0.000	0.000	
0.000	-0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000
0.000	0.000	-0.001	0.000	0.001	0.000	0.000	0.000	-0.001
0.000	0.000		0.001	0.001		0.000	-0.001	

3.2 MINICORE MODEL CALCULATIONS

Due to the strong interaction between MOX and UO₂ fuel assemblies, it has been a challenge for traditional core design methods to model UO₂-MOX mixed cores. To evaluate the impact of the re-homogenization methods, a 3x3 UO₂-MOX checker-board mini-core case was setup with 5 MOX (M) and 4 UO₂ (U) fuel assemblies. The configuration of the mini-core case is given in Figure 10. The reflective boundary condition is applied to the outer surface of the mini-core system.

Figure 10 Configuration of 3x3 Mini-Core

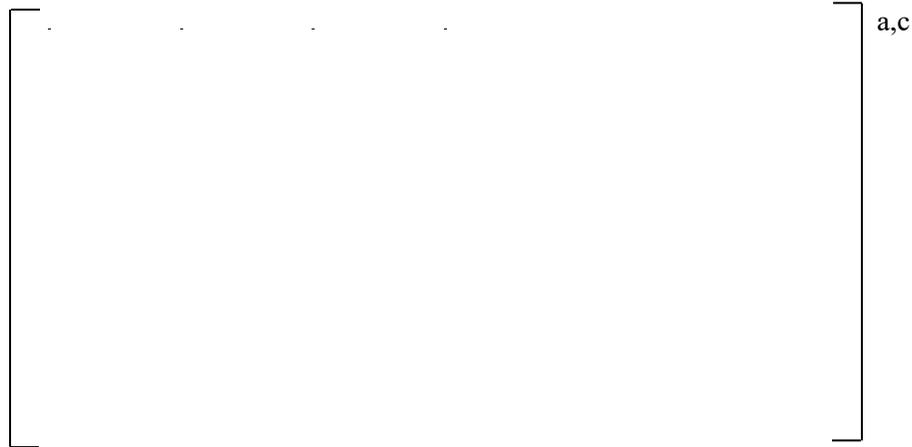
M	U	M
U	M	U
M	U	M

NEXUS/ANC calculations were performed with and without the re-homogenization model, while a PARAGON calculation was performed with the same geometry to generate reference results. The k_{∞} comparison of NEXUS/ANC predictions against the reference is given in Table 31, while Figure 11 shows the comparison of assembly power distribution.

The re-homogenization model captures the interaction effect between the dissimilar fuel assemblies and improves the prediction on both the reactivity and assembly power distribution.

Table 31 Comparison of k_{∞} for 3X3 Mini-Core Case

	a,c
--	-----

Figure 11 Comparison of Assembly Power Comparison for Mini-Core Case

3.3 PWR CORE CALCULATIONS

Core models were generated using both the currently licensed and the updated NEXUS/ANC methodologies to demonstrate the accuracy of the updated NEXUS/ANC system for actual core calculations. Core models representing previously operated cycles were set up for four plants:

Plant A: Combustion Engineering plant: 217 assembly core, 16x16 lattice. Cycles 11, 12, 13, and 14 are modeled. Burnable absorber is Gd_2O_3 for all modeled cycles.

Plant B: Westinghouse plant: 193 assembly core (4 loops), 17x17 OFA lattice. Cycles 8, 9, 10, 11, 12 are modeled. Burnable absorber for all cycles is IFBA.

Plant C: Westinghouse plant: 157 assembly core (3 loops), 17x17 standard lattice. Cycles 18, 19, and 20 are modeled. Burnable absorber for all cycles is IFBA.

Plant D: The Westinghouse **AP1000**[®] Plant: 157 assembly core, 17x17 lattice. First cycle. Burnable absorbers are WABA and IFBA.

In addition to modeling these actual plant cycles, an equilibrium cycle model was set up based on a Westinghouse 4 loop 17x17 core with standard size fuel rods. This model was set up using both the currently licensed NEXUS/ANC9 method and the updated NEXUS/ANC method to compare power distributions, rodworths, and cold critical boron calculations.

3.3.1 At-Power Critical Boron Results

Figures 12 through 23 present the comparisons of the currently licensed and the updated NEXUS/ANC results against measured data for at-power RCS critical boron concentration versus cycle burnup. [

] ^{a,c} Note that adjustments to the measured data to account for B depletion were not included in any of these calculations although it is clearly in evidence in several of the cycles.

3.3.2 At-Power Axial Offset Results

Table 32 gives the axial offset (AO) comparison as a function of cycle burnup for cycles 18 through 20 of Plant C. [

] a,c

3.3.3 Startup Test Physics Predictions

Tables 33 and 34 show the comparison of low power physics test results (i.e., measured values) against predictions from both the currently licensed and updated NEXUS/ANC models for cycles 18 through 20 for Plant C and the first cycle of Plant D. The comparison was made to the available measurement data such as hot zero power (HZP), all rods out (ARO) critical boron, HZP ARO isothermal temperature coefficient (ITC), HZP ARO moderator temperature coefficient (MTC), and HZP ARO boron worth.

[

] a,c

3.3.4 Power Distributions

Comparisons of radial power distributions between currently licensed and updated NEXUS/ANC are shown in Figures 24-29 for the equilibrium cycle core described above. Both assembly power and peak rod power are compared at three times in life: Beginning of Cycle (BOC) (0 MWD/MTU), Middle of Cycle (MOC) (10000 MWD/MTU) and at End of Cycle (EOC) (21436 MWD/MTU).

[

] a,c

3.3.5 Rod Worths

Rod worth comparisons between the currently licensed and updated NEXUS/ANC were performed with the equilibrium cycle models. The results are shown in Table 35 for BOC, MOC, and EOC. [

] ^{a,c}

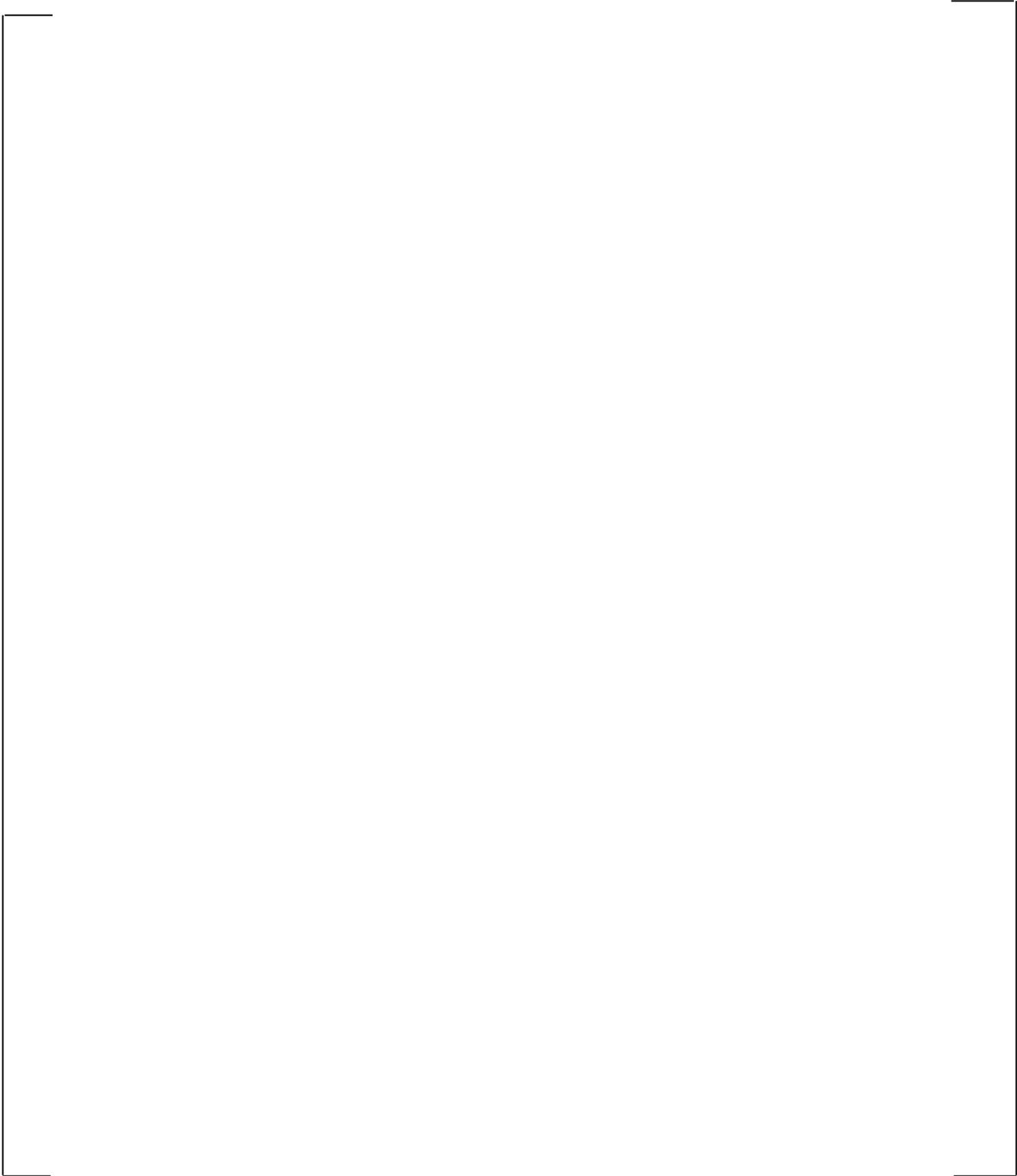
3.3.6 Cold Reactivity Calculations

Table 36 provides comparisons of critical boron concentrations at 68°F, 200°F, and 350°F for all control rods out (ARO), all control rods in (ARI) and with all rods in but the most reactive rod (ARI-1) for BOC, MOC, and EOC of the equilibrium cycle models. The table shows the reactivity difference between both models in ppm and the rod worth of the ARI and ARI-1 cases.

