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JUL 21 2015

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Serial No.	14-625
NLOS/WDC	R0
Docket No.	50-336
License No.	DPR-65

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2
RESPONSE TO SECOND REQUEST FOR ADDITIONAL INFORMATION REGARDING PROPOSED TECHNICAL SPECIFICATION CHANGE FOR SPENT FUEL STORAGE

By letter dated December 17, 2012, Dominion Nuclear Connecticut, Inc. (DNC) submitted a license amendment request (LAR) for Millstone Power Station Unit 2 (MPS2). The proposed amendment would revise Technical Specification (TS) 1.39, "Storage Pattern," TS 3/4.9.18, "Spent Fuel Pool – Storage," TS 3/4.9.19, "Spent Fuel Pool – Storage Patterns," TS 5.3.1, "Fuel Assemblies," TS 5.6.1, "Criticality," and TS 5.6.3, "Capacity" with conforming changes to Technical Specifications Bases (TS Bases) 3/4.9.18 and 3/4.9.19. The proposed changes would reflect the results and constraints of a new criticality safety analysis for fuel assembly storage in the MPS2 fuel storage racks.

In a letter dated February 11, 2013, the NRC provided DNC an opportunity to supplement the LAR identified above. The NRC requested DNC justify the continued credit of Boraflex. DNC provided the supplement in a letter dated February 25, 2013. In a letter dated April 26, 2013, the NRC transmitted a request for additional information (RAI) to DNC related to the LAR. DNC responded to the RAI in a letter dated May 28, 2013.

In an email dated June 16, 2014, the NRC transmitted a draft second request for additional information (RAI) to DNC related to the LAR. In an email dated July 20, 2015, the NRC confirmed that the draft questions are considered final. Attachment 1 to this letter provides DNC's response to the NRC's RAI.

DNC performed additional analyses to provide the information requested in the RAI. As a result, several TS changes and TS Bases changes previously proposed have been revised and additional TS changes are being proposed. The additional proposed changes would add TS 1.40, "Non-standard Fuel Configurations and Components" and modify TS 3/4.9.17 "Spent Fuel Pool Boron Concentration" with conforming changes being made to TS Bases 3/4.9.17.

The revised TS provided with this RAI response supersede the proposed TS changes provided in the December 17, 2012 LAR in their entirety. Some of the enclosed proposed TS changes have not changed from the original LAR. Including all of the proposed changes is done for the convenience of placing all the proposed TS changes together in one letter. The proposed changes have been reviewed and approved by the Facility Safety Review Committee.

During development of the RAI responses, DNC determined a revision to the No Significant Hazards Consideration (NSHC) was warranted to include discussion of an additional

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Attachment 1 contains information that is being withheld from public disclosure under 10 CFR 2.390. Upon separation of Attachment 1, this letter is decontrolled.

accident scenario. However, the conclusions of the NSHC submitted in the December 2012 LAR remain unchanged.

The proposed change is being requested to allow removal of Boraflex credit and implement the following conditions associated with fuel storage at MPS2:

- Eliminate reactivity credit for Boraflex panels in current regions A and B of the spent fuel pool (SFP).
- Define "Non-standard Fuel Configurations."
- Revise allowed storage patterns for fuel in the spent fuel pool to meet K_{eff} requirements under normal and accident conditions.
- Revise alphanumeric designation of spent fuel regions from Regions A, B, and C to Regions 1, 2, 3, and 4 to reflect storage requirements and to clearly distinguish from existing designations.
- Require use of a Control Element Assembly (CEA) or three Borated Stainless Steel Poison Rodlets (Rodlets) in fuel assemblies stored in Region 3.
- Eliminate requirement to use spent fuel rack cell blocking devices.
- Provide storage requirements for SFP storage locations in which the Boraflex panel boxes have been removed.

Information provided in the attachments to this letter is summarized below:

- Attachment 1 provides DNC's responses to the RAI with information proprietary to DNC, AREVA Inc., and Westinghouse Electric Company, LLC (Westinghouse). DNC proprietary information is denoted with brackets and b. AREVA, Inc. proprietary information is denoted with brackets and A. Westinghouse proprietary information is denoted with brackets and a, c.

- Attachment 2 provides DNC's responses to the RAI (Non-Proprietary).

- Attachment 3 provides a Description, Criticality Technical Analysis, Regulatory Analysis and Environmental Analysis of the proposed changes. As discussed in this attachment, the proposed amendment does not involve a significant hazards consideration pursuant to the provisions of 10 CFR 50.92.

- Attachment 4 provides the analysis of Non-standard Fuel Configurations and non-fuel components.

- Attachment 5 provides the revised SFP Region 1-4 bias, uncertainty, margin and burn-up curves.

- Attachment 6 provides marked-up pages to reflect the proposed changes to the TS.

- Attachment 7 provides marked-up pages to reflect the proposed changes to the TS Bases for information only.

- Attachment 8 provides a summary of deletions, revisions, and additions to the original LAR resulting from the RAI responses.

- Attachment 9 provides the Dominion Nuclear Connecticut, Inc. Application for Withholding Proprietary Information from Public Disclosure and Affidavit.

- Attachment 10 provides the AREVA Inc. Affidavit supporting AREVA Inc. Proprietary Information contained in Dominion's RAI responses regarding proposed TS changes for spent fuel storage.

- Attachment 11 provides the Westinghouse Electric Company, LLC Application for Withholding Proprietary Information from Public Disclosure CAW-15-4225 and accompanying affidavit.

DNC will implement the revised TS within 120 days of NRC approval of the proposed amendment.

In accordance with 10 CFR 50.91(b), a copy of this license amendment request is being provided to the State of Connecticut.

If you have any questions regarding this submittal, please contact Wanda Craft at (804) 273-4687.

Sincerely,

Mark D. Sartain
Vice President – Nuclear Engineering

STATE OF CONNECTICUT)
)
COUNTY OF NEW LONDON)

The foregoing document was acknowledged before me, in and for the County and State aforesaid, today by Mark D. Sartain, who is Vice President – Nuclear Engineering of Dominion Nuclear Connecticut, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 21st day of JULY, 2015.

My Commission Expires: 2/28/16.

THOMAS CLEARY
NOTARY PUBLIC
MY COMMISSION EXPIRES
FEBRUARY 28, 2016

Notary Public

Commitments made in this letter: None

Attachments:

1. Response to Second Request for Additional Information Regarding Proposed Technical Specification Change for Spent Fuel Storage (Proprietary)
2. Response to Second Request for Additional Information Regarding Proposed Technical Specification Change for Spent Fuel Storage (Non-Proprietary)
3. Discussion of Technical Specification Changes
4. Analysis of Non-standard Fuel Configurations and Non-fuel Components
5. Revised SFP Regions 1-4 bias, Uncertainty, Margin and Burnup Curves
6. Marked-up Technical Specifications Pages
7. Marked-up Technical Specifications Bases Pages (For Information Only)
8. Summary of Deletions, Revisions, and Additions to the MPS2 Spent Fuel Pool Criticality Analysis with No Credit for Boraflex
9. Application for Withholding Proprietary Information and Affidavit of Dominion Nuclear Connecticut, Inc.
10. Application for Withholding Proprietary Information and Affidavit of AREVA Inc.
11. Application for Withholding Proprietary Information and Affidavit of Westinghouse Electric Company, LLC

cc: U.S. Nuclear Regulatory Commission
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ATTACHMENT 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING PROPOSED TECHNICAL SPECIFICATION CHANGE FOR SPENT FUEL STORAGE (NON-PROPRIETARY)

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

By letter dated December 17, 2012, Dominion Nuclear Connecticut, Inc. (DNC) submitted a license amendment request (LAR) for Millstone Power Station Unit 2 (MPS2). The proposed amendment would revise Technical Specification (TS) 1.39, "Storage Pattern," TS 3/4.9.18, "Spent Fuel Pool – Storage," TS 3/4.9.19, "Spent Fuel Pool – Storage Patterns," TS 5.3.1, "Fuel Assemblies," TS 5.6.1, "Criticality," and TS 5.6.3, "Capacity" with conforming changes to Technical Specifications Bases (TS Bases) 3/4.9.18 and 3/4.9.19. The proposed changes would reflect the results and constraints of a new criticality safety analysis for fuel assembly storage in the MPS2 fuel storage racks.

In a letter dated February 11, 2013, the NRC provided DNC an opportunity to supplement the LAR identified above. The NRC requested DNC justify the continued credit of Boraflex. DNC provided the supplement in a letter dated February 25, 2013. In a letter dated April 26, 2013, the NRC transmitted a request for additional information (RAI) to DNC related to the LAR. DNC responded to the RAI in a letter dated May 28, 2013.

In an email dated June 16, 2014, the NRC transmitted a second request for additional information (RAI) to DNC related to the LAR. This attachment provides DNC's response to the NRC's RAI.

RAI -1

The updated criticality analysis, which was provided as Attachment 4 to the LAR, does not contain criticality analysis supporting storage of consolidated fuel storage boxes (CFSBs). Instead, it claims that, due to changes associated with crediting soluble boron, the original criticality safety analysis was conservative enough that no further analysis is required.

According to the current operating license, fuel stored in the CFSBs must meet burnup credit limits that provide minimum burnup requirements as a function of initial (fresh fuel) enrichment.

While it is quite unlikely that analysis of the non-CFSB fuel will be adversely affected by the presence of fuel in completely full CFSBs, it is less obvious to the NRC staff that the old CFSB burnup credit limits would be unaffected.

Further, the proposed TS would permit storage of CFSB fuel in locations adjacent to new Regions 1, 2 and 4. Some of these rack modules previously credited Boraflex. Consequently, it is unlikely that the old analysis included consideration of fuel stored in CFSBs in positions on the periphery of Region 3 and adjacent to fuel stored in racks that no longer credit Boraflex.

Provide supplementary criticality analysis or justify that the old analysis demonstrates that storage of fuel in CFSBs meets the requirements of 10 CFR 50.68. This analysis must include consideration of mixed fuel storage configurations (i.e. CEAs, poison pins and CFSBs) in Region 3 and interaction between fuel in adjacent regions. Note that including analysis of close-packed fuel pins in CFSBs will likely require updating the criticality analysis validation study to extend the area of applicability to cover fuel in the CFSBs.

DNC Response

The consolidated fuel storage boxes (CFSBs) are now included in the analysis. Consolidation of fuel is not anticipated for the future, so storage of the CFSBs utilizes the specific fuel in these boxes. There are three CFSBs. They contain Region A fuel used in the first cycle. The enrichment of this fuel is 1.93 wt% U-235. The burnup of this fuel exceeds 15 gigawatt days/metric ton uranium (GWd/MTU). Due to the reduced moderator in these boxes, low enrichment, and their burnup, the reactivity of the boxes is low.

Region 3 (rodlet) burnup credit requirements are the most restrictive in the spent fuel pool. To show the reactivity of the CFSBs is less than the Region 3 maximum allowed reactivity, analysis of the CFSBs in Region 3 was performed. This analysis uses a 3x3 model of Region 3 with nine Region 3 fuel assemblies and all three CFSBs. Two arrangements of the CFSBs are modeled, grouped together and spread out in the 3x3 model. Since the standard Region 3 analysis included 2.1 wt% U-235 fuel with 10 GWd/MTU burnup, use of this burnup and enrichment combination is convenient to very conservatively represent the fuel in the CFSBs. For convenience, the isotopic content of the CFSB fuel is represented using 28 major nuclides ("Set 2" of Table 4 in Ref. 1.1), providing additional conservatism.

There are 352 fuel pins in each CFSB box. Although the fuel pins are loaded into the box as a close-packed (hexagonal) array, the CFSB does not have any structure in the box to maintain this geometry. The CFSBs are modeled as a rectangular array of 19x19 pins with 9 pins removed. This approach preserves the overall fuel to moderator ratio in the CFSB. Pin pitch is set to match the inner diameter of the CFSB box. The axial burnup shape used for the CFSB fuel is uniform. A uniform shape (versus the NUREG/CR-6801 axial shape) was determined to be more limiting in the Region 3 (rodlet) analysis, and the NUREG/CR-6801 axial shape was determined to be slightly more limiting in the Region 3 (control element assembly (CEA)) analysis.

Figures 1.1 and 1.2 show the two CFSB models (clustered and diagonal). The model uses a periodic boundary condition so although there are only three CFSBs, it is assumed a third of the pool is CFSBs.