[

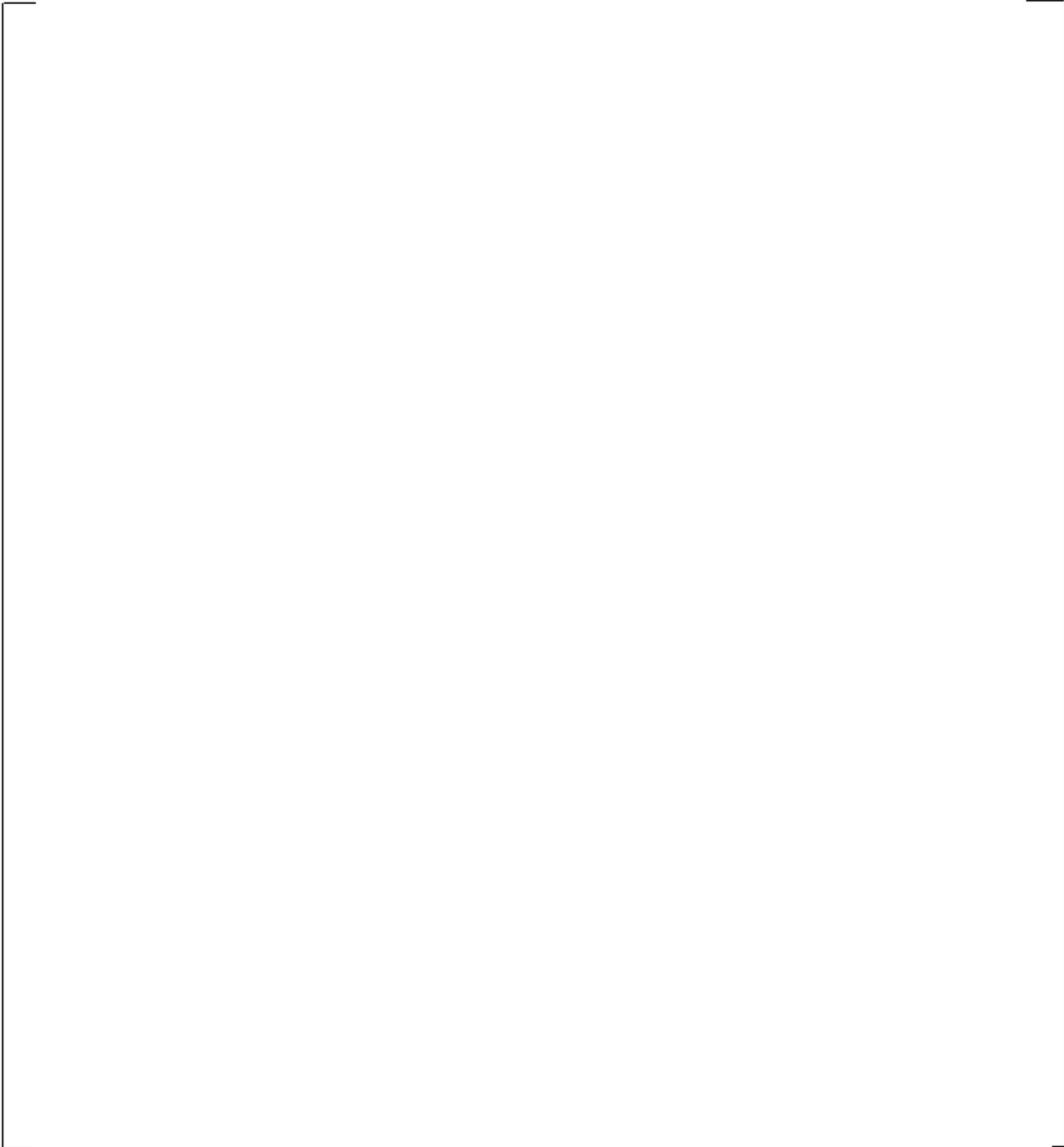
] ^{a,c}

**Figure 12 Plant A Cycle 11
Critical Boron Concentration versus Cycle Burnup**



a,b,c

**Figure 13 Plant A Cycle 12
Critical Boron Concentration versus Cycle Burnup**



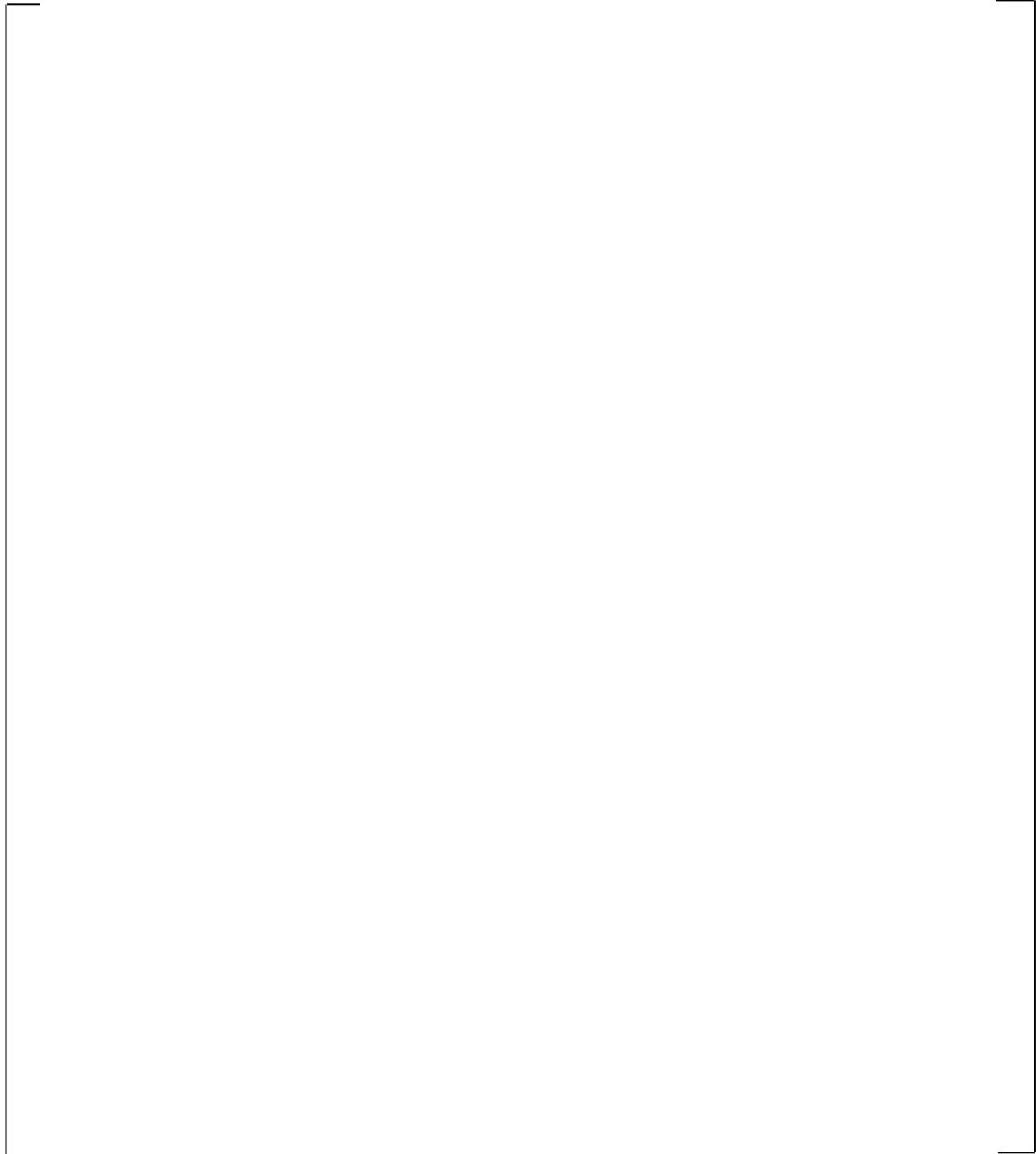
a,b,c

**Figure 14 Plant A Cycle 13
Critical Boron Concentration versus Cycle Burnup**

a,b,c

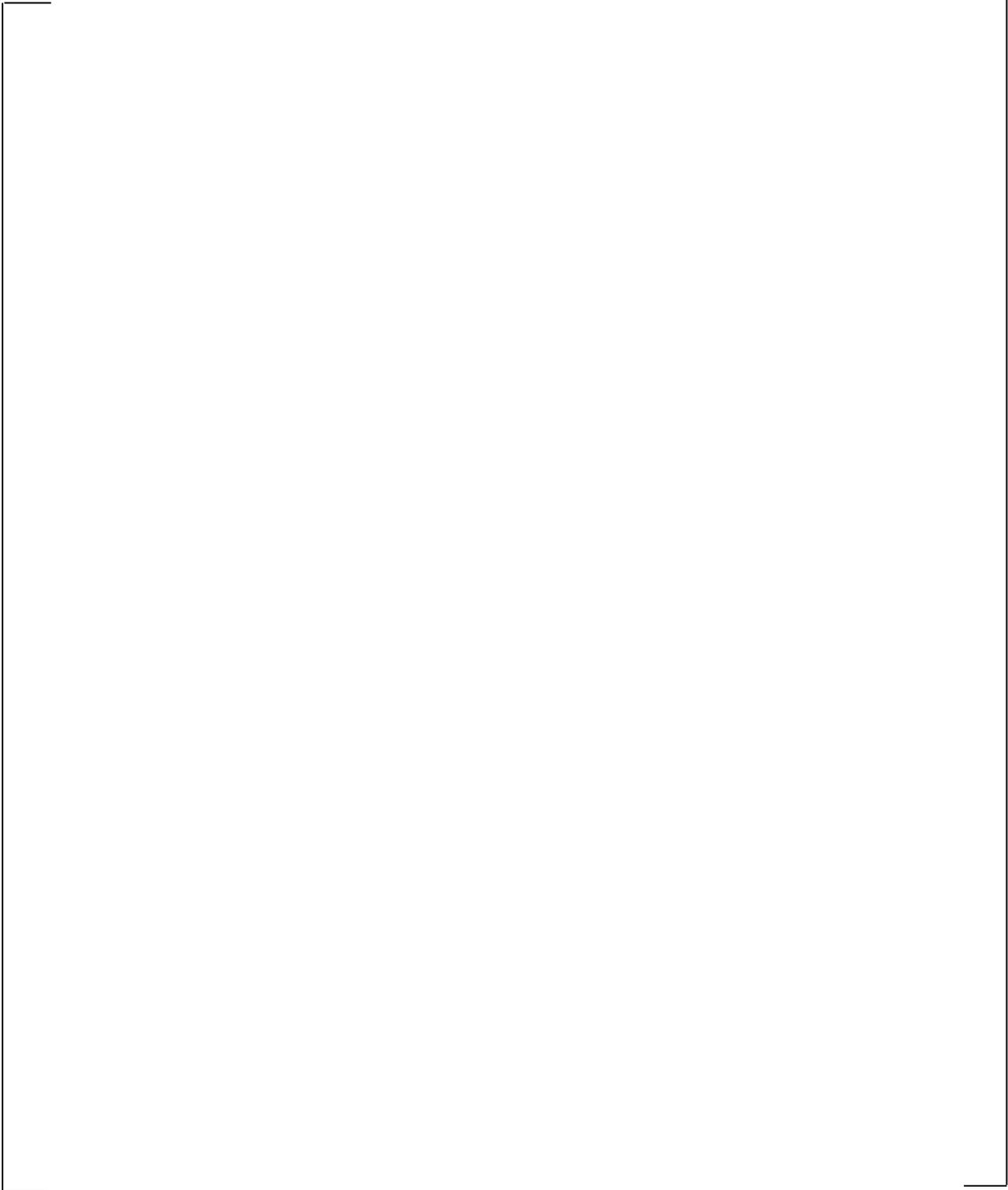


**Figure 15 Plant A Cycle 14
Critical Boron Concentration versus Cycle Burnup**



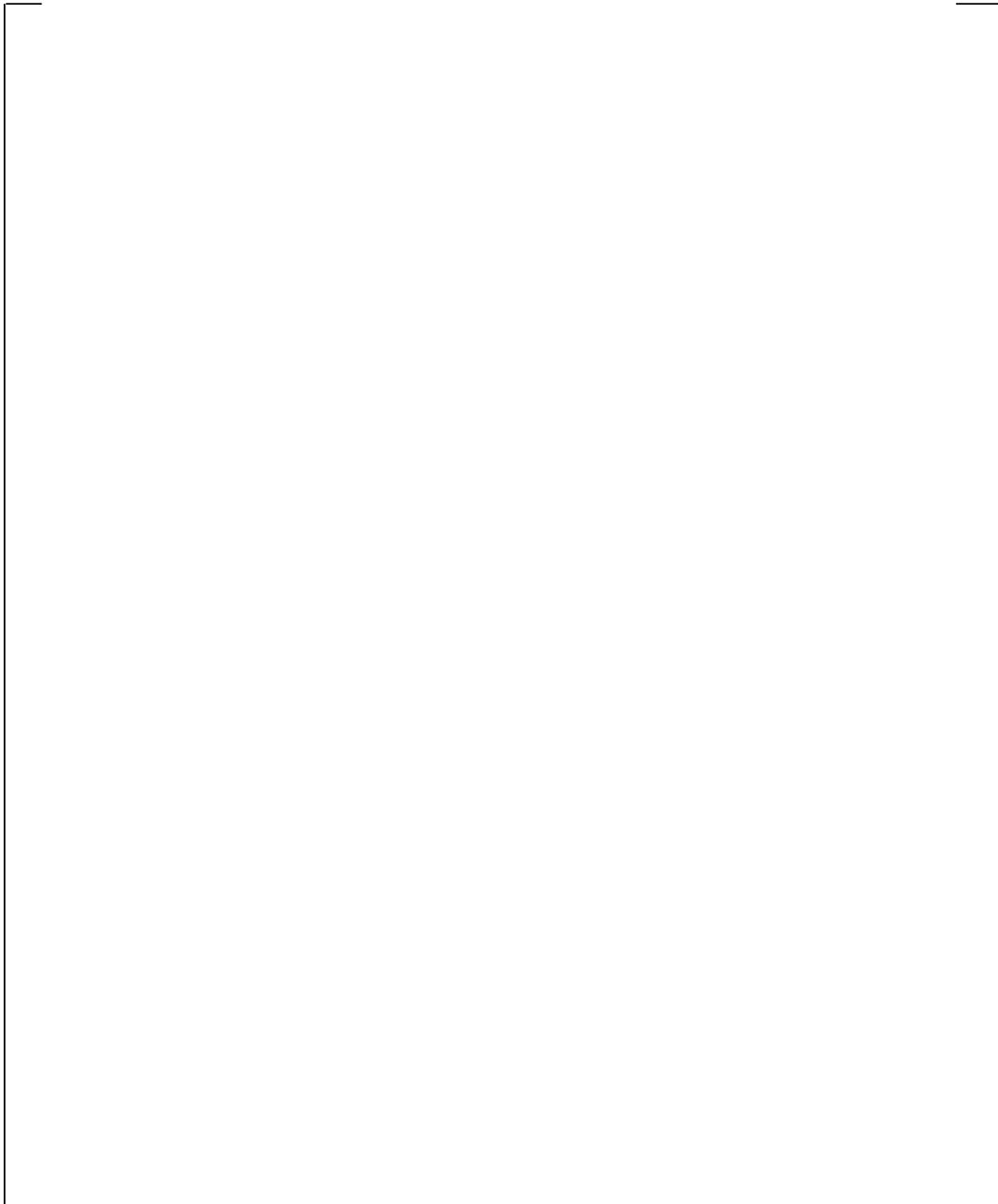
a,b,c

**Figure 16 Plant B Cycle 8
Critical Boron Concentration versus Cycle Burnup**



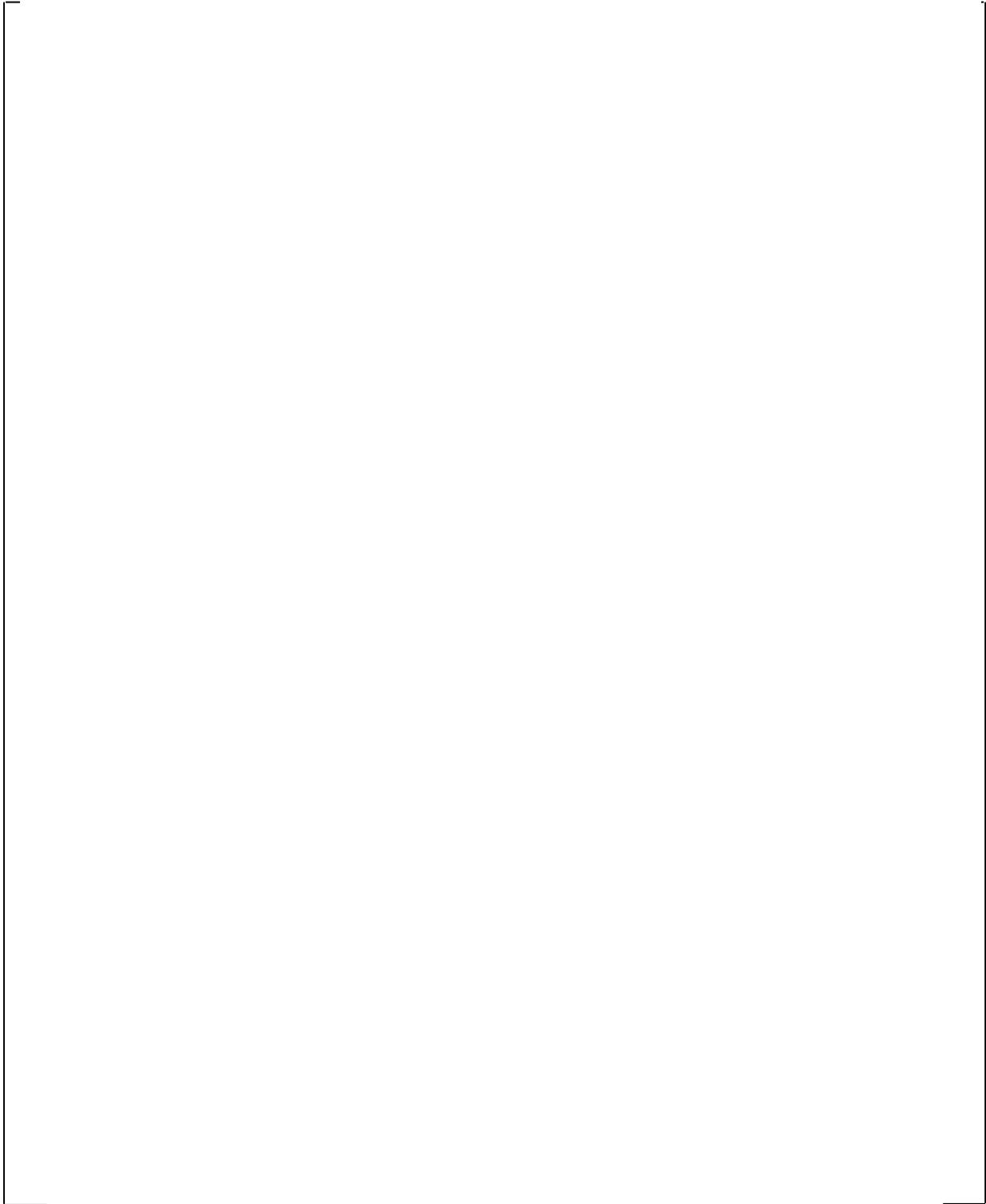
a,b,c

**Figure 17 Plant B Cycle 9
Critical Boron Concentration versus Cycle Burnup**



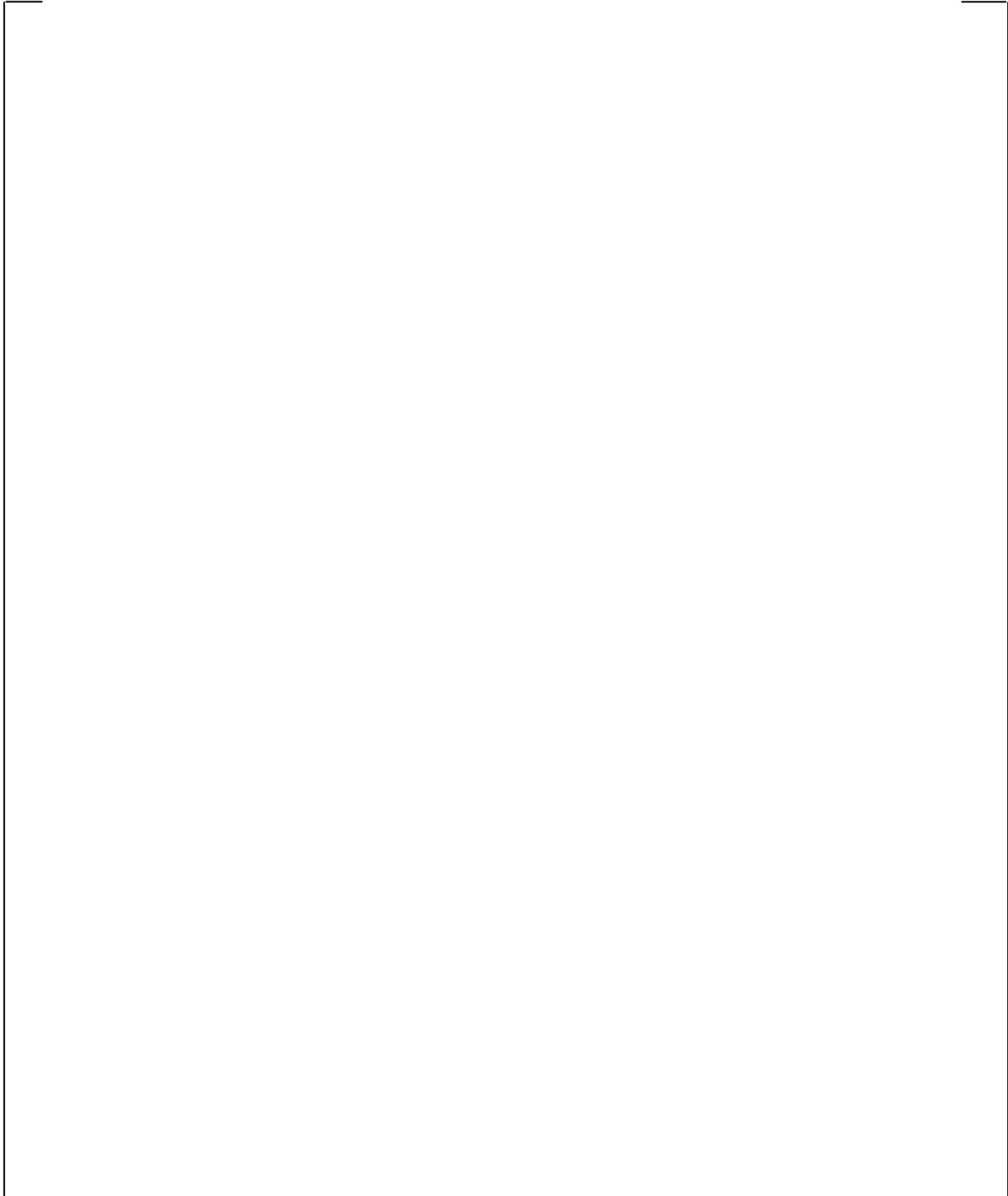
a,b,c

**Figure 18 Plant B Cycle 10
Critical Boron Concentration versus Cycle Burnup**



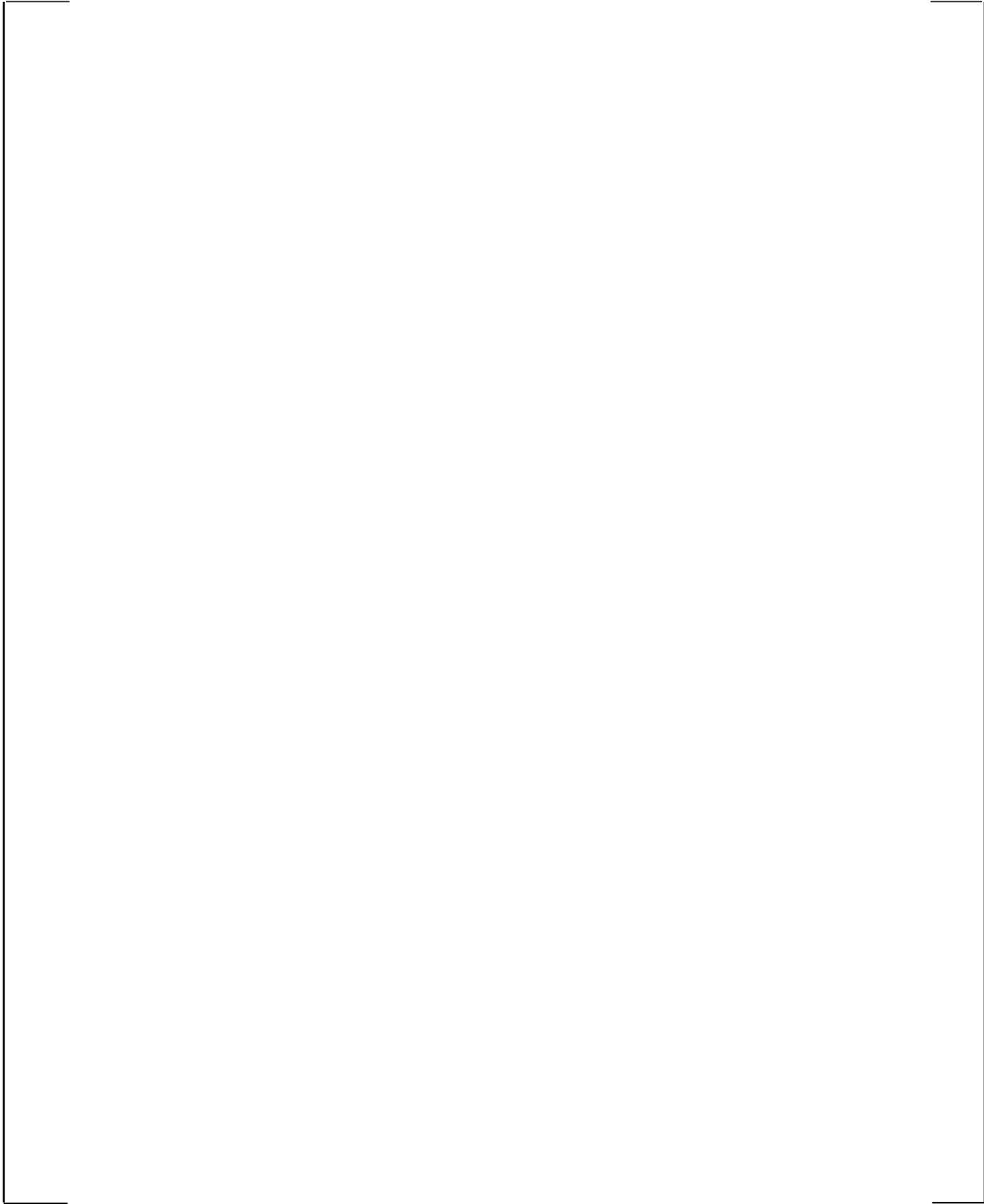
a,b,c