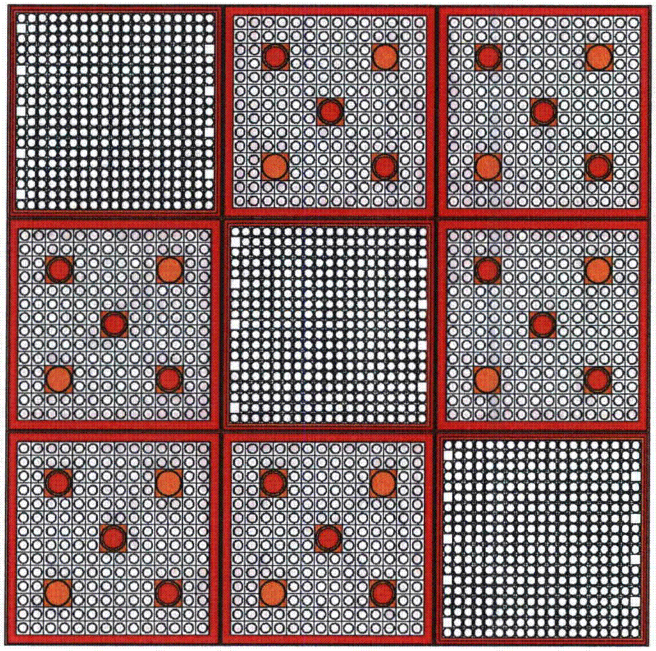


Figure 1.1: Consolidated Fuel Storage Boxes in Region 3 using a Diagonal Arrangement

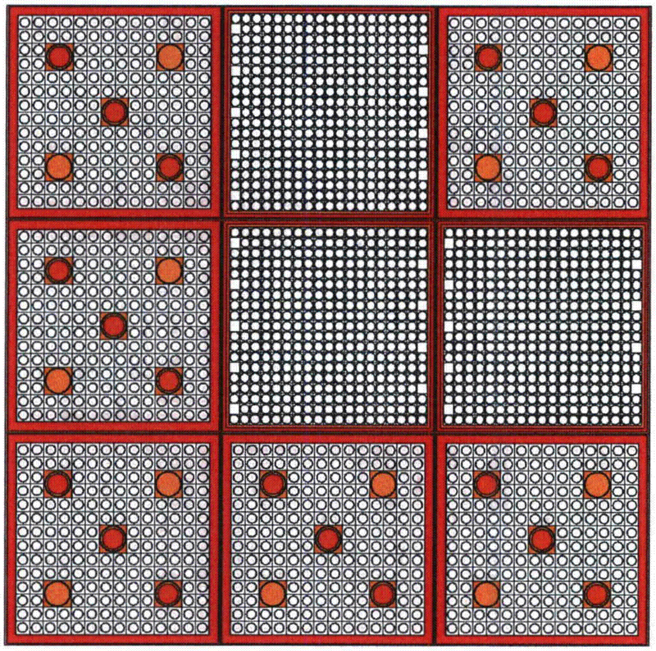


Figure 1.2: Consolidated Fuel Storage Boxes in Region 3 using a Clustered Arrangement

Table 1.1 provides calculated k_{eff} for the CFSB cases. As shown in Table 1.1, even modeled using a higher enrichment and lower burnup than actual, the CFSBs reduce k_{eff} well below the normal Region 3 k_{eff}. The arrangement of the CFSBs has a small

effect on k_{eff}. The effect of CFSBs on k_{eff} is greater for the CEA case than the rodlet case. Depleted fuel cases in Table 1.1 represent the fuel using 28 major nuclides. This reduced set of nuclides is adequate to determine the reactivity of the CFSBs relative to the normal fuel in Region 3.

Table 1.1: Analysis of the Consolidate Fuel Storage Boxes (CFSB)

Region 3 Assembly Conditions			CFSB Arrangement	Calculated k_{eff}	EALF (eV)	Soluble Boron (ppm)
Rodlets/CEA	**Enrichment (wt% U-235)**	**Burnup (GWd/T)**				
Rodlets	1.6	0	None	0.9621	0.15	0
Rodlets	1.6	0	Diagonal	0.9487	0.29	0
Rodlets	1.6	0	Clustered	0.9470	0.28	0
Rodlets	4.85	50	None	0.9779	0.26.	0
Rodlets	4.85	50	Diagonal	0.9491	0.46	0
Rodlets	4.85	50	Clustered	0.9503	0.44	0
Rodlets	4.85	50	Diagonal	0.8798	0.59	550
CEA	2.2	0	None	0.9605	0.18	0
CEA	2.2	0	Diagonal	0.9419	0.36	0
CEA	4.85	33	None	0.9760	0.31	0
CEA	4.85	33	Diagonal	0.9472	0.53	0
CEA	4.85	33	Diagonal	0.8864	0.66	550

Since the CFSB displaces borated water and hardens the spectrum, the boron worth is less than for normal fuel. Boron credit of 550 ppm is sufficient to demonstrate k_{eff} < 0.95. Total bias and uncertainty from the Region 1-4 analyses is less than 0.046 delta k (dk), so the 0.95 criterion is met for CFSBs.

The reactivity of the CFSBs is less than any fuel represented by the burnup credit curves of all regions in the MPS2 spent fuel pool (SFP). Therefore, the three CFSBs do not introduce an interface concern.

The highest Energy of the Average Lethargy causing Fission (EALF) for the cases shown on Table 1.1 is 0.66 electron volts (eV). The critical experiments used in the validation ranged between 0.0605 and 0.8485 eV. The bias increases with EALF. The EALF used to select the bias and uncertainty for the SFP was 0.65 eV. The bias as a function of EALF derived from the analysis presented in the December 2012 LAR Appendix A is:

Bias= 1- 0.998983 + 0.00588*EALF

For 0.66 eV, the bias is 0.00490. The bias used for the SFP analysis in general is 0.00484. The difference in bias is not significant to the margin shown on Table 1.1.

This analysis allows the CFSBs to be placed anywhere in the SFP where fuel is allowed. CFSBs do not require rodlets or CEAs.

Reference:

1.1 NUREG/CR-6801 , "Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses," March, 2003.

RAI-2

Proposed TS Section 5.6.1(g) includes the following text:

Finally, fuel assemblies utilizing Figure 3.9-1 D require that a control element assembly be installed in the fuel assembly (except for the full-length, reduced-strength control element assemblies and the part-length control element assemblies).

The intent of the text in the parenthetical expression is not clear. Please revise the proposed TS to improve clarity.

DNC Response

The proposed TS section has been revised to:

> *Finally, fuel assemblies utilizing Figure 3.9-1 D require that a full-length, full strength, control element assembly be inserted in the fuel assembly. (No credit is allowed for reduced-strength control element assemblies or part-length control element assemblies).*

RAI-3

In several places the amendment talks about non-standard fuel configurations and components being analyzed at some time in the future. 'Non-standard fuel configurations and components' are never defined nor are any limitations placed on what might constitute a 'non-standard fuel configurations and components'. Given that vagueness in the request, it is essentially trying to establish a prior approval.

DNC Response

Standard fuel configuration is a 14 x 14 array of fuel rods (or with one or more fuel rods replaced by un-enriched fuel rods or stainless steel rods) with 5 guide tubes that occupy

four lattice pitch locations each. Reconstituted fuel in which one or more fuel pins have been replaced by either un-enriched fuel pins or stainless steel pins is considered standard fuel and has been analyzed generically [Attachment 4]. Fuel in any other array is a "Non-standard fuel configuration" (NSFC). Each NSFC requires a criticality analysis. The analysis of the current non-standard fuel configurations is presented in Attachment 4. At this time, no further non-standard fuel configurations are anticipated.

RAI-4

Regarding any potential change without fully establishing a methodology for analyzing future fuel assemblies, please remove the discussion of the new "non-standard fuel configuration and components." Alternatively, the NRC staff requests the licensee to a provide full and complete description of the methodology including all analyses performed to support the methodology, assumptions both implicit and explicit, detailed implementation guidance, and all limitations and conditions.

DNC Response

Dominion concurs that the discussion in the December 2012 LAR [Ref. 4.1] Section 4.4, "Non-Standard Storage Configurations," is no longer applicable. All items currently stored in the spent fuel pool are specifically addressed and the analyses are presented in Attachment 4 of this letter. At this time no further non-standard fuel configurations are anticipated. However, analysis of additional NSFC that are similar to those analyzed in Attachment 4 could be similarly evaluated under the provisions of 10 CFR 50.59, within the scope of the methodology and subject to the restrictions and limitations specified in the NRC Safety Evaluation Report.

Reference:

4.1 Letter Serial No. 12-678, Dominion Nuclear Connecticut, Inc. to U.S. Nuclear Regulatory Commission, "Dominion Nuclear Connecticut, Inc, Millstone Power Station Unit 2 License Amendment Request Regarding Proposed Technical Specifications Changes for Spent Fuel Storage," December 17, 2012.

RAI-5

Attachment 2 includes a new Figure 3.9-2 showing the SFP layout. A note on the figure states "A Restricted Location may contain non-standard fuel configurations or components, or is empty." It is not clear from the criticality analysis that it is safe to store an unspecified non-standard fuel configuration in the "Restricted Locations." Please justify using the "restricted locations" for storing non-standard fuel configurations.

DNC Response

An NSFC analysis is presented in Attachment 4 of this letter. The analysis qualifies NSFCs for storage in locations intended to store fuel. None of the existing NSFCs have been qualified for storage in a Restricted Location. In addition, this analysis does not generically support storage of non-fuel items in Regions 1, 2, or 4 Restricted Locations with the exception of full length, full strength CEAs (control rods). Although CEAs are analyzed for storage in Restricted Locations, for simplicity and clarity, the note on Figure 3.9-2 will be changed to "Restricted Locations shall remain empty of fuel and non-fuel components." Non-fuel items can be placed in any location intended for fuel, including in a location intended for fuel in which the poison box has been removed.

RAI-6

The analysis for Regions 1, included the presence of the "Boraflex boxes," which are said in Section 6.1.1.1 to be removable. The proposed TS do not address whether or not the removable boxes are required. Revise the TS or provide justification for not doing so.

DNC Response

The Boraflex boxes are required for Regions 1 and 2 fuel locations and not required (but may be included) in the Regions 1 and 2 Restricted Locations. The analyses for Regions 1 and 2 burnup credit curves include a bias accommodating removal of the boxes from the Restricted Locations. The Boraflex box removal biases are 0.0036 and 0.0007 for Regions 1 and 2, respectively. The proposed TS will be revised to clarify that Boraflex boxes are required in fuel locations and are not required in Restricted Locations.

RAI-7

Identify which SCALE 6.0 nuclear data libraries were used for k_{eff} calculations and for fuel depletion calculations.

DNC Response

The 238 group ENDF/B-VII cross section library is used for the calculations.

RAI-8

Describe how convergence was checked for KENO k_{eff} calculations.

DNC Response

K_{eff} convergence of KENO cases was verified by checking for satisfaction of the chi-squared test in the log file and by looking for excessive variation or trend in the k_{eff} versus generation from the KENO output file edit. Cases which failed the screening were either rerun with additional generations and generations skipped, or were shown to be non-limiting or otherwise non-applicable cases. Changes in k_{eff} in the rerun cases were typically small, with the largest change less than 0.0004 dk.

RAI-9

T5-DEPL does not include a maximum flux difference check similar to that performed by the deterministic depletion codes. K_{eff} convergence in a Monte Carlo style code does not ensure local flux convergence. Describe how the convergence was checked for the burned fuel composition calculations.

DNC Response

T5-DEPL (TRITON) depletions use KENO to determine the spatial and energy distribution of the flux used to prepare few group cross sections and fluxes for ORIGEN. For the criticality analysis depletions, all fuel pins in the fuel assembly are the same mixture, which means that convergence is not related to a local flux but rather to the average flux over all fuel pins. Convergence of the average over many pins is relatively easier and more likely to occur. Further, convergence of interest to this application is the convergence in the atom densities as a function of burnup to the extent that they affect the SFP k_{eff}.

Section 3.1.3.7 of Rev. 0 of the December 2012 LAR [Ref. 9.1] stated, "Increasing the number of KENO neutron histories above 1000 generations of 2000 neutrons per generation does not have a significant effect on convergence." Nevertheless, depletions were performed using 2000 generations with 2000 neutrons per generation. Due to this RAI question, two depletion cases were rerun using 3000 generations with 3000 neutrons per generation. The first case was 4 wt% U-235 fuel burned to 40 GWd/T. Figure 9.1 plots k_{eff} versus burnup from the TRITON output for both the standard depletion (2000/2000 neutrons) and the convergence test (3000/3000 neutrons). The two plots are indistinguishable. Because the top node contains a control rod which could challenge the spatial convergence, the convergence test was repeated for the top node. This is plotted as Figure 9.2. The two plots are indistinguishable.

Convergence is expected with 4,000,000 neutron histories. The same number of neutron histories was used in Reference 9.2. In Reference 9.2 (Section 4) convergence was confirmed by comparison to a test case with 16,000,000 neutron histories.

References:

9.1 Letter Serial No. 12-678, Dominion Nuclear Connecticut, Inc. to U.S. Nuclear Regulatory Commission, "Dominion Nuclear Connecticut, Inc, Millstone Power Station Unit 2 License Amendment Request Regarding Proposed Technical Specifications Changes for Spent Fuel Storage," December 17, 2012.

9.2 Dale Lancaster, "Utilization of the EPRI Depletion Benchmarks for Burnup Credit Validation," EPRI, Palo Alto, CA, 1025203 (2012). Adams Accession Number: ML12165A456.