**Figure 19 Plant B Cycle 11
Critical Boron Concentration versus Cycle Burnup**



a,b,c

**Figure 20 Plant B Cycle 12
Critical Boron Concentration versus Cycle Burnup**



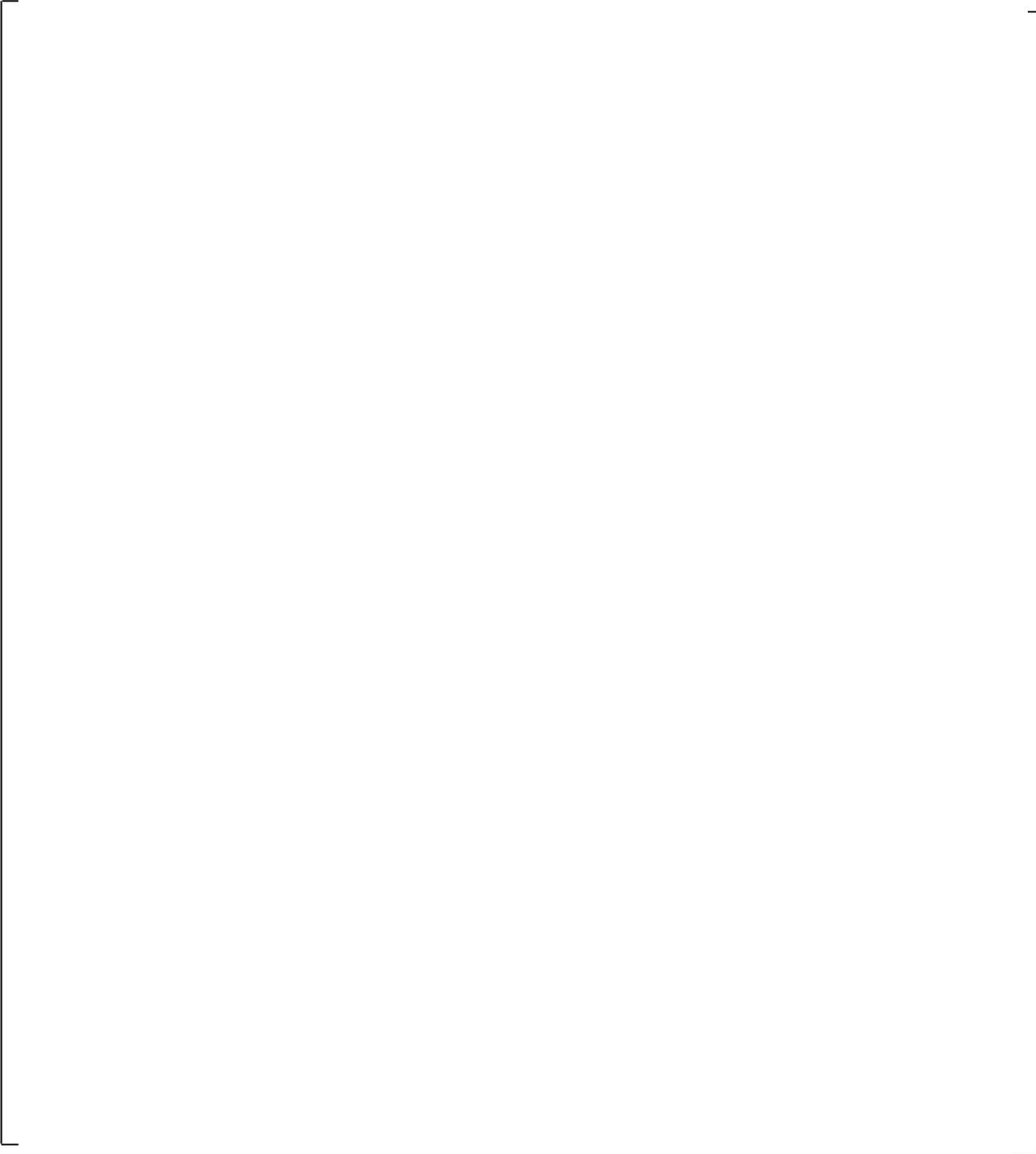
a,b,c

**Figure 21 Plant C Cycle 18
Critical Boron Concentration versus Cycle Burnup**

a,b,c

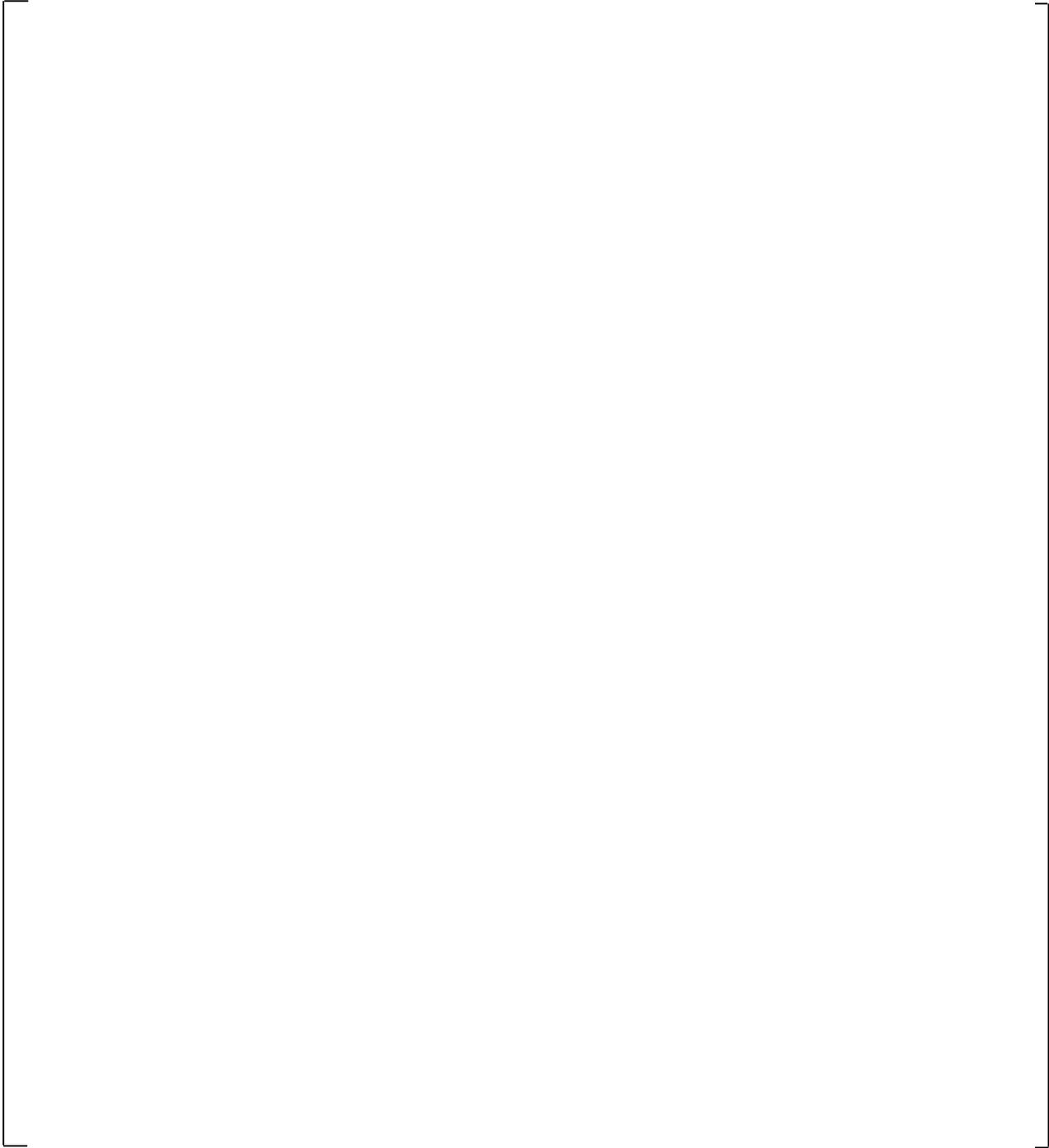


**Figure 22 Plant C Cycle 19
Critical Boron Concentration versus Cycle Burnup**



a,b,c

**Figure 23 Plant C Cycle 20
Critical Boron Concentration versus Cycle Burnup**

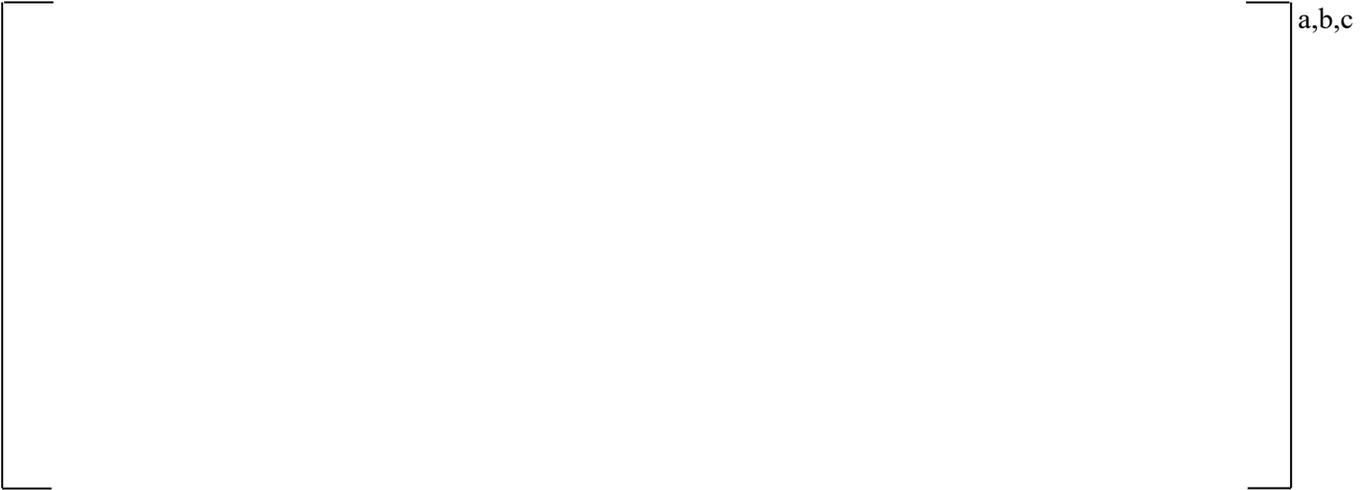


a,b,c

Table 32 Plant C Axial Offset versus Cycle Burnup

a,b,c

Table 33 Plant C Low Power Physics Test Data



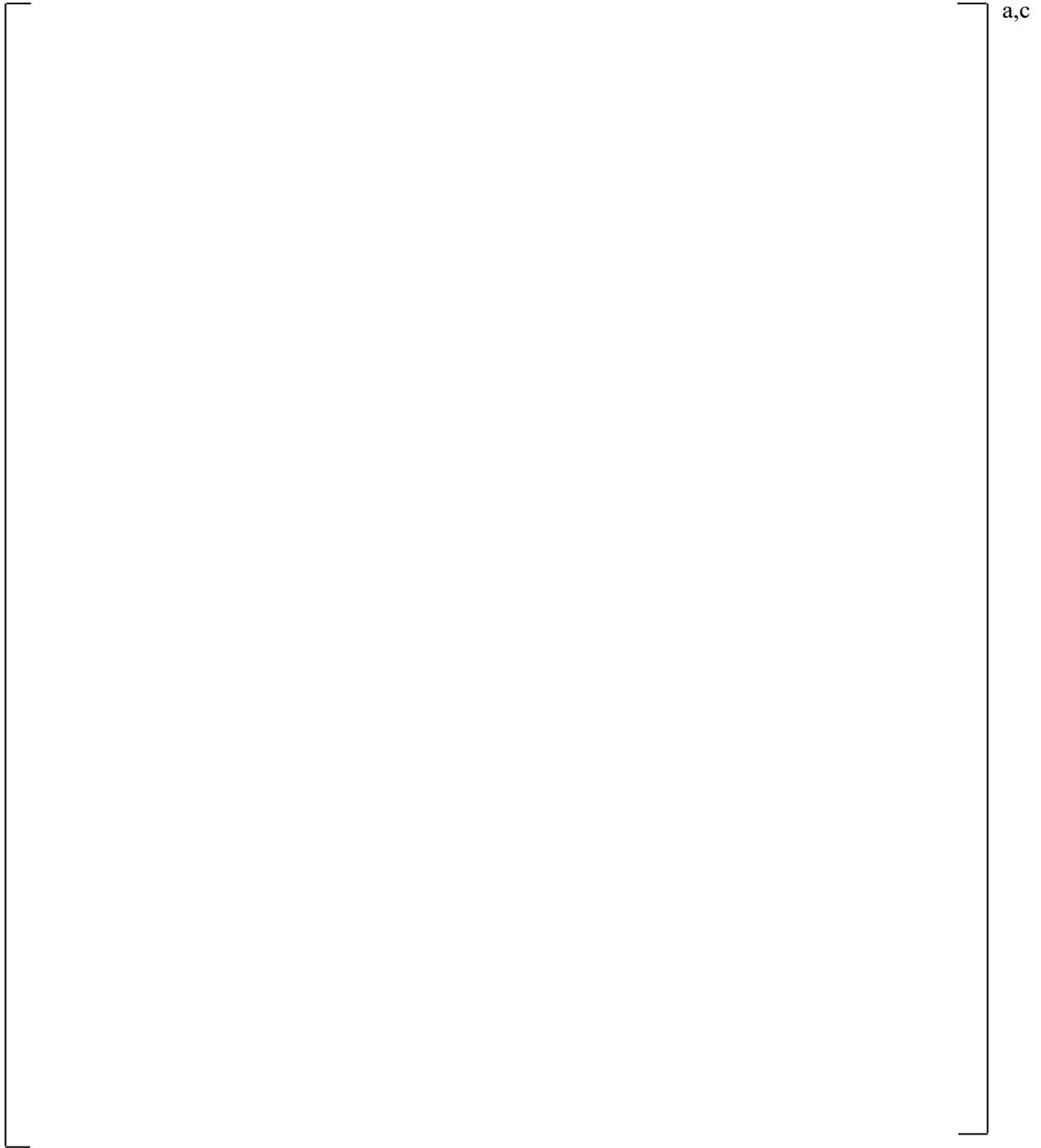
a,b,c

Table 34 Plant D First Cycle Startup Low Power Physics Test Data

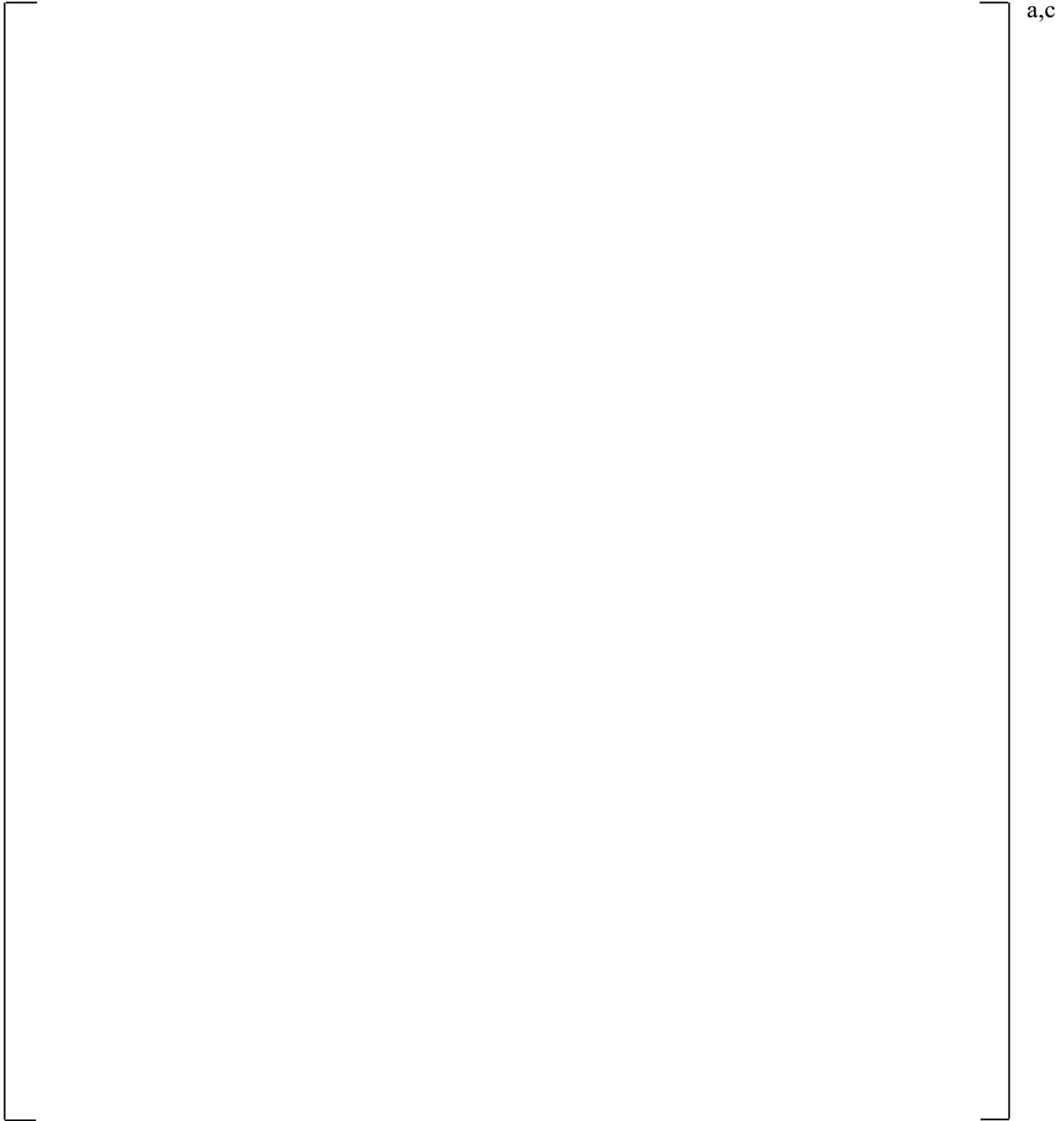


a,b,c

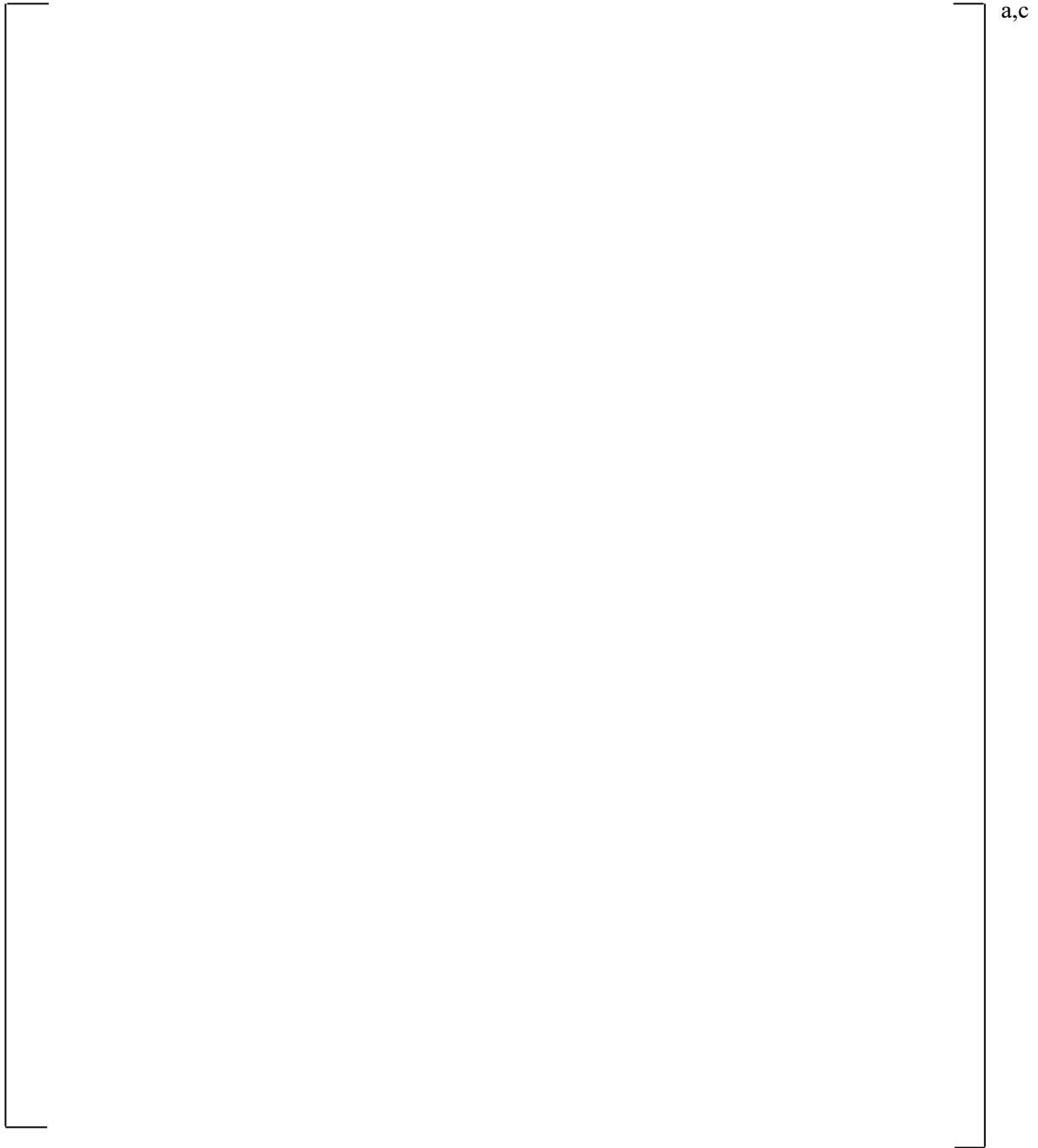
**Figure 24 Equilibrium Cycle BOC Assembly Power Distribution
New versus Current NEXUS/ANC**