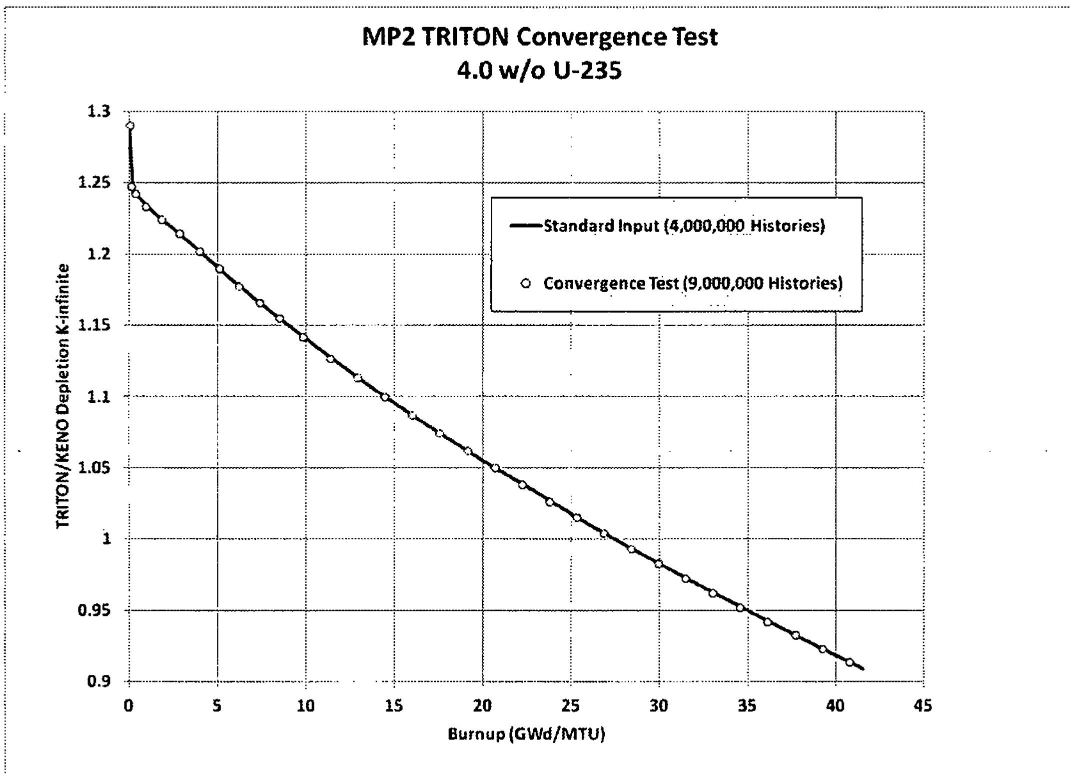


Figure 9.1: TRITON Depletion Done with 4,000,000 and 9,000,000 Neutron Histories

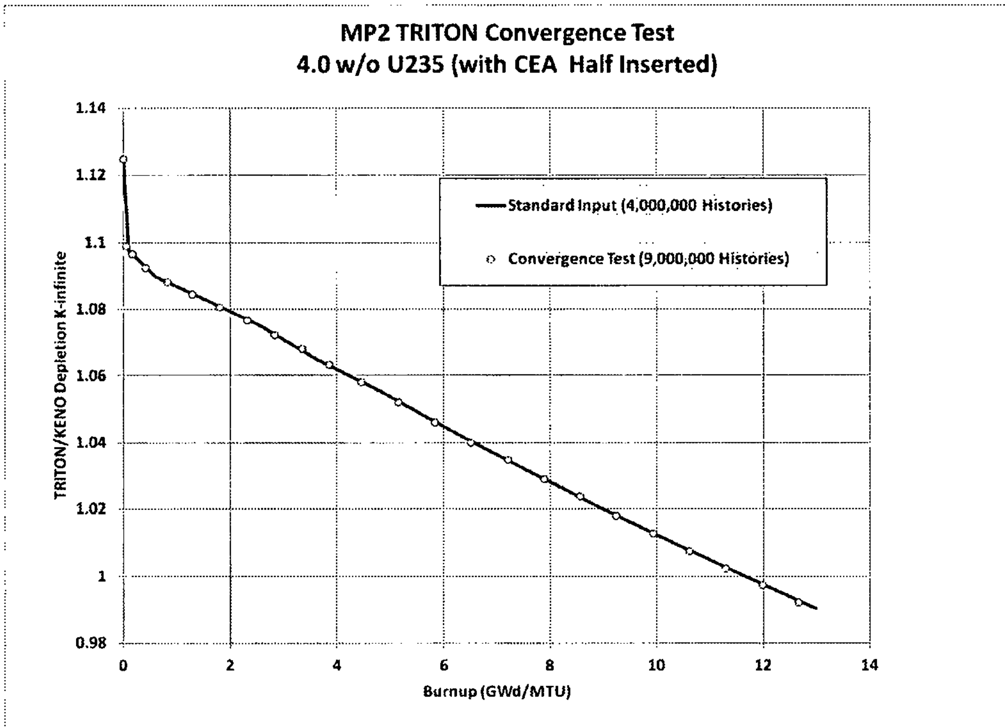


Figure 9.1: Rodded TRITON Depletion Done with 4,000,000 and 9,000,000 Neutron Histories

RAI-10

Section 3.1.1 covers bounding fuel assembly selection. A study is reported that identifies a bounding fuel assembly design. Was this bounding design also used for the new fuel storage analysis?

If so, provide a demonstration that the adopted bounding fuel assembly design also yields conservative k_{eff} values at peak moderation and full density moderation in the new fuel storage analysis. If not, explain what was analyzed for the new fuel storage.

DNC Response

A separate sensitivity study was performed for the new fuel storage analysis. Each fuel type ever used at MPS2 was analyzed as well as a new proposed fuel design. The sensitivity study included flooded conditions with both full density moderation and peak k_{eff} low-density moderation. The results are provided in Table 10.1 and demonstrate that the proposed fuel design is the most reactive fuel design for the new fuel storage racks at both full density moderation and the peak low-density moderation conditions. Most of these fuel designs will not go into the new fuel storage rack since the fuel has been burned and no new fuel of many of these designs is anticipated.

Table 10.1: Evaluation of Fuel Designs in the New Fuel Storage Rack

Fuel Type	100% Moderator Density	4% Moderator Density
	k_{eff}	k_{eff}
Proposed	0.92561	0.89521
1	0.92424	0.89431
2	0.92269	0.89267
3	0.92385	0.89417
4	0.92177	0.89233
5	0.92327	0.89285
6	0.91888	0.88782

RAI-11

This RAI is related to the uncertainty associated with burned fuel composition calculations

a. *Table 3.1-1 of Ref. 2 contains the following errors:*

   i. *Case 13, "NUREG Table 6.3, Nuclide dK" is listed as 0.00081. It should be 0.0081.*

   ii. *Cases 57 through 64, incorrect values were used for "NUREG Table 6.3, Depleted Fuel k-eff" values.*

   iii. *Case 81, "NUREG Table 6.3, Nuclide dK" is listed as 0.0008. It should be 0.0080.*

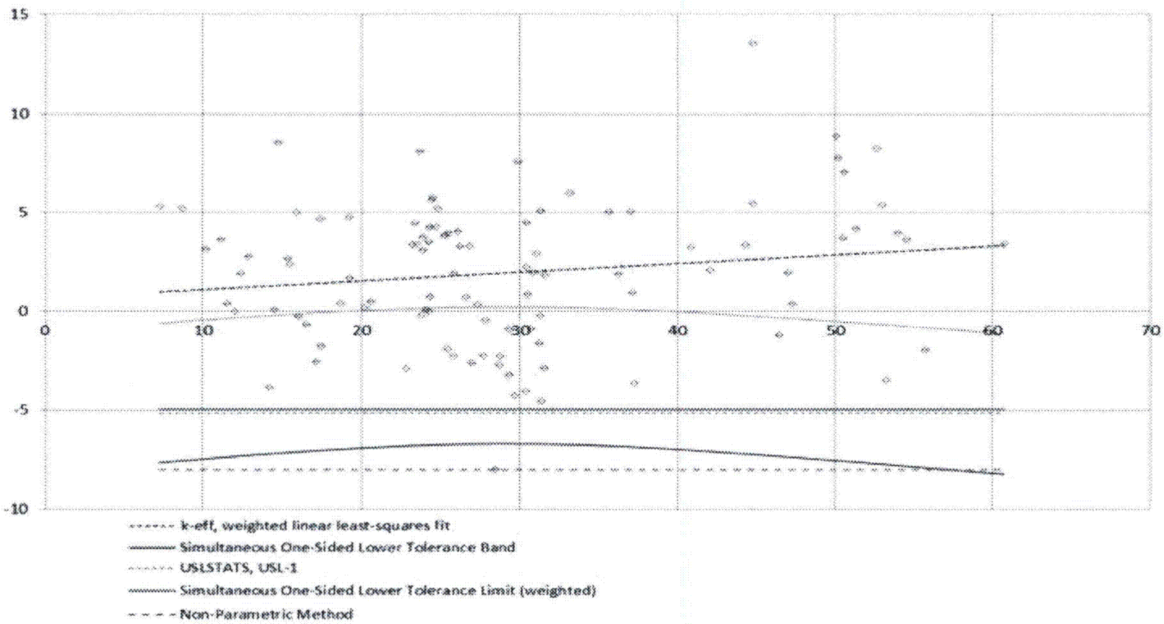
b. *The "Fresh Fuel k-eff" values reported in Table 3.1-1 were calculated using a different code than was used to calculate the values extracted from NUREG/CR-7108 Table 6.3. Since the "Burnup Worth Diff" values presented in Table 3.1-1 were calculated using the delta-k and "Depleted Fuel k-eff" values from NUREG/CR-7108 and the "Fresh Fuel k-eff" values calculated by the licensee, use of a different code system to calculate the "Fresh Fuel k-eff" values adds a potentially "systematic error" or bias.*

c. *The "dk" values used in Table 3.1-1 were calculated for NUREG/CR-7108 using a different fuel depletion sequence. It is not appropriate to assume that the dk values calculated for NUREG/CR-7108 using SCALE 6.1 and the NEWT-based depletion calculations would be the same if they were calculated using SCALE 6.0 and the KENO-based depletion calculation. KENO and NEWT have two significantly different flux solution techniques. NEWT iterates on the flux in each*

spatial mesh and in each energy group until the largest flux change in any mesh/energy group is less than the convergence criteria. KENO calculates fluxes that are passed to ORIGEN, but does not use the flux in the transport calculation or check the fluxes for convergence.

d. The 4.55% adopted for burnup worth uncertainty does not appear to have 95/95 statistical basis. Figure 3.1-2 plots the values calculated by the licensee for the burnup worth uncertainty.

First, it is not appropriate to extrapolate outside the data points (i.e. below 7.4 GWd/MTU and above 60.7 GWd/MTU). Further, statistical analysis of the data should be used to set the 95/95 uncertainty. For data with a trend, the 95/95 uncertainty should increase near the edges of the data and within the range when the data is sparser. The figure below demonstrates a more statistically defensible uncertainty analysis.



e. Consistent with guidelines, bias and bias uncertainty values are calculated based on measured data. Extrapolation outside the data should be avoided and care should be exercised when doing so. Extrapolation to low burnups should be particularly avoided because the non-uranium actinides and fission products are changing rapidly over the first several GWd/MTU. Consequently, there is no technical justification to support linear extrapolation of uncertainties to low burnup values.

DNC Response

Rather than revising the derived depletion uncertainty analysis, Dominion has performed burned fuel uncertainty calculations using Interim Staff Guidance DSS-ISG-2010-01 Section IV.2.a [Ref. 11.1].

Interim Staff Guidance DSS-ISG-2010-01 Section IV.2.a states:

> *"The staff should use the Kopp memorandum (5% of the reactivity decrement) as follows:*
>
> *i. "Depletion uncertainty" as cited in the Kopp memorandum should only be construed as covering the uncertainty in the isotopic number densities generated during the depletion simulations.*
>
> *ii. The "reactivity decrement" should be the decrement associated with the k_{eff} of a fresh unburned fuel assembly that has no integral burnable neutron absorbers, to the k_{eff} of the fuel assembly with the burnup of interest either with or without residual integral burnable neutron absorbers, whichever results in the larger reactivity decrement."*

The Kopp memorandum [Ref. 11.2] states:

> *"Where possible the primary method of analysis should be verified by a second, independent method of analysis. Acceptable computer codes include, but are not necessarily limited to, the following:*
>
> - *CASMO – a multigroup transport theory code in two dimensions*
> - *NITAWL-KENO5a – a multigroup transport theory code in three dimensions, using the Monte Carlo technique*
> - *PHOENIX-P – a multigroup transport theory code in two dimensions, using discrete ordinates*
> - *MONK6B – a multigroup transport theory code in three dimensions, using the Monte Carlo technique*
> - *DOT – a multigroup transport theory code in two dimensions, using discrete ordinates"*

The 2010 ISG allows use of 5% uncertainty for CASMO-4 depletions. Since TRITON/KENO-V.a is not listed in the Kopp memo and the Kopp memo suggests verification by a second method, support for use of 5% uncertainty for TRITON/KENO-V.a depletions will be provided via two sets of comparisons of TRITON/KENO-V.a and CASMO-4 depletion reactivity and a set of in-rack CASMO-4/KENO and TRITON/KENO k_{eff} cases. The intent of these comparisons is to show that the 5% depletion reactivity uncertainty presented in the Kopp memo and the 2010 ISG is also valid for TRITON/KENO-V.a depletions.