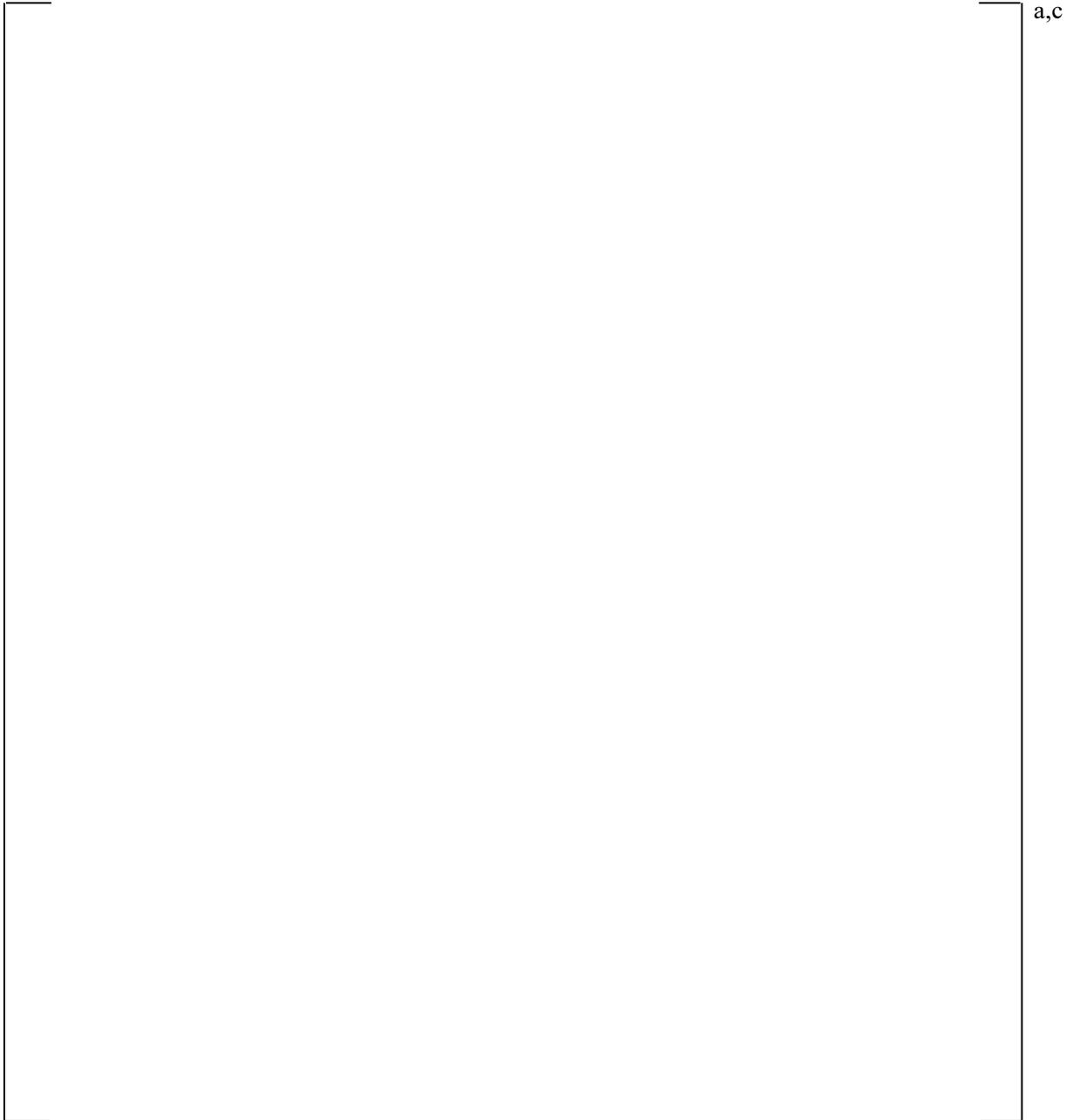
**Figure 25 Equilibrium Cycle MOC Assembly Power Distribution
New versus Current NEXUS/ANC**



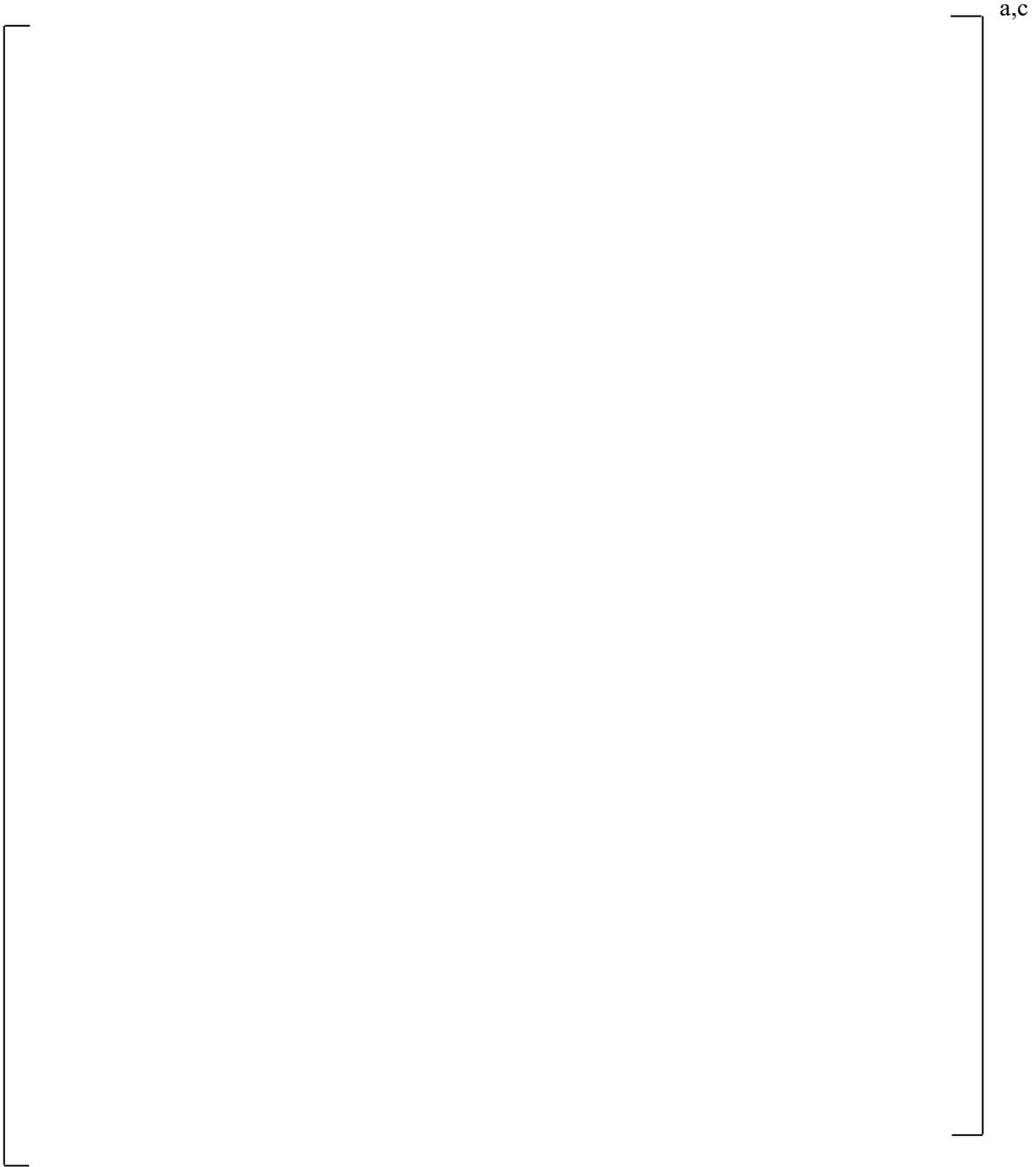
**Figure 26 Equilibrium Cycle EOC Assembly Power Distribution
New versus Current NEXUS/ANC**



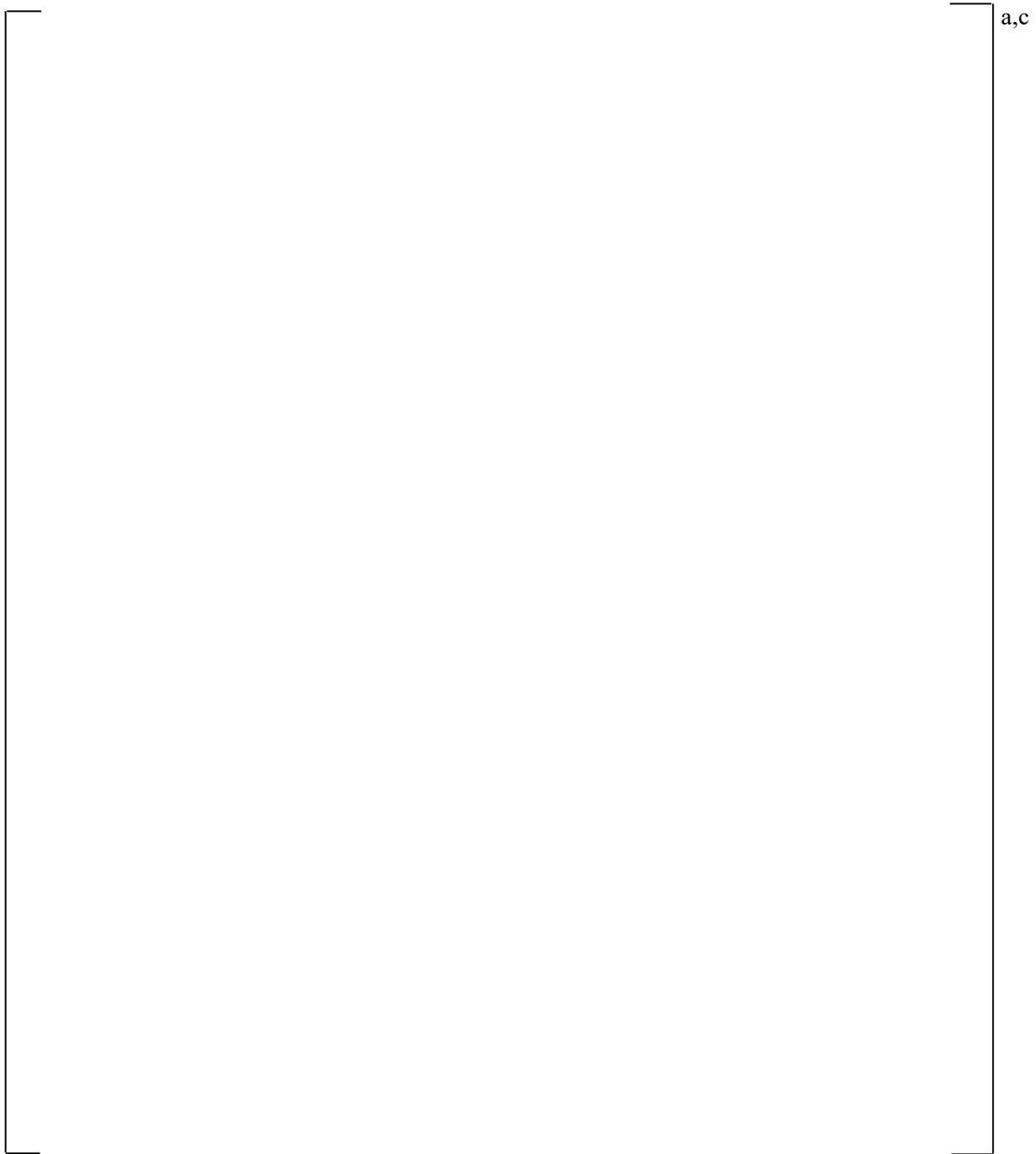
**Figure 27 Equilibrium Cycle BOC Radial Peaking Factor ($F_{\Delta H}$) Distribution
New versus Current NEXUS/ANC**