CASMO-4 is used for the comparisons to TRITON. Although CASMO-4 is not used for reload core design of MPS2 reload cores (the fuel vendor uses an earlier version of CASMO), CASMO-4 has been approved for reload design at plants of various types and fuel designs. Reload design includes use of CASMO-4 for fuel depletion, generation of isotopic inventory, and calculation of key physics parameters used in the reload core safety analyses. A partial list of plants licensed to use CASMO-4 is included in Table 11.1.

Table 11.1
Partial List of Plants With NRC Approval of CASMO-4 for Reload Design

Plant	Plant Type	ADAMS Accession#
North Anna	Westinghouse 3 loop 17x17	ML030700038
Surry	Westinghouse 3 loop 15x15	ML030700038
Kewaunee	Westinghouse 2 loop 14x14	ML072290373
Palo Verde	CE 2 loop 16x16 large guide tubes	ML010860187

CASMO-4 has been approved for use in a variety of plant types with varying fuel designs that encompass MPS2 design features (14x14 pin lattice, large guide tubes, gadolinia integral poison). Dominion has used CASMO-4 for reload design analyses for North Anna, Surry, and Kewaunee plants. In addition, burnup credit spent fuel pool criticality analyses employing CASMO-4 for calculation of fuel depletion have been approved by the NRC [Refs. 11.3, 11.4]. One of these two is for St. Lucie Unit 1, which is a 14x14 fuel (large guide tube) CE design plant similar to MPS2. Therefore, CASMO-4 can be properly used to calculate depleted fuel nuclide concentrations for MPS2 fuel.

A set of CASMO-4 versus TRITON/KENO-V.a comparisons is performed covering the range of depletion conditions used for the MPS2 criticality analysis using MPS2 models. The MPS2 comparisons are at hot conditions after 5 days decay. In addition, CASMO-4 versus TRITON/KENO-V.a comparisons are made for the set of 66 cases in the EPRI depletion benchmarks [Ref. 11.5]. The EPRI comparisons are at cold conditions after 100 hours decay.

Finally, five in-rack KENO k_{eff} cases are provided. The five cases are representative points from the burnup credit curves in Attachment 5 of this letter. For each in-rack case, two KENO models are compared. One model uses isotopics from CASMO-4, and one model uses isotopics from TRITON. Both models use the same set of 50 isotopes (49 plus oxygen), which represent about 96% of the depletion reactivity obtained using all TRITON isotopes. The CASMO lumped fission product is not modeled.

MPS2 Specific Analysis

The MPS2 specific analysis uses the TRITON/KENO-V.a input decks used to develop MPS2 burnup credit curves at 10, 20, 30, 40, and 50 GWd/ MTU burnup. Each input deck represents one fuel node and has key input variables of power, water temperature, fuel temperature, and fuel enrichment. The input decks used for the CASMO-4 comparison include three of the axial nodes (1, 13, and 17). Node 1 has the lowest fuel and moderator temperatures in combination. Node 13 has the highest average power and fuel temperature of the NUREG/CR-6801 [Ref. 11.6] axial burnup shapes used in the analysis. Node 17 is a gridded node with high moderator temperature and moderate to high fuel temperature (depending on the axial shape).

Analysis is performed at the minimum and maximum fuel enrichment used in the burnup curves for each burnup. This case set consists of 36 state points for comparison with CASMO-4 depletion reactivity that provides reasonable coverage of the depletion analysis for all MPS2 burnup credit curves. TRITON/KENO-V.a and CASMO-4 cases used for the MPS2 specific comparisons are listed in Table 11.2. Comparison results are listed in Table 11.3. The largest difference is 2.2%, and the average difference is 1%. Isotopic content for these cases is provided in Table 11.4 for 24 of the 28 nuclides listed as "Set 2" of Table 4 in NUREG/CR-6801. The four nuclides not included are Mo-95, Tc-99, Ru-101, and Eu-151, which are not available in the CASMO-4 output.

Table 11.2
TRITON/KENO-V.a and CASMO-4 Cases for Depletion Reactivity Comparison

Enrich. (w/o)	(GWd/MTU)	Node	Shape
2.1	10	1	Uniform
		13	Uniform
		17	Uniform
3.0	10	1	Uniform
		13	Uniform
		17	Uniform
4.2	10	1	Uniform
		13	Uniform
		17	Uniform
2.65	20	1	NUREG
		13	NUREG
		17	NUREG
2.65	20	1	Uniform
		13	Uniform
		17	Uniform
3.75	20	1	NUREG
		13	NUREG
		17	NUREG
3.7	30	1	NUREG
		13	NUREG
		17	NUREG
4.5	30	1	NUREG
		13	NUREG
		17	NUREG
4.5	30	1	Uniform
		13	Uniform
		17	Uniform
4.1	40	1	NUREG
		13	NUREG
		17	NUREG
4.85	40	1	NUREG
		13	NUREG
		17	NUREG
4.85	50	1	NUREG
		13	NUREG
		17	NUREG

Table 11.3
TRITON/KENO-V.a and CASMO-4 Depletion Reactivity Comparison

Enrich. (w/o)	Burnup (GWd/MTU)	Node	Shape	Mod Temp (K)	Fuel Temp (K)	Power (MW/MTU)	TRITON dK	CASMO dK	T/C-1 (%)
2.1	10	1	Uniform	562	1051	45.1	-0.1041	-0.1042	0.0%
		13	Uniform	593	1082	45.1	-0.1020	-0.1027	-0.6%
		17	Uniform	602	1091	45.1	-0.1014	-0.1015	-0.1%
3.0	10	1	Uniform	562	1051	45.1	-0.1186	-0.1168	1.5%
		13	Uniform	593	1082	45.1	-0.1191	-0.1174	1.4%
		17	Uniform	602	1091	45.1	-0.1188	-0.1177	1.0%
4.2	10	1	Uniform	562	1051	45.1	-0.1153	-0.1131	1.9%
		13	Uniform	593	1082	45.1	-0.1171	-0.1152	1.7%
		17	Uniform	602	1091	45.1	-0.1183	-0.1163	1.7%
2.65	20	1	NUREG	561	883	30.1	-0.1491	-0.1473	1.2%
		13	NUREG	595	1131	51.0	-0.2217	-0.2213	0.2%
		17	NUREG	603	926	30.2	-0.1472	-0.1451	1.5%
2.65	20	1	Uniform	562	1038	45.1	-0.2073	-0.2067	0.3%
		13	Uniform	593	1069	45.1	-0.2021	-0.2018	0.1%
		17	Uniform	602	1078	45.1	-0.1980	-0.1981	0.0%
3.75	20	1	NUREG	561	883	30.1	-0.1492	-0.1469	1.6%
		13	NUREG	595	1131	51.0	-0.2283	-0.2264	0.8%
		17	NUREG	603	926	30.2	-0.1515	-0.1489	1.7%
3.7	30	1	NUREG	561	854	27.9	-0.1981	-0.1946	1.8%
		13	NUREG	595	1113	51.2	-0.3094	-0.3090	0.1%
		17	NUREG	603	932	31.6	-0.2149	-0.2126	1.1%
4.5	30	1	NUREG	561	854	27.9	-0.1904	-0.1863	2.2%
		13	NUREG	595	1113	51.2	-0.3038	-0.3019	0.6%
		17	NUREG	603	932	31.6	-0.2100	-0.2070	1.5%
4.5	30	1	Uniform	562	1019	45.1	-0.2802	-0.2775	1.0%
		13	Uniform	593	1051	45.1	-0.2770	-0.2742	1.0%
		17	Uniform	602	1060	45.1	-0.2740	-0.2715	0.9%
4.1	40	1	NUREG	561	843	27.7	-0.2603	-0.2560	1.7%
		13	NUREG	592	1034	45.5	-0.3693	-0.3687	0.2%
		17	NUREG	600	943	34.6	-0.2986	-0.2966	0.7%
4.85	40	1	NUREG	561	843	27.7	-0.2484	-0.2445	1.6%
		13	NUREG	592	1034	45.5	-0.3615	-0.3591	0.7%
		17	NUREG	600	943	34.6	-0.2918	-0.2882	1.2%
4.85	50	1	NUREG	561	788	22.6	-0.2705	-0.2648	2.1%
		13	NUREG	590	982	42.0	-0.4269	-0.4253	0.4%
		17	NUREG	598	907	32.4	-0.3483	-0.3451	0.9%
			Avg	585	1000	39.8	-0.2167	-0.2147	1.0%
			Max	603	1131	51.2	-0.1014	-0.1015	2.2%
			Min	561	788	22.6	-0.4269	-0.4253	-0.6%

Table 11.4
Isotopic Content Comparisons for MPS2-specific CASMO/TRITON Cases

b

U235 wt%	GWd/ MTU	Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C	U235 wt%	GWd/ MTU	Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C
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Table 11.4 (continued)

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U235 wt%	GWd/ MTU		Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C	U235 wt%	GWd/ MTU		Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C
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Table 11.4 (continued)

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U235 wt%	GWd/ MTU		Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C	U235 wt%	GWd/ MTU		Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C
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Table 11.4 (continued)

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U235 wt%	GWd/ MTU		Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C	U235 wt%	GWd/ MTU		Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C
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Table 11.4 (continued)

U235 wt%	GWd/ MTU	Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C	U235 wt%	GWd/ MTU	Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C
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Table 11.4 (continued)

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U235 wt%	GWd/ MTU		Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C	U235 wt%	GWd/ MTU		Node	Nuclide	Triton at/bn-cm	Casmo at/bn-cm	Ratio T/C
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EPRI Benchmark Analysis

EPRI report TR-1022909, "Benchmarks for Quantifying Fuel Reactivity Depletion Uncertainty," EPRI (August 2011) [Ref. 11.5] provides data from which CASMO-4 and CASMO-5 depletion reactivities are calculated. CASMO depletion reactivity is obtained by adding the values from the EPRI report Table 8-11 (code biases) to measured benchmark delta k_{eff}'s. The benchmarks are at cold conditions in the standard in-core geometry.

The fuel in the benchmark cases is 17x17 lattices, but 17x17 fuel has a very similar neutron energy spectrum to other PWR designs during depletion. Table 13-2 of Reference 11.7 shows a comparison of the EALF burnup averaged during depletion for various fuel types. This table shows that CE 14x14 fuel is close to W 17x17 fuel and in-between standard and optimized fuel assembly (OFA) fuel (Case 4 of the benchmarks).

Table 11.5 shows the comparison of CASMO-4 and CASMO-5 to TRITON/KENO-V.a depletions for the benchmarks. The differences are less than 2%, and the average difference is less than 1%. The largest differences are for Cases 6 and 7 which contain boron coated pellets (IFBAs). Depletion reactivity for Cases 6 and 7 includes the change in worth of the IFBA. Since boron coated fuel is not used at MPS2 the average error is calculated without the Case 6 and 7 differences at 10, 20, and 30 GWd/MTU. The good agreement between codes supports using the 5% 2010 ISG depletion reactivity uncertainty for TRITON/KENO-V.a depletions.

No isotopic content comparisons are provided for the EPRI benchmark cases because the CASMO isotopic content is not available.

Depletion isotopic uncertainty confirmation work performed for the industry (EPRI benchmarks) is still under review by the NRC. The EPRI data presented in support of the MPS2 analysis herein does not depend on that review because only the CASMO and TRITON depletion reactivity at cold conditions has been used.

Table 11.5
Comparison of CASMO-4 and CASMO-5 Depletion Reactivity to TRITON/KENO V.a

	Burnup (GWd/MTU)					
	10	**20**	**30**	**40**	**50**	**60**
Case 1: 3.25% enrichment depletion						
CASMO 4 decrement Δk	0.1337	0.2353	0.3229	0.3976	0.4573	0.5019
CASMO 5 decrement Δk	0.1331	0.2344	0.3219	0.3969	0.4572	0.5026
SCALE 6.0 TRITON decrement Δk	0.1321	0.2332	0.3204	0.3949	0.4550	0.5000
100*(SCALE 6.0 - CASMO4)/CASMO4	-1.2	-0.9	-0.8	-0.7	-0.5	-0.4

	Burnup (GWd/MTU)					
	10	**20**	**30**	**40**	**50**	**60**
100*(SCALE 6.0 - CASMO5)/CASMO5	-0.7	-0.5	-0.5	-0.5	-0.5	-0.5
Case 2: 5.0% enrichment depletion						
CASMO 4 decrement Δk	0.1154	0.2035	0.2824	0.3565	0.4257	0.4884
CASMO 5 decrement Δk	0.1148	0.2026	0.2814	0.3558	0.4256	0.4891
SCALE 6.0 TRITON decrement Δk	0.1148	0.2025	0.2813	0.3550	0.4245	0.4877
100*(SCALE 6.0 - CASMO4)/CASMO4	-0.5	-0.5	-0.4	-0.4	-0.3	-0.1
100*(SCALE 6.0 - CASMO5)/CASMO5	0.0	0.0	0.0	-0.2	-0.3	-0.3
Case 3: 4.25% enrichment depletion						
CASMO 4 decrement Δk	0.1231	0.2171	0.3008	0.3778	0.4464	0.5046
CASMO 5 decrement Δk	0.1225	0.2162	0.2998	0.3771	0.4463	0.5053
SCALE 6.0 TRITON decrement Δk	0.1224	0.2160	0.2990	0.3759	0.4444	0.5030
100*(SCALE 6.0 - CASMO4)/CASMO4	-0.6	-0.5	-0.6	-0.5	-0.4	-0.3
100*(SCALE 6.0 - CASMO5)/CASMO5	-0.1	-0.1	-0.3	-0.3	-0.4	-0.5
Case 4: Smaller Fuel Rod Diameter						
CASMO 4 decrement Δk	0.1215	0.2190	0.3093	0.3951	0.4734	0.5402
CASMO 5 decrement Δk	0.1209	0.2181	0.3083	0.3944	0.4733	0.5409
SCALE 6.0 TRITON decrement Δk	0.1200	0.2167	0.3065	0.3918	0.4703	0.5375
100*(SCALE 6.0 - CASMO4)/CASMO4	-1.2	-1.0	-0.9	-0.8	-0.7	-0.5
100*(SCALE 6.0 - CASMO5)/CASMO5	-0.7	-0.6	-0.6	-0.6	-0.6	-0.6
Case 5: 20 WABA depletion						
CASMO 4 decrement Δk	0.2053	0.2349	0.3016	0.3737	0.4391	0.4949
CASMO 5 decrement Δk	0.2047	0.2340	0.3006	0.3730	0.4390	0.4956
SCALE 6.0 TRITON decrement Δk	0.2042	0.2338	0.3001	0.3736	0.4373	0.4936
100*(SCALE 6.0 - CASMO4)/CASMO4	-0.5	-0.5	-0.5	0.0	-0.4	-0.3
100*(SCALE 6.0 - CASMO5)/CASMO5	-0.2	-0.1	-0.2	0.2	-0.4	-0.4
Case 6: 104 IFBA depletion						
CASMO 4 decrement Δk	0.1744	0.2229	0.2986	0.3746	0.4437	0.5026

	Burnup (GWd/MTU)					
	10	**20**	**30**	**40**	**50**	**60**
CASMO 5 decrement Δk	0.1738	0.2220	0.2976	0.3739	0.4436	0.5033
SCALE 6.0 TRITON decrement Δk	0.1765	0.2236	0.2966	0.3703	0.4370	0.4938
100*(SCALE 6.0 - CASMO4)/CASMO4	1.2	0.3	-0.7	-1.1	-1.5	-1.7
100*(SCALE 6.0 - CASMO5)/CASMO5	1.5	0.7	-0.3	-1.0	-1.5	-1.9
Case 7: 104 IFBA, 20 WABA depletion						
CASMO 4 decrement Δk	0.2532	0.2432	0.2999	0.3706	0.4362	0.4927
CASMO 5 decrement Δk	0.2526	0.2423	0.2989	0.3699	0.4361	0.4934
SCALE 6.0 TRITON decrement Δk	0.2547	0.2442	0.2986	0.3667	0.4301	0.4849
100*(SCALE 6.0 - CASMO4)/CASMO4	0.6	0.4	-0.4	-1.0	-1.4	-1.6
100*(SCALE 6.0 - CASMO5)/CASMO5	0.9	0.8	-0.1	-0.8	-1.4	-1.7
Case 8: high boron depletion = 1500 ppm						
CASMO 4 decrement Δk	0.1224	0.2143	0.2950	0.3682	0.4329	0.4877
CASMO 5 decrement Δk	0.1218	0.2134	0.2940	0.3675	0.4328	0.4884
SCALE 6.0 TRITON decrement Δk	0.1215	0.2130	0.2934	0.3663	0.4312	0.4865
100*(SCALE 6.0 - CASMO4)/CASMO4	-0.8	-0.6	-0.5	-0.5	-0.4	-0.2
100*(SCALE 6.0 - CASMO5)/CASMO5	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4
Case 9: branch to hot rack = 338.7K						
CASMO 4 decrement Δk	0.1245	0.2185	0.3016	0.3776	0.4451	0.5022
CASMO 5 decrement Δk	0.1239	0.2176	0.3006	0.3769	0.4450	0.5029
SCALE 6.0 TRITON decrement Δk	0.1236	0.2174	0.2998	0.3757	0.4434	0.5009
100*(SCALE 6.0 - CASMO4)/CASMO4	-0.8	-0.5	-0.6	-0.5	-0.4	-0.2
100*(SCALE 6.0 - CASMO5)/CASMO5	-0.3	-0.1	-0.3	-0.3	-0.4	-0.4
Case 10: branch to 1500 ppm rack boron						
CASMO 4 decrement Δk	0.0975	0.1798	0.2548	0.3237	0.3845	0.4352
CASMO 5 decrement Δk	0.0969	0.1789	0.2538	0.3230	0.3844	0.4359
SCALE 6.0 TRITON decrement Δk	0.0963	0.1774	0.2516	0.3201	0.3807	0.4317

	Burnup (GWd/MTU)					
	10	**20**	**30**	**40**	**50**	**60**
100*(SCALE 6.0 - CASMO4)/CASMO4	-1.3	-1.4	-1.2	-1.1	-1.0	-0.8
100*(SCALE 6.0 - CASMO5)/CASMO5	-0.7	-0.8	-0.9	-0.9	-1.0	-1.0
Case 11: high power density depletion						
CASMO 4 decrement Δk	0.1243	0.2163	0.2963	0.3684	0.4318	0.4855
CASMO 5 decrement Δk	0.1237	0.2154	0.2953	0.3677	0.4317	0.4862
SCALE 6.0 TRITON decrement Δk	0.1235	0.2151	0.2944	0.3669	0.4305	0.4848
100*(SCALE 6.0 - CASMO4)/CASMO4	-0.7	-0.6	-0.6	-0.4	-0.3	-0.1
100*(SCALE 6.0 - CASMO5)/CASMO5	-0.2	-0.1	-0.3	-0.2	-0.3	-0.3
Average (excluding IFBA)						
CASMO 4 deviation	**-0.8**	**-0.7**	**-0.7**	**-0.6**	**-0.7**	**-0.6**
CASMO 5 deviation	**-0.3**	**-0.3**	**-0.4**	**-0.5**	**-0.6**	**-0.7**

In-rack CASMO/KENO and TRITON/KENO Analysis

Table 11.6 lists the nuclides used for the in-rack KENO k_{eff} comparisons. Table 11.7 summarizes the burnup credit curve sample points chosen for the in-rack k_{eff} comparison.

Table 11.6
Nuclides Used for CASMO/KENO and TRITON/KENO In-rack K_{eff} Comparisons

U-234	Pu-242	Kr-83	Cs-137	Sm-149
U-235	Am-241	Rh-103	Ba-140	Sm-150
U-236	Am-242m	Rh-105	La-140	Sm-151
U-238	Am-242	Ag-109	Nd-143	Sm-152
Np-237	Am-243	Xe-131	Nd-145	Eu-153
Np-239	Cm-242	Cs-133	Pm-147	Eu-154
Pu-238	Cm-243	Cs-134	Sm-147	Eu-155
Pu-239	Cm-244	I-135	Pm-148	Gd-155
Pu-240	Cm-245	Xe-135	Pm-148m	Eu-156
Pu-241	Cm-246	Cs-135	Pm-149	

Table 11.7
MPS2 Burnup Credit Curve Points for CASMO/TRITON In-Rack K_{eff} Comparison

Region	Enrichment (wt% U-235)	Burnup (GWd/MTU)	Shape	Axial Nodes Used
2	4.2 / 4.5	10 / 30	Uniform	13
3 (rodlets)	4.85	50	NUREG	1-18
3 (CEA)	4.50	30	NUREG	1-18
4	4.85	40	NUREG	1-18
4	3.00	20	NUREG	1-18

This set of cases covers the regions, uniform and non-uniform axial shapes, and a range of burnup credit from 10 to 50 GWd/MTU. One case, Region 2, uses only one axial node (node 13 isotopic content) to represent the entire axial length. This is reasonable for the Region 2 case because for this burnup credit point the uniform shape produced the highest k_{eff}, because the variation in isotopic content over the 18 axial nodes is not large, and because the node 13 case produces almost the same rack k_{eff} as a case with all 18 nodes.

Tables 11.8 through 11.12 contain the results of the in-rack analysis. In each table, a fresh fuel case (from the Region analysis results) is provided so that in addition to having the rack k_{eff}, the burnup worth may also be calculated and compared. The five cases show that the in-rack k_{eff} is higher using TRITON fuel content than using CASMO-4 fuel content. The ratio of TRITON burnup worth to CASMO-4 in-rack burnup worth ranges from 0.977 to 0.991. The average ratio is 0.984 and the standard deviation is 0.005. These cases confirm that use of TRITON isotopic content for in-rack burnup credit is conservative by about 1.6% of burnup worth as compared to CASMO-4 isotopic content. Therefore, if 5% burnup worth uncertainty is acceptable using CASMO-4 for burnup credit analysis, then it should also be acceptable using TRITON.

Isotopic content for the five in-rack k_{eff} cases is provided in Table 11.13. For the 18 node cases, the average number density for the 18 nodes is provided.

Table 11.8
In-rack K_{eff} Comparison of TRITON and CASMO Isotopic Content – Region 2

Region	Enrich (w/o)	Burnup (MWd/MTU)	Keff	Keff Uncert	Burnup Worth (dK)	Worth Ratio (T/C)	Depletion Code
2	4.2 / 4.5	0	1.09546	0.00010			
2	4.2 / 4.5	10 / 30	0.96875	0.00011	0.1267	**0.981**	TRITON Node 13
2	4.2 / 4.5	10 / 30	0.96635	0.00011	0.1291		CASMO Node 13

Table 11.9
In-rack K_{eff} Comparison of TRITON and CASMO Isotopic Content – Region 3 (rodlets)

Region	Enrich (w/o)	Burnup (MWd/MTU)	Keff	Keff Uncert	Burnup Worth (dK)	Worth Ratio (T/C)	Depletion Code
3	4.85	0	1.28553	0.0001			
3	4.85	50	0.96296	0.0001	0.3226	**0.985**	TRITON
3	4.85	50	0.95802	0.0001	0.3275		CASMO

Table 11.10
In-rack K_{eff} Comparison of TRITON and CASMO Isotopic Content – Region 3 (CEA)

Region	Enrich (w/o)	Burnup (MWd/MTU)	Keff	Keff Uncert	Burnup Worth (dK)	Worth Ratio (T/C)	Depletion Code
3 CEA	4.5	0	1.15663	0.00010			
3 CEA	4.5	30	0.96573	0.00098	0.1909	**0.991**	TRITON
3 CEA	4.5	30	0.96391	0.00009	0.1927		CASMO

Table 11.11
In-rack K_{eff} Comparison of TRITON and CASMO Isotopic Content – Region 4 (Case 1)

Region	Enrich (w/o)	Burnup (MWd/MTU)	Keff	Keff Uncert	Burnup Worth (dK)	Worth Ratio (T/C)	Depletion Code
4	3.0	0	1.12151	0.00098			
4	3.0	20	0.96597	0.00011	0.1555	**0.977**	TRITON
4	3.0	20	0.96232	0.00010	0.1592		CASMO

Table 11.12
In-rack K_{eff} Comparison of TRITON and CASMO Isotopic Content – Region 4 (Case 2)

Region	Enrich (w/o)	Burnup (MWd/MTU)	Keff	Keff Uncert	Burnup Worth (dK)	Worth Ratio (T/C)	Depletion Code
4	4.85	0	1.22625	0.00010			
4	4.85	40	0.96974	0.00010	0.2565	**0.986**	TRITON
4	4.85	40	0.96603	0.00009	0.2602		CASMO

b

Table 11.13
In-rack Comparison TRITON and CASMO Isotopic Content

Burnup	10	10	10	30	30	30	50	50	50
Isotope	TRITON	CASMO	T/C Ratio	TRITON	CASMO	T/C Ratio	TRITON	CASMO	T/C Ratio
U-234									
U-235									
U-236									
U-238									
Pu-238									
Pu-239									
Pu-240									
Pu-241									
Pu-242									
Am-241									
Am-242									
Am-243									
Rh-103									
Ag-109									
Cs-133									
Nd-143									
Nd-145									
Sm-147									
Sm-149									
Sm-150									
Sm-151									
Sm-152									
Eu-153									
Gd-155									

b

Table 11.13 (continued)

Region	3	3	3	4	4	4	4	4	4
Burnup	30	30	30	20	20	20	40	40	40
Isotope	TRITON	CASMO	T/C Ratio	TRITON	CASMO	T/C Ratio	TRITON	CASMO	T/C Ratio
U-234									
U-235									
U-236									
U-238									
Pu-238									
Pu-239									
Pu-240									
Pu-241									
Pu-242									
Am-241									
Am-242									
Am-243									
Rh-103									
Ag-109									
Cs-133									
Nd-143									
Nd-145									
Sm-147									
Sm-149									
Sm-150									
Sm-151									
Sm-152									
Eu-153									
Gd-155									

Summary of Support for Use of 5% of the Depletion Reactivity for the Isotopic Uncertainty

The 2010 ISG permits using 5% of the depletion reactivity for the isotopic uncertainty when using core-follow depletion codes such as CASMO-4. Use of CASMO-4 has previously been approved for SFP burnup credit analysis including for a plant of the MPS2 design (14x14 CE guide thimble fuel). Results in Tables 11.3 and 11.5 show that TRITON/KENO V.a depletion reactivity is in close agreement with CASMO-4 depletion reactivity. The average difference between CASMO-4 and TRITON/KENO-V.a depletion reactivity is less than 1% at cold conditions (W17x17 fuel) and 1% for MPS2 fuel at hot conditions.