**Figure 28 Equilibrium Cycle MOC Radial Peaking Factor ($F_{\Delta H}$) Distribution
New versus Current NEXUS/ANC**



**Figure 29 Equilibrium Cycle EOC Radial Peaking Factor ($F_{\Delta H}$) Distribution
New and Current NEXUS/ANC**



**Table 35 Hot Zero Power Control Rod Worths – Equilibrium Cycle
New versus Current NEXUS/ANC**



a,c

Table 36 Cold Reactivity Comparisons – Equilibrium Cycle

a,c

4 PROCESS FOR FUTURE CODE/METHODOLOGY MODIFICATIONS

The key indicator of the accuracy of an analytic method is the agreement of its predictions with measured data (“measured minus predicted”, or “M-P”, performance). Agreement between readily measurable parameters, including reactivity, rod worths, temperature coefficients and radial and axial power distribution and their calculated values, provides assurance that the reactor geometry, materials, and thermal hydraulic conditions are modeled correctly and that the analytic methods represent the core physics with sufficient accuracy. Close agreement between measured and predicted values of these key parameters validates the safety analysis for the cycle under startup or during operation.

With the anticipated future increase in computing power and speed, and increased data storage capability, Westinghouse expects to further refine the numerical methods described in this report to further improve predictive capabilities. Enhancements may, for example, include: the use of different or additional state parameters in the formulation of the nuclear cross-sections, improved thermal hydraulic modeling, improved fuel rod thermal modeling, and use of an improved multi-energy group cross-section structure.

The process that Westinghouse will use to implement future changes to the methodology is as follows. Prior to implementing such future improvements, Westinghouse will benchmark the impact of the changes on the M-P performance of ANC/NEXUS, using the criteria shown in Table 37. These criteria are based on licensed uncertainty values, or uncertainties used or assumed in the safety analysis. Meeting the criteria in Table 37 will provide sufficient validation of the methodology changes. Licensed uncertainties or previously established restrictions on the use of ANC/NEXUS will not be affected. Validations will be documented and maintained internally by Westinghouse. Changes which have been validated against the stated criteria can be used in subsequent licensing applications.

Table 37 Qualification Criteria

Parameter	M-P Agreement
Core Reactivity	500 pcm
Isothermal Temperature Coefficient	2 pcm/°F
Total control rod bank worth (where measured)	7%
Individual control rod bank worth (where measured)	Maximum of 15% or 100pcm
$F_{\Delta H}$	4%
F_Q	5%

5 SUMMARY AND CONCLUSIONS

Westinghouse has developed updated NEXUS cross-section methodologies including cross-section reformulation and re-homogenization that are designed to replace the currently licensed NEXUS methodology for PWR nuclear core design and safety analysis calculations.

In the updated NEXUS methodology presented herein, the cross-sections calculated using a standard set of lattice code calculations are [

] ^{a,c} The updated methodology can more accurately simulate the fuel and core under accident scenarios, such as steamline breaks, locked rotor events, or rod ejection incidents, that can lead to a large change in core pressure or cause large local voiding conditions.

A further improvement in the updated NEXUS methodology is [

] ^{a,c}

Results are presented in this report to show the accuracy of NEXUS for cross-section representation. Six different UO₂ assembly types including both Westinghouse and CE assembly types, and IFBA, WABA, and Gd₂O₃ burnable absorbers, have been calculated using the updated NEXUS method. The k-infinity results from these calculations were compared directly to PARAGON k-infinity values at the corresponding conditions. This comparison demonstrates that the NEXUS cross-sections are accurate over the range of temperatures, boron concentrations, and power levels expected to be encountered in PWR core calculations including off-nominal voided conditions, such as encountered during certain accident scenarios. Comparisons have also been made for configurations of heterogeneous adjacent assemblies (mixed core) which demonstrate that the updated NEXUS method captures the effects of the heterogeneities.

Finally NEXUS/ANC core models were developed for four actual plants (13 cycles total) and an equilibrium cycle. Results from specific cycle models were compared to actual measured values and to corresponding results from the same cycles using the currently licensed NEXUS methodology. Comparisons were made for at-power critical boron versus burnup, startup measurements, radial power distributions, rodworths, and cold reactivity calculations. For most parameters [

] ^{a,c}

In conclusion, the following improvements have been incorporated in an updated NEXUS methodology:

- Provide results that are the same as or better than the currently licensed NEXUS for cross-section prediction.
- Improve the capability to calculate cross-section data under accident scenarios that result in large core pressure changes or large local voiding.
- Continue to work seamlessly with the NEXUS/ANC code system, allowing the updated NEXUS methodology to be used as a direct replacement of all existing uses of the currently licensed NEXUS methodology.

These improvements have been shown to maintain or even improve the accuracy of the NEXUS methodology. While currently licensed NEXUS remains an accurate and applicable cross-section methodology, updated NEXUS provides a broader range of capabilities and improved computational efficiency.

6 REFERENCES

1. Liu, Y. S., et al., “ANC: A Westinghouse Advanced Nodal Computer Code,” WCAP-10965-P-A (Proprietary) and WCAP-10966-A (Non-Proprietary), September, 1986
2. Zhang, B., et al., “Qualification of the NEXUS Nuclear Data Methodology,” WCAP-16045-P-A Addendum 1-A (Proprietary) and WCAP-16045-A (Non-Proprietary), August, 2007
3. Zhang, B., et al., “Qualification of the New Pin Power Recovery Methodology,” WCAP-10965-P-A, Addendum 2-A (Proprietary) and WCAP-10966-A, Addendum 2-A (Non-Proprietary), September, 2010
4. Ouisloumen, M., et al., “Qualification of the Two-Dimensional Transport Code PARAGON,” WCAP-16045-P-A (Proprietary) and WCAP-16045-NP-A (Non-Proprietary), August, 2004
5. Zhang, B., et al., “Application of Westinghouse NEXUS/ANC9 Cross-Section Model for PWR Accident Analysis,” PHYSOR2014, The Role of Reactor Physics Toward a Sustainable Future, Kyoto, Japan, September 28 ~ October 3, 2014

Section D
Submittal of Responses to Requests for Additional Information



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LTR-NRC-20-13

March 3, 2020

Subject: Responses to NRC Request for Additional Information for Westinghouse Topical Report WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology"

Enclosed are the proprietary and non-proprietary versions of Responses to NRC Request for Additional Information for Westinghouse Topical Report WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology".

This submittal contains proprietary information of Westinghouse Electric Company LLC ("Westinghouse"). In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Nuclear Regulatory Commission's ("Commission's") regulations, we are enclosing with this submittal an Affidavit. The Affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the proprietary aspects of this submittal or the Westinghouse Affidavit should reference AW-20-5012 and should be addressed to Korey L. Hosack, Manager, Licensing, Analysis, & Testing, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Cranberry Township, PA 16066.

A handwritten signature in black ink, appearing to read 'K. Hosack', written over a circular stamp or seal.

Korey L. Hosack, Manager
Licensing, Analysis, & Testing

cc: Ekaterina Lenning (NRC)
Dennis Morey (NRC)

Enclosures:

1. Affidavit AW-20-5012
2. Responses to NRC Request for Additional Information for Westinghouse Topical Report WCAP-16045-P-, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology" (Proprietary)
3. Responses to NRC Request for Additional Information for Westinghouse Topical Report WCAP-16045-P-A, Addendum 2, Revision 0, and WCAP-16045-NP-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology" (Non-Proprietary)

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

COUNTY OF BUTLER:

- (1) I, Korey L. Hosack, have been specifically delegated and authorized to apply for withholding and execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse).
- (2) I am requesting the proprietary portions of LTR-NRC-20-13 Enclosure 2 be withheld from public disclosure under 10 CFR 2.390.
- (3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged, or as confidential commercial or financial information.
- (4) Pursuant to 10 CFR 2.390, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.
 - (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse and is not customarily disclosed to the public.
 - (ii) Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

AFFIDAVIT

- (5) Westinghouse has policies in place to identify proprietary information. Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:
- (a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.
 - (b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage (e.g., by optimization or improved marketability).
 - (c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.
 - (d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.
 - (e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.
 - (f) It contains patentable ideas, for which patent protection may be desirable.
- (6) The attached documents are bracketed and marked to indicate the bases for withholding. The justification for withholding is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These

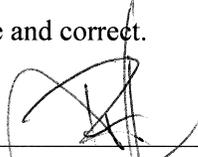
AFFIDAVIT

lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (5)(a) through (f) of this Affidavit.

I declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: 2020 03 03



Korey L. Hosack, Manager
Licensing, Analysis, & Testing

**Responses to NRC Request for Additional Information for
Westinghouse Topical Report WCAP-16045-P-A, Addendum 2, Revision 0, and
WCAP-16045-NP-A, Addendum 2, Revision 0, “Updated NEXUS Cross-Section
Methodology”**

(Non-Proprietary)

March 2020

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**Responses to NRC Request for Additional Information for
Westinghouse Topical Report WCAP-16045-P-A, Addendum 2, Revision 0, and
WCAP-16045-NP-A, Addendum 2, Revision 0, “Updated NEXUS Cross-Section
Methodology”**

The NRC staff completed an audit of Westinghouse on October 8 and 9, 2019 to facilitate the NRC staff review of the topical report. As a result of the audit, the NRC staff requires additional information to complete its review of this request. The Westinghouse responses to these RAIs are provided herein.

RAI 1 - Modifications

Section 4 of Addendum 2 to WCAP-16045-P-A describes a process that, if approved, would be used to implement future changes to the NEXUS code/methodology without submission for NRC review and approval. The possibility exists that certain changes may affect the technical basis for NRC approval of the currently proposed NEXUS code/methodology. In these cases, the NRC approval may no longer be relevant to the modified version of the NEXUS code/methodology. Therefore, the NRC staff requests the following clarifications to ensure that the scope of changes allowed without prior NRC staff review and approval will be consistent with the technical basis for approval of the methodology, including the process for future code/methodology modifications.

1. Define the scope of the qualification, especially with respect to the intended area of applicability. Include information defining the area of applicability (e.g., key parameters to be bounded) for the updated code/methodology and demonstrate how the benchmarking data set is expected to adequately cover this area of applicability. Discuss how this area of applicability and accompanying benchmarking data sets may be modified due to updates (e.g., adding new state parameters to the formulation of the nuclear cross-sections).

Response to Part 1

Updates to the NEXUS/ANC code/methodology can be characterized into two categories. The first relates exclusively to changes to the cross-section representation by parameterization of PARAGON nuclear data for use by ANC. This is the essence of the NEXUS methodology. Such updates include adding or replacing state parameters to the formulation of the nuclear cross-sections. The intended scope of the qualification of such updates involves comparison of two-dimensional ANC mini-core model results with corresponding PARAGON mini-core model results to show the key parameters (reactivity, power distribution, control rod worth) across the range of thermal operating conditions, are essentially the same. Accurate replication of the PARAGON results in ANC is sufficient to show that the updated NEXUS formulation of the cross-sections in ANC accurately represents the basic cross-sections generated by PARAGON.