In-rack KENO k_{eff} cases in Tables 11.8-11.12 show that the in-rack k_{eff} is higher using TRITON fuel content than using CASMO-4 fuel content. The ratio of in-rack TRITON burnup worth to CASMO-4 burnup worth ranges from 0.977 to 0.991. The average ratio is 0.984 and the standard deviation is 0.005. These cases confirm that use of TRITON isotopic content for in-rack burnup credit is conservative by about 1.6% of burnup worth as compared to CASMO-4 isotopic content.

TRITON/KENO V.a has been recently used to analyze NUREG/CR-7108 chemical assay data. [Ref. 11.8] This analysis used the direct difference approach as presented in NUREG/CR-7108 [Ref. 11.9] and concluded that depletions using TRITON/KENO-V.a with ENDF/B-VII (same library used in the MPS2 analysis) requires an isotopic uncertainty less than 5% of the depletion reactivity. The analysis derived an uncertainty of ≤ 0.01 dk at 50 GWd/MTU using two different data analysis methods. This is ~3% of burnup worth based on the MPS2 Region 3 (rodlets) 50 GWd/MTU burnup worth of 0.33 dk (Table 5.3.1-1 in Attachment 5 of this letter).

A diverse set of comparisons has been provided to show that the 5% depletion reactivity uncertainty presented in the Kopp memo and the 2010 ISG as applicable to depletion analysis using CASMO is also justified for depletion analysis using TRITON/KENO-V.a.

References:

11.1 NRC Interim Staff Guidance (ISG) DSS-ISG-2010-01, "Staff Guidance Regarding the Nuclear Criticality Safety Analysis for Spent Fuel Pools," 2011.

11.2 L. Kopp, NRC memorandum from L. Kopp to T. Collins, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants," dated August 19, 1998 (ADAMS Accession No. ML003728001).

11.3 ADAMS Accession No. ML072620412, "Arkansas Nuclear One, Unit No. 2 – Issuance of Amendment No. 273 Re: Revisions to Technical Specifications to Support Partial Re-Rack and Revised Loading Patterns in the Spent Fuel Pool."

11.4 ADAMS Accession No. ML042670562, "St. Lucie, Unit 1, License Amendment, Permits Credit Soluble Boron, Fuel Loading Restrictions & Control Element Assemblies in Spent Fuel Pool Criticality Analyses & Eliminate Need to Credit Boraflex Neutron Absorbing Material for Reactivity Control."

11.5 2003 K. S. Smith, et al., *Benchmarks for Quantifying Fuel Reactivity Depletion Uncertainty*, EPRI Technical Report No. 1022909, Electric Power Research Institute, Palo Alto, CA, August 2011.

11.6 NUREG/CR-6801, "Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses," March, 2003.

11.7 "Response to Request for Additional Information Specific to the Electric Power Research Institute Report 1025203, "Utilization of the EPRI Depletion Benchmarks for Burnup Credit Validation,"" Attachment 2 of Letter from K. Cummings of the Nuclear Energy Institute to J. Holonich of the Nuclear Regulatory Commission, dated March 2, 2015. (ADAMS Accession No. ML15061A288)

11.8 *Criticality Safety Analysis of the Indian Point Unit 2 Spent Fuel Pool with Credit for Inserted Neutron Absorber Panels*, NET-300067-01, Rev. 0. (ADAMS Accession No. ML14329A195)

11.9 G. Radulescu, I. C. Gauld, et al., *An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Isotopic Composition Predictions*, NUREG/CR-7108 (ORNL/TM-2011/509), U.S. Nuclear Regulatory Commission, Oak Ridge National Laboratory, April 2012.

RAI-12

Section 3.1.2.4 provides limited justification for a 3.5% uncertainty for the assigned assembly average burnup. Please provide a more detailed justification for the burnup uncertainty that is integrated with the criticality analysis. The justification should address the calorimetric uncertainty, the uncertainty in flux measurements, the uncertainty associated with inferring assembly power from flux measurements, the uncertainty in assembly average power inferred for non-instrumented assemblies, and uncertainties associated with integration of power over the assembly's life.

A review of the RW-859 (2002) data for Millstone Unit 2 shows that many of the older fuel assemblies have identical burnup values. This likely means that the RW-859

burnup values were either region average or design values. Confirm that the burnup values for these older assemblies have been recalculated from measurements. If the burnup values cannot be recalculated, include additional uncertainty to cover use of design and/or average assembly burnup values. The justification for the 3.5% uncertainty requested above should address this issue.

*From the description in the analysis, it looks like this uncertainty would be calculated as 0.035 times the burnup worth. From examining the various tables in the Region 2, 3 and 4 analyses, this does not appear to be how it was calculated. For one of many examples, see Table 6.1-11, uncertainty for 2B burnup (3.5% reduced bu), which is listed as 0.0009, when it seems it should be 0.035*0.106 =0.0037. It looks like it is being calculated incorrectly. Note in the same table, the Region 2B 3.5% uncertainty in the last two columns decreases from 0.0026 to 0.0009, while the burnup increases from 30 to 34.1 GWd/MTU. There are other instances of this uncertainty behavior. Describe and justify how the assembly burnup uncertainty ("3.5% reduced bu") is calculated. Where appropriate, review and revise the uncertainty analyses for Regions 2, 3 and 4.*

DNC Response

The 3.5% burnup measurement uncertainty was developed by statistically combining root sum square (RSS) assembly relative power measurement uncertainty with calorimetric power uncertainty. Relative power measurement uncertainty is part of the station safety analysis and includes uncertainty in flux measurements, uncertainty associated with inferring assembly power from flux measurements and uncertainty in assembly average power inferred for non-instrumented assemblies. Calorimetric power measurement uncertainty is part of the safety analysis of the plant and has been quantified. The RSS for these components is 2.6%.

Fuel assembly loading uncertainty is another independent contributor to RSS burnup measurement uncertainty. Burnup measurements assume a batch average MTU loading for each fuel assembly. However, MTU loading variation within each batch is small and does not significantly impact the RSS measured burnup uncertainty (less than 0.2%).

Uncertainty in measured burnup due to time integration includes an assumption of constant power distribution between power distribution measurements and the uncertainty of total core burnup for the time period between power distribution measurements. The uncertainty introduced by these terms is not included in the proposed 3.5% uncertainty value. However, because MPS2 normally performs weekly power distribution surveillance, the error introduced by the constant power distribution assumption is small. Core power distributions change slowly during steady state operation. In addition, total core burnup is accurately calculated because it is the product of calorimetric power measurement (calorimetric uncertainty is already accounted for in the 3.5% value) and time.

Equating assembly power measurement uncertainty (applicable to a single measurement) with burnup uncertainty (integrated over multiple measurements and multiple cycles / loading patterns for highly burned fuel) ignores the beneficial effects of multiple independent measurements. Mean reversion is likely to result in burnup uncertainty being substantially less than power measurement uncertainty. Therefore, the 3.5% value is a conservative value for recent and future MPS2 operation.

The second paragraph of this RAI addresses sets of assemblies having the same burnup. There are fuel assemblies in the MPS2 SFP that resided in cycles that used an older measurement system, and that were only measured using 1/8 core averaging. The older measurement system RSS uncertainty, including calorimetric is 4.3%. Prior to cycle 12, MPS2 software averaged the power of the eight symmetric locations for each octant position in the core. This should not be confused with region burnup since the eight locations are designed to have the same power if no radial tilts occur. Figure 12.1 shows the MPS2 core map. The symmetric groups of assemblies are identified in Table 12.1.

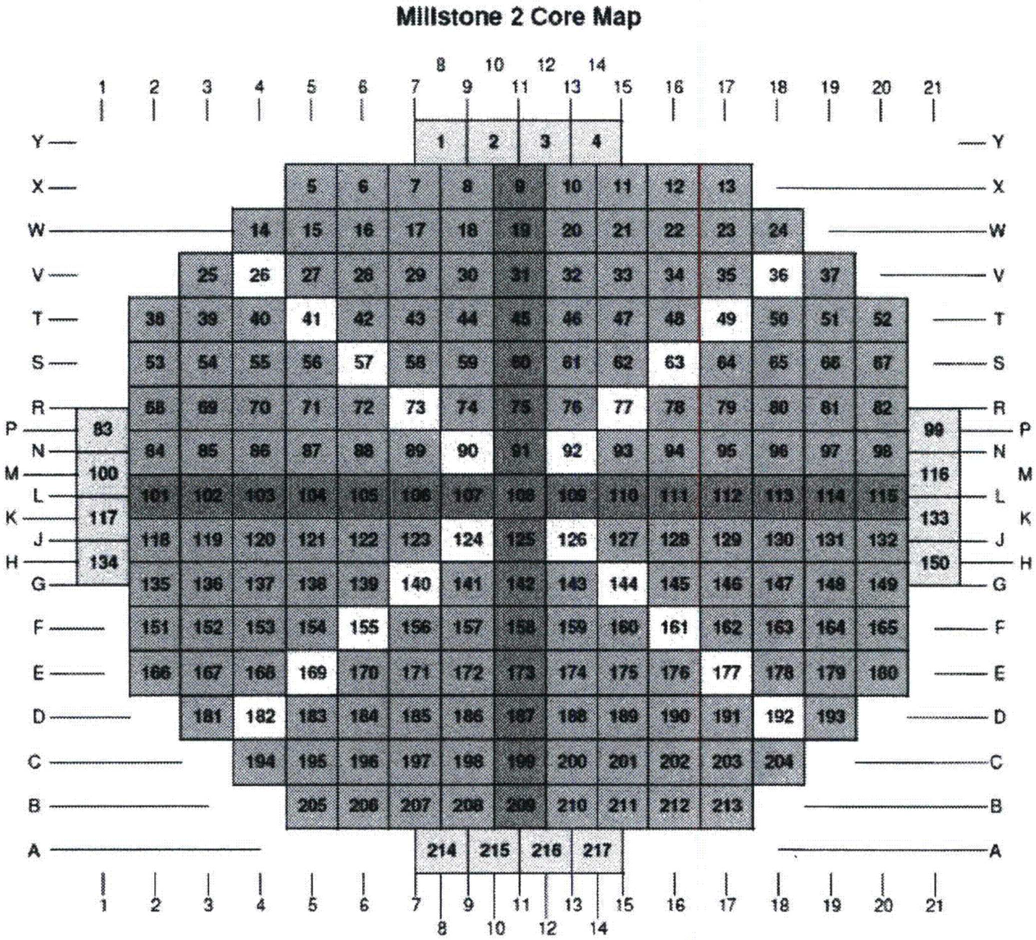


Figure 12.1: Core Map for Millstone Unit 2

Table 12.1 Symmetric Sets of Assemblies
(Each set has the same record burnup in cycles 1 to 11)

Symmetric Set Number	Assemblies in Set (See Figure 12.1)							
1				108				
2			126	92	90	124		
3			109	91	107	125		
4			144	77	73	140		
5			110	75	106	142		
6			161	63	57	155		
7			111	60	105	158		
8			177	49	41	169		
9			112	45	104	173		
10			192	36	26	182		
11			113	31	103	187		
12			114	19	102	199		
13			115	9	101	209		
14	127	93	76	74	89	123	141	143
15	145	78	62	58	72	139	156	160
16	128	94	61	59	88	122	157	159
17	162	64	48	42	56	154	170	176
18	146	79	47	43	71	138	171	175
19	129	95	46	44	87	121	172	174
20	178	50	35	27	40	168	183	191
21	163	65	34	28	55	153	184	190
22	147	80	33	29	70	137	185	189
23	130	96	32	30	86	120	186	188
24	193	37	24	14	25	181	194	204
25	179	51	23	15	39	167	195	203
26	164	66	22	16	54	152	196	202
27	148	81	21	17	69	136	197	201
28	131	97	20	18	85	119	198	200
29	180	52	13	5	38	166	205	213
30	165	67	12	6	53	151	206	212
31	149	82	11	7	68	135	207	211
32	132	98	10	8	84	118	208	210
33	150	99	4	1	83	134	214	217
34	133	116	3	2	100	117	215	216

In order to determine the uncertainty in the individual assembly burnup when only the symmetric set burnup is known, end of cycle burnups for each assembly for cycles 14 through 22 were collected. For each symmetric location, the % deviation from the mean burnup for that set for that cycle was determined for each assembly. Then the standard

deviation of the % deviation was calculated for each symmetric location. Table 12.2 shows the uncertainty in the burnup for each symmetric location. Uncertainty is calculated as N x σ (normality assumed), where N is the one-sided 95% confidence / 95% probability multiplier for the number of observations. Figure 12.2 graphically portrays the uncertainty by location in an octant of the MPS2 core.

Table 12.2 Uncertainty in Assembly Burnup Due to Using the Symmetric Average Burnup

Core Location	Uncertainty (% burnup)	Core Location	Uncertainty (% burnup)
2	0.62	19	0.82
3	0.64	20	0.86
4	0.81	21	0.82
5	0.65	22	0.90
6	0.66	23	0.83
7	0.60	24	1.08
8	0.56	25	1.12
9	0.77	26	1.43
10	0.76	27	1.10
11	0.94	28	0.85
12	0.70	29	0.99
13	1.07	30	0.81
14	0.69	31	1.05
15	0.62	32	1.17
16	0.84	33	0.81
17	0.78	34	1.03
18	0.84		

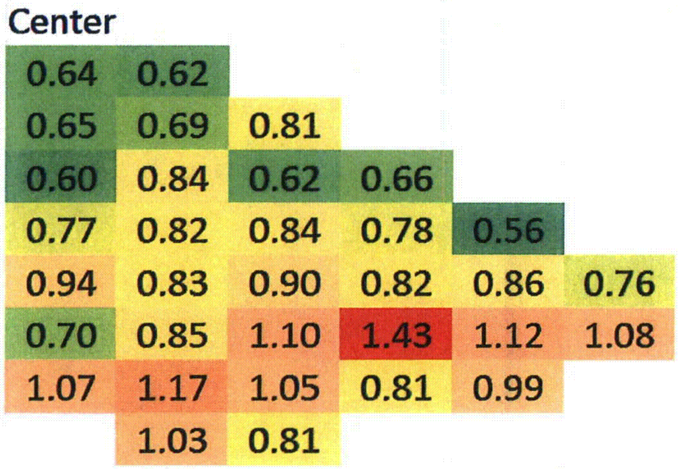


Figure 12.2 Octant of Millstone Unit 2 Core with % Burnup Uncertainty due to Octant Averaging

Figure 12.2 suggests that the octant averaging could produce a 1.43% error in the burnup. Some of this could be already included in the flux map uncertainty but it will be assumed that it is all due to core power tilts. Some of these assemblies also have the larger burnup measurement uncertainty previously described (4.3% measured burnup uncertainty versus 2.6% for newer fuel). The fuel assemblies subject to larger burnup uncertainty have all been discharged for at least 10 years with two exceptions (8.3 and 9.8 years decay time). The effect of decay time is more than sufficient to accommodate higher measured burnup uncertainty for these older assemblies. Decay time is not credited in the burnup curve calculation.

A Region 3 decay time calculation was performed at 10 and 50 GWd/MTU fuel burnup. Results are shown in Table 12.3. The reactivity decrement due to depletion ("burnup worth") increases with increasing decay time. For 10 years decay time, burnup worth increases over 12%. Decay time reactivity reduction is much larger than increased burnup measurement uncertainty for older fuel, so there is no need to explicitly account for those issues.

The final paragraph of RAI 12 addresses calculation of the reactivity due to the reactor record burnup uncertainty. Assembly burnup was actually decreased by 3.5% and the reactivity of this change was determined by interpolation of k_{eff} versus burnup. The approach suggested in the RAI is approximately correct and always conservative due to the curvature of the depletion reactivity curve. For the revised burnup credit curve calculation, reactor record burnup uncertainty will be calculated as 3.5% of the burnup worth.

Table 12.3
Decay Time Effect on Burnup Worth

Enrichment (w/o U235)	Burnup (GWd/MTU)	Decay Time	KENO K-eff	KENO K-eff Deviation	Burnup Worth (dK)	10 Year Decay time % of Burnup Worth
2.1	0	0	1.055197	0.00009	N/A	N/A
2.1	10	5 d	0.96040	0.00008	-0.0948	N/A
2.1	10	10 y	0.94841	0.00008	-0.1068	12.6%
4.85	0	0	1.28553	0.00010	N/A	N/A
4.85	50	5 d	0.92351	0.00008	-0.3620	N/A
4.85	50	10 y	0.87693	0.00008	-0.4086	12.9%

RAI-13

Section 3.1.3.1 discusses axial burnup distributions. Typically, at low assembly burnup values (i.e. < 20GWd/MTU) and for systems with mixed fresh and spent fuel, such as at

the region-to-region interfaces on the edges of Region 1, and for accident analysis models involving misloading of a fresh fuel assembly, the NUREG/CR-6801 axial burnup profiles may not be limiting. Typically, this is addressed by using both uniform and distributed axial burnup profiles and using the most reactive for that model. The physics involved is that a fresh fuel assembly will have a fission density peak near its axial mid-plane, while in a highly burned assembly in excess of 90% of the fission density is near the top. This sort of axial fission density axial location mismatch was not considered when the limiting axial burnup distributions described in NUREG/CR-6801 were determined. Confirm whether uniform axial burnup distributions were considered for the analysis and also that the uniform axial burnup distributions were also utilized when burnup credit curves were generated, when k_{eff} values for region-to-region interfaces were quantified, and when accident analysis calculations were performed.

DNC Response

In the December 2012 LAR, the analyses with burned fuel used the shapes from NUREG/CR-6801. Uniform shapes have been added to the analysis. Revised bias, uncertainty, and burnup curves are provided in Attachment 5 of this letter. Revised accident and interface calculations were performed with both uniform and NUREG/CR-6801 shapes.

References:

13.1 NUREG/CR-6801, "Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses," March, 2003.

RAI-14

Section 3.1.3.3 discusses fuel temperature. Please confirm that a conservative fuel temperature has utilized during fuel depletion calculations. Higher temperature increases resonance absorption in ^{238}U, resulting in higher Pu generation. The input file included in Ref. 2 as Appendix B reflects a fuel temperature of 907K. Doing a quick survey of resonance effective fuel temperatures used in other work, this value seems to be a little low compared to values that range between 900 and 1200k. Typically, the resonance effective fuel temperature (REFT) is a weighted average of the pellet surface, center-line and mid-radius fuel temperatures. The weighting factors include the effects of temperature and neutron flux distributions. Confirm that conservative REFT values were used. Note that low burnup fuel generally has a higher than average power density and, consequently, higher fuel temperatures.

DNC Response

The fuel temperatures used are the best estimate volume averaged fuel temperatures from the licensed core design model, PRISM. The volume averaged fuel temperature is higher (more conservative) than the resonance effective fuel temperature since the resonance flux is higher in the outer portions of the fuel where the fuel temperature is lower. Fuel temperatures are also conservative because of the use of bounding assembly average power. The red (top) line on Figure 14.1 shows the conservative assembly average relative power used in the depletion to the indicated burnup. As the RAI question suggests, the relative power decreases with burnup.

The fuel temperature of 907 degrees Kelvin (°K) cited in the RAI appears to be low because it is for Node 17 (2^{nd} node of 18 from the top of the fuel) at 50 GWd/MTU assembly burnup (non-uniform axial burnup shape). The assembly depletion power for the 50 GWd/MTU case (1.25) is lower than earlier burnups (1.45) due to the decline in assembly power as burnup increases. Nodal power for the case cited in the RAI is relatively low (0.83 of the assembly average) due to the proximity of the node to the top of the fuel. A more complete representation of depletion parameters is shown in Figure 14.1. Included in the figure are the history averaged assembly power, history averaged assembly fuel temperature, and history averaged peak nodal fuel temperature. History averaged values are those used to deplete to the indicated burnup.

A

Figure 14.1 Depletion Fuel Temperature as a Function of Burnup

RAI-15

Provide a list of nuclides that were retained for criticality calculations. Confirm that noble or volatile gases and short-lived radioactive nuclides are not credited, because they would not be present in the SFP. For such nuclides that were retained in the analysis, provide an estimate for their worth.

DNC Response

Table 15.1 shows the 252 isotopes used in the criticality analysis. At low burnups, TRITON removes a few of these isotopes. The analysis employed the TRITON parameter addnux=3 to maximize the number of isotopes included in the analysis. The spent fuel reactivity was maximized by using the isotopic content after five days of decay. Other than removing light elements (less than oxygen, except B-10) the set of isotopes is taken directly from the TRITON output. Note that the actual output included more isotopes than in the tables in the TRITON user's manual.

Table 15.1 Isotopes Used In the MPS2 Criticality Analyses

^{10}B	^{16}O	^{69}Ga	^{71}Ga	^{70}Ge	^{72}Ge	^{73}Ge	^{74}Ge	^{76}Ge	^{74}As
^{75}As	^{74}Se	^{76}Se	^{77}Se	^{78}Se	^{79}Se	^{80}Se	^{82}Se	^{79}Br	^{81}Br
^{80}Kr	^{82}Kr	^{83}Kr	^{84}Kr	^{85}Kr	^{86}Kr	^{85}Rb	^{86}Rb	^{87}Rb	^{84}Sr
^{86}Sr	^{87}Sr	^{88}Sr	^{89}Sr	^{90}Sr	^{89}Y	^{90}Y	^{91}Y	^{90}Zr	^{91}Zr
^{92}Zr	^{93}Zr	^{94}Zr	^{95}Zr	^{96}Zr	^{93}Nb	^{94}Nb	^{95}Nb	^{94}Mo	^{95}Mo
^{96}Mo	^{97}Mo	^{98}Mo	^{99}Mo	^{100}Mo	^{99}Tc	^{98}Ru	^{99}Ru	^{100}Ru	^{101}Ru
^{102}Ru	^{103}Ru	^{104}Ru	^{106}Ru	^{103}Rh	^{105}Rh	^{102}Pd	^{104}Pd	^{105}Pd	^{106}Pd
^{107}Pd	^{108}Pd	^{110}Pd	^{107}Ag	^{109}Ag	^{110m}Ag	^{111}Ag	^{108}Cd	^{110}Cd	^{111}Cd
^{112}Cd	^{113}Cd	^{114}Cd	^{115m}Cd	^{116}Cd	^{113}In	^{115}In	^{114}Sn	^{115}Sn	^{116}Sn
^{117}Sn	^{118}Sn	^{119}Sn	^{120}Sn	^{122}Sn	^{123}Sn	^{124}Sn	^{125}Sn	^{126}Sn	^{121}Sb
^{123}Sb	^{124}Sb	^{125}Sb	^{126}Sb	^{122}Te	^{123}Te	^{124}Te	^{125}Te	^{126}Te	^{127m}Te
^{128}Te	^{129m}Te	^{130}Te	^{132}Te	^{127}I	^{129}I	^{130}I	^{131}I	^{135}I	^{126}Xe
^{128}Xe	^{129}Xe	^{130}Xe	^{131}Xe	^{132}Xe	^{133}Xe	^{134}Xe	^{135}Xe	^{136}Xe	^{133}Cs
^{134}Cs	^{135}Cs	^{136}Cs	^{137}Cs	^{132}Ba	^{133}Ba	^{134}Ba	^{135}Ba	^{136}Ba	^{137}Ba
^{138}Ba	^{140}Ba	^{138}La	^{139}La	^{140}La	^{138}Ce	^{139}Ce	^{140}Ce	^{141}Ce	^{142}Ce
^{143}Ce	^{144}Ce	^{141}Pr	^{142}Pr	^{143}Pr	^{142}Nd	^{143}Nd	^{144}Nd	^{145}Nd	^{146}Nd
^{147}Nd	^{148}Nd	^{150}Nd	^{147}Pm	^{148}Pm	^{148m}Pm	^{149}Pm	^{151}Pm	^{147}Sm	^{148}Sm
^{149}Sm	^{150}Sm	^{151}Sm	^{152}Sm	^{153}Sm	^{154}Sm	^{151}Eu	^{152}Eu	^{153}Eu	^{154}Eu
^{155}Eu	^{156}Eu	^{157}Eu	^{152}Gd	^{153}Gd	^{154}Gd	^{155}Gd	^{156}Gd	^{157}Gd	^{158}Gd
^{160}Gd	^{159}Tb	^{160}Tb	^{158}Dy	^{160}Dy	^{161}Dy	^{162}Dy	^{163}Dy	^{164}Dy	^{165}Ho
^{166m}Ho	^{164}Er	^{166}Er	^{167}Er	^{168}Er	^{170}Er	^{208}Pb	^{228}Th	^{229}Th	^{230}Th
^{232}Th	^{234}Th	^{231}Pa	^{233}Pa	^{232}U	^{233}U	^{234}U	^{235}U	^{236}U	^{237}U
^{238}U	^{235}Np	^{236}Np	^{237}Np	^{238}Np	^{239}Np	^{236}Pu	^{237}Pu	^{238}Pu	^{239}Pu
^{240}Pu	^{241}Pu	^{242}Pu	^{244}Pu	^{241}Am	^{242}Am	^{242m}Am	^{243}Am	^{244}Am	^{241}Cm
^{242}Cm	^{243}Cm	^{244}Cm	^{245}Cm	^{246}Cm	^{247}Cm	^{248}Cm	^{249}Bk	^{249}Cf	^{250}Cf
^{251}Cf	^{252}Cf								

The second part of RAI 15 addresses noble or volatile gases (hereafter called fission gases) and the amount these are credited in the criticality analysis. Table 15.2 lists the fission gases used in the criticality analysis. Two of the isotopes, Cs-133 and Xe-131, dominate the reactivity worth of the fission gases. To analyze the worth of the fission gases, a Region 3 (with rodlets) model with 4.85 wt% U-235 enrichment and 50 GWd/T burnup was run with various fission gases removed. Table 15.3 shows the results. As shown in the table, the worth of Cs-133 and Xe-131 is almost 80% of the worth of the fission gases.