The second category of updates to the code/methodology relates to changes not confined to how the PARAGON cross-sections are represented. Examples of this type include: improving the representation of boundary conditions (spectral interaction) between assemblies, and extension of the ANC nodal solution to using more than two energy groups. Since such updates to the code/methodology may affect ANC results beyond changes due to the NEXUS formulation, resulting in non-negligible changes to the ANC results, then further benchmarking is required. Such updates may affect the key core parameters used in safety analyses including core reactivity,

peaking factors, rod worths and temperature coefficient, which will be benchmarked by comparison with measured data. Startup test predictions will be used to compare reactivity (at zero power), rod worths and isothermal temperature coefficient (during these tests the core conditions are well characterized: zero power, isothermal). In addition, at-power reactivity comparisons of critical moderator boron concentration (adjusted for B-10 depletion) are used to compare core reactivity at operating conditions. Key peaking factors (FDH and FQ) are compared using power distribution measurements taken at various times during the cycle. Any changes to the code/methodology which non-negligibly impact these key parameters are assessed by assuring, prior to release of the code/methodology, that the comparisons of each parameter do not exceed the criteria shown in the table. These comparisons will consist of a number of different plants of different sizes (number of loops), fuel lattice size, and burnable absorber types. Startup M-P data will come from beginning of cycle; at-power boron and peaking factor M-P data will be taken from multiple times during the cycle. The results from all these comparisons will be pooled and the resultant M-P, to a 95/95 confidence interval, will be compared to the appropriate parameter shown in the table. If all criteria are met, the code/methodology change will have been validated for use. If any criteria are not met, the code/methodology will be refined such that the criteria are met. If the parameter remains outside the criteria, the code/methodology will be submitted to the NRC for review.

In summary: where updates to code/methodology affects the cross-section formulation, code-to-code comparisons between ANC and PARAGON mini-core models and calculations will be used to demonstrate that the formulation updates accurately recreate the PARAGON cross-sections in ANC. Where the updates have non-negligible impact on ANC results not directly related to the cross-section formulation, statistical comparisons of key parameters between ANC predictions and corresponding measured data shall be evaluated against acceptance criteria provided in the report.

2. Since the acceptance criteria are based on licensing uncertainties, discuss how any systematic biases would be identified and treated.

Response to Part 2

The benchmarking and validation of NEXUS has shown there is no significant bias and uncertainty introduced by the NEXUS methodology. In fact, the application of NEXUS in design applications requires confirmation that the fitting accuracy of the formulation for a given cross-section data set in ANC is within acceptable tolerances. Therefore, any updates to the code/methodology affecting the NEXUS formulation will not introduce significant biases or uncertainties. Where comparisons of PARAGON/ANC predictions to core measurement is concerned, the systematic biases in the key parameters are small, and additional enhancements are expected to further reduce these biases (improving the accuracy is the primary driver of any code/methodology update). Where M-P benchmarking is required (see the response to Part 1 of this Question), the intent is to compare the upper and/or lower tolerance limit, as appropriate, which accounts for both the bias and the uncertainty, with the acceptance criteria.

3. Discuss how this update process may be applied for novel fuel materials or structural materials not currently included in the benchmarking data set. Include information about how the updated methodology would be validated for first-time applications where measured data has not been collected yet.

Response to Part 3

For any novel fuel or structural material, if no methodology change is needed, the new material specific qualification will be performed before being applied for the actual core design calculation and safety analysis. This qualification always includes the single assembly and mixed fuel mini-core benchmarks and 3D core modeling cases. In the event that the methodology needs to be updated for this application, Westinghouse will follow the procedure as described in the response to Part 1 to perform full qualification for the updated methodology.

For qualification of novel fuel or structural material, Westinghouse will always try to compare the predicted results against measurements. However, if the measured data is not available for first-time application, well-recognized high-fidelity code (e.g. continuous energy Monte Carlo code) will be used to generate reference results for the comparison. The high-fidelity code must:

- a) be mature
 - b) use high order transport methodology without limitation to the neutron spectrum
 - c) be able to model the exact material and geometry of the application conditions.
4. The acceptance criteria are based on typical cold and hot operating parameters, but the intended area of applicability for the updated NEXUS methodology includes off-normal conditions such as partially voided conditions. Discuss how the benchmarking would confirm that an updated NEXUS methodology will be valid for any intended applications involving off-normal conditions.

Response to Part 4

For off-normal condition application where no measured data are available, Westinghouse will validate the methodology through the following benchmark steps:

Step 1: Confirm the lattice code is qualified and approved at these off-normal conditions.

Step 2: Qualify the ANC methodology for the application by comparing the methods predictions with the lattice code results for the same model at the same off-normal conditions. This step is to confirm that the methodology can reproduce the lattice code results in both cross-sections and reactivities at the off-normal conditions.

RAI 2 – Mini-core

Due to the strong interaction between MOX and UO₂ fuel assemblies, it has been a challenge for traditional core design methods to model UO₂-MOX mixed cores. To evaluate the impact of the re-homogenization methods, a 3x3 UO₂-MOX checker-board mini-core case was setup with 5 MOX (M) and 4 UO₂ (U) fuel assemblies. The configuration of the mini-core case is given in Figure 10 of the TR. The reflective boundary condition is applied to the outer surface of the mini-core system.

NEXUS/ANC calculations were performed with and without the re-homogenization model, while a PARAGON calculation was performed with the same geometry to generate reference results. The k_{∞} comparison of NEXUS/ANC predictions against the reference is given in Table 31 in the TR, while Figure 11 shows the comparison of assembly power distribution.

1. The NRC staff has determined that additional information is needed regarding the comparison of k_{∞} (eigenvalues) in Table 31 of the TR. Based on the NRC staff’s review of the docketed materials the correct eigenvalues are not currently listed in the TR. The staff is requesting that the applicant update Table 31 of the TR with the most accurate eigenvalues and docket the supporting information.

Response to RAI 2

Mini-core calculations were performed with PARAGON and ANC to demonstrate the re-homogenization effect. The initial calculations were done, and the results were reviewed and presented in the international conference PHYSOR2018 (Reference: “Advanced Cross-Section Re-Homogenization Based on 3D-Pseudo Pin-by-Pin Calculation (P3C) Methodology”, PHYSOR2018 Reactor Physics paving the way towards more efficient system, Cancun, Mexico, April 22-26, 2018).

Subsequent to the conference presentation, the mini-core case was re-modeled at a different condition, which lead to a small change in the reactivity and no change to the assembly power distribution. As a part of the final qualification, the updated results were documented in the Westinghouse Calculation Note CN-NEU-REH-021.

The reactivity results currently given in the Table 31 in the Topical Report are the published results from the initial calculated case (per the conference presentation). The final qualification results are presented in Calculational Note CN-NEU-REH-021, which was reviewed with the NRC Staff at the October 2019 audit. Table 31 will be updated as follows:

Table 31 Comparison of k_{∞} for 3X3 Mini-Core Case

] a,c

RAI 3 – Validation

Section 3.1.3 of the updated NEXUS methodology incorporates cross-section calculations at voided conditions as a new feature. [

] a,c

The qualification of this new feature of NEXUS follows the same logic as the single assembly qualification – comparison between values updated NEXUS and PARAGON.

1. The NRC staff have determined that additional information is needed regarding the validation of PARAGON for the voided conditions. Explain the process used to demonstrate that PARAGON can accurately model the voided conditions.

Response to RAI 3

The challenge to model the fuel assembly at the voided condition is that neutron spectra is significantly different from those at non-voided conditions. Since MCNP with continuous energy library has no limit to the neutron spectrum and fuel composition, it was used to provide the reference results. [

] ^{a,c}

Section E
Audit Information



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LTR-NRC-19-75

December 9, 2019

Subject: Submittal of NEXUS Audit Information (EPID L-2019-TOP-0026) (Proprietary/Non-Proprietary)

Enclosed are the proprietary and non-proprietary versions of the References list that was presented at the NRC Audit of WCAP-16045-P-A/WCAP-16045-NP-A, Addendum 2, Revision 0, "Updated NEXUS Cross-Section Methodology," held October 8-9, 2019. Submittal of this information was requested by the NRC at the audit.

This submittal contains proprietary information of Westinghouse Electric Company LLC ("Westinghouse"). In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Nuclear Regulatory Commission's ("Commission's") regulations, we are enclosing with this submittal an Affidavit. The Affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the proprietary aspects of this submittal or the Westinghouse Affidavit should reference AW-19-4981 and should be addressed to Korey L. Hosack, Manager, Licensing, Analysis, & Testing, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Cranberry Township, PA 16066.

A handwritten signature in black ink, appearing to read 'K. Hosack', is positioned above the printed name.

Korey L. Hosack, Manager
Licensing, Analysis, & Testing

cc: Ekaterina Lenning (NRC)
Dennis Morey (NRC)

Enclosures:

1. Affidavit AW-19-4981
2. Proprietary Information Notice and Copyright Notice
3. Submittal of NEXUS Audit Information (EPID L-2019-TOP-0026) (Proprietary)
4. Submittal of NEXUS Audit Information (EPID L-2019-TOP-0026) (Non-Proprietary)

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

COUNTY OF BUTLER:

- (1) I, Korey L. Hosack, have been specifically delegated and authorized to apply for withholding and execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse).
- (2) I am requesting the proprietary portions of LTR-NRC-19-75 be withheld from public disclosure under 10 CFR 2.390.
- (3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged, or as confidential commercial or financial information.
- (4) Pursuant to 10 CFR 2.390, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.
 - (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse and is not customarily disclosed to the public.
 - (ii) Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.
- (5) Westinghouse has policies in place to identify proprietary information. Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

AFFIDAVIT

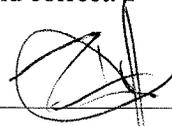
- (a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.
 - (b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage (e.g., by optimization or improved marketability).
 - (c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.
 - (d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.
 - (e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.
 - (f) It contains patentable ideas, for which patent protection may be desirable.
- (6) The attached documents are bracketed and marked to indicate the bases for withholding. The justification for withholding is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (5)(a) through (5)(f) of this Affidavit.

AFFIDAVIT

I declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: 2019/209



Korey L. Hosack, Manager
Licensing, Analysis, and Testing

Enclosure 4

**Submittal of NEXUS Audit Information
(EPID L-2019-TOP-0026)**

(Non-Proprietary)

December 2019

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References

- CN-NEU-REH-030: “Single Assembly Calculations for the NEXUS Cross-Section Reformulation Qualification Report”
- CN-NEU-REH-021: “Validation of ANC971R with Rehomogenization Capability”
- CN-NEU-REH-031: “Evaluation of NEXUS Cross-Section Reformulation Impact on Pin-Power Reconstruction Results”
- CN-NEU-REH-024 Rev.1: “CD Files and ANC9 (With Rehomogenization Methodology) Models for []^{a,c} Using ENDF/B-VII.1 Based PARAGON Library”
- CN-NEU-REH-026 Rev.1: “CD Files and ANC9 (With Rehomogenization Methodology) Models for []^{a,c} Using ENDF/B-VII.1 Based Library”
- CN-NEU-REH-028 Rev.2: “CD Files and ANC9 (With Rehomogenization Methodology) Models for []^{a,c}”
- CN-NEU-REH-032: “Qualification of NEXUS Cross-Section Reformulation and Re-Homogenization: Equilibrium Cycle”
- CN-NEU-REH-033: “Qualification of NEXUS Cross-Section Reformulation and Re-Homogenization: AP1000 First Cycle Low Power Test”