Table 15.2
Noble and Volatile Gases Used In the MPS2 Criticality Analysis

Noble Gases	^{80}Kr, ^{82}Kr, ^{83}Kr, ^{84}Kr, ^{85}Kr, ^{86}Kr ^{126}Xe, ^{128}Xe, ^{129}Xe, ^{130}Xe, **^{131}Xe**, ^{132}Xe, ^{133}Xe, ^{134}Xe, ^{135}Xe, ^{136}Xe
Alkali Metals	^{85}Rb, ^{86}Rb, ^{87}Rb **^{133}Cs**, ^{134}Cs, ^{135}Cs, ^{136}Cs, ^{137}Cs
Halogens	^{79}Br, ^{81}Br ^{127}I, ^{129}I, ^{130}I, ^{131}I, ^{135}I

The **bolded** isotopes have the highest reactivity worth.

Table 15.3
Maximum Worth of the Noble and Volatile Gases Used In the MPS2 Criticality Analysis
(Region 3 with rodlets, 4.85 wt% U-235, 50 GWd/T)

Isotope	**Worth (delta k)**
^{80}Kr, ^{82}Kr, ^{83}Kr, ^{84}Kr, ^{85}Kr, ^{86}Kr ^{126}Xe, ^{128}Xe, ^{129}Xe, ^{130}Xe, , ^{132}Xe, ^{133}Xe, ^{134}Xe, ^{135}Xe, ^{136}Xe ^{85}Rb, ^{86}Rb, ^{87}Rb ^{134}Cs, ^{135}Cs, ^{136}Cs, ^{137}Cs ^{79}Br, ^{81}Br ^{127}I, ^{129}I, ^{130}I, ^{131}I, ^{135}I	0.0026
^{133}Cs,	0.0046
^{131}Xe	0.0054

RAI 15 states that volatile nuclides would not be present in the spent fuel. Although it would be conservative to ignore the gaseous fission products, most of them are still in the active fuel. The mobility of fission gases is important in assessing the

consequences of reactor accidents. There is data on fission gas release that has been reviewed and approved by the NRC. Regulatory Guide RG 1.183 provides conservative release fractions for fission gases. [Ref. 15.1]

It is expected that RG 1.183 will be updated soon to reflect higher linear powers than were used in developing the current limits. PNNL-18212 Rev. 1, "Update of Gap Release Fractions for Non-LOCA Events Utilizing the Revised ANS 5.4 Standard," which was completed in June 2011, provides the new analysis [Ref. 15.2]. Table 2.9 of PNNL-18212 provides new limiting release rates. PNNL-18212 Appendix C also provides an example of calculated release rates when the linear power is known. Figure 15.1 shows the limiting linear power as a function of burnup expected to bound all plants and a more typical plant specific (Appendix C) bounding assumption. Under these limiting linear powers is the cycle average linear power for each assembly in MPS2 for cycles 1 through 20. As shown on Figure 15.1, the Appendix C example is adequate for MPS2.

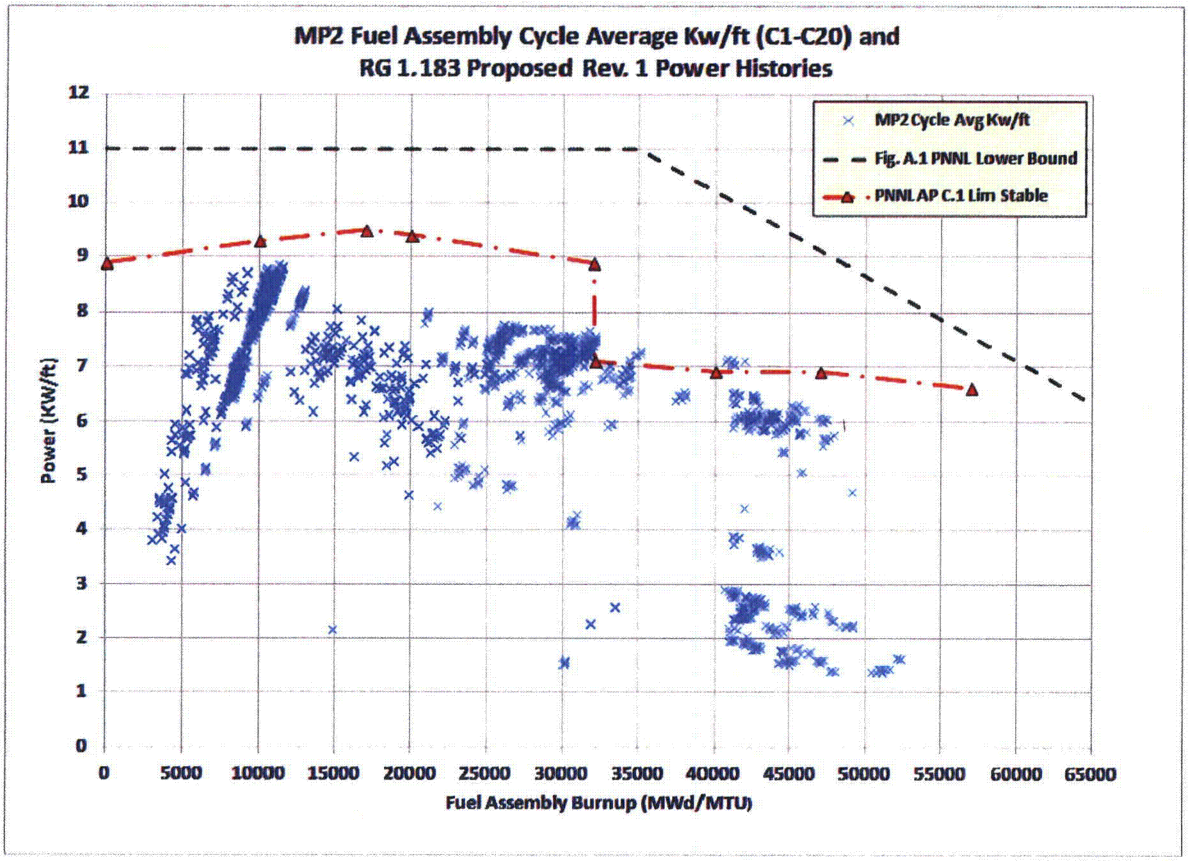


Figure 15.1 MPS2 Cycle Average Linear Power by Assembly Compared to PNNL Limiting Linear Power as a Function of Burnup

For revised burnup credit calculations, the atom densities of the fission gases were reduced to account for the fission gas release fraction. Table 15.4 shows the fission

gas release fractions from the current RG 1.183, the PNNL-18212 recommended change to the RG, the PNNL-18212 plant dependent release rate from Appendix C, and the release rate assumed for revised MPS2 criticality analysis. As shown on Table 15.4, the fission gas release fraction selected is generous compared to Appendix C of PNNL-18212 and is more bounding than the current RG (note that I-131 is low worth). K_{eff} increased 0.0014 in a Region 3 (rodlets) model with the highest credited fuel burnup due to the reduction in fission gas atom densities.

Table 15.4
Fission Gas Release Fractions

Isotopes	Current RG 1.183	Bounding Proposed in PNNL-18212	Appendix C of PNNL-18212	Implemented in MPS2 Criticality Analysis
K-85	0.10	0.38	0.13	0.20
I-131	0.08	0.08	0.02	0.05
Other Nobles Gases	0.05	0.08	0.02	0.05
Other Halogens	0.05	0.05	0.01	0.05
Alkali Metals	0.12	0.50	0.16	0.20

The fission gas release fractions used are conservative due to a number of factors:

1. The bounding analysis done by PNNL was done for W 14x14 fuel which has a smaller pellet diameter than the CE 14x14 fuel. CE 14x14 fuel requires a greater distance for fission gas diffusion.
2. Cs-133 migrates toward the edge of the pellet but it is assumed in this analysis that it then moves away from the active fuel. The temperatures at the edge of the pellet are well below the boiling point of cesium (951 °K). If cesium is highly reactive and if it reacts with other available elements, it becomes a solid that is unlikely to move axially.
3. The release fractions are bounding rather than nominal. The analysis could be divided into nominal and uncertainties where the uncertainties could be statistically combined with other independent uncertainties. Bounding features include measured fission gas releases and linear power.

References:

15.1 USNRC Reg. Guide 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” July 2000.

15.2 PNNL-18212 Rev. 1, ADAMS ML112070118, “Update of Gap Release Fractions for Non-LOCA Events Utilizing the Revised ANS 5.4 Standard,” June 2011.

RAI-16

Section 4.4 is on "Non-Standard Storage Configurations." The text in this section states:

> There are non-standard fuel configurations and components, and non-fuel containing components present in the MP2 SFP.

The text goes on to say:

These non-standard configurations and components may be stored in fuel assembly locations or in Restricted Locations (see Section 6.1) if they are demonstrated to be non-limiting with respect to the storage patterns that have been analyzed. The same methodology used for the analysis herein that established the Technical Specification requirements will be employed to evaluate non-standard configurations and components. These assessments would employ the requirements for documentation and implementation under the provisions of 10CFR50.59.

The analysis provided does not include evaluation of the effects of non-standard "fuel" configurations and components (NSFCC) that may be stored in both the fuel assembly locations and in the restricted locations.

Please provide the evaluation of the effects of the NSFCC. The supplementary criticality analyses described in Section 4.4 should include consideration of whether or not the validation study is applicable to the NSFCC, whether or not any new accident conditions are introduced, whether or not the additional NSFCC are modeled conservatively, and whether or not neutronic interaction between NSFCC and intact fuel assemblies is appropriately considered.

DNC Response

The responses to RAI 3 and RAI 4 and the analysis presented in Attachment 4 of this letter provide the requested information.

RAI-17

Section 5.1 notes that the new fuel storage racks are reflected by concrete on all six faces. Describe and justify the concrete composition model used. Note that sensitivity studies performed for a different new fuel storage vault have shown that k_{eff} may vary by up to 3% Δk with different concrete compositions. If the concrete composition is unknown, a conservative bounding model should be used, which should also include

consideration of the potential for water loss associated with concrete aging. Revise the uncertainty analysis for the new fuel storage racks to address the uncertainties in the concrete composition.

DNC Response

The concrete employed in the analysis is a Portland cement as specified in the MPS2 Final Safety Analysis Report (FSAR). The composition is the same as the SCALE concrete, "reg-concrete." The composition of this concrete is given in Table 17.1.

Table 17.1 Material Composition of the Concrete Used in the Analysis

Material	Atom Density (atoms/barn-cm)
Oxygen	0.04608
Hydrogen	0.01375
Aluminum	0.00175
Calcium	0.00152
Iron	0.00035
Silicon	0.01663
Sodium	0.00175

The EPRI sensitivity report [Ref. 17.1] developed a limiting concrete composition. This limiting composition contains no hydrogen to bound full dry out of the concrete. The new fuel storage racks were run with the EPRI conservative dry concrete and a significant positive reactivity was observed. To compensate for this increase in reactivity the NFSR model was revised to more realistically represent the NFSR.

Figure 17.1 is a picture of the room for the NFSR. The NFSR is inside a set of walls that are 1 foot thick and 16 feet high. Outside these walls is a large open area in all directions. The new model has the active fuel sitting on a 60 cm block of concrete. The fuel assemblies are modeled as close to each other as allowed assuming the eccentrically positioned fuel in rack cells that are as close as the manufacturing tolerance allows. Since the model includes tolerances for the rack dimensions, the only uncertainties statistically combined are related to the fuel.

The outside surface of the walls is modeled with a void boundary condition. Foam or water is allowed to fill the room to the top of the 16 foot wall. Above that, a void boundary condition is used. The changes in the model accommodate the use of the conservative EPRI concrete. The model ignores features which would absorb neutrons such as the upper and lower tieplates, rebar in the concrete, and the steel angle brackets that make up the storage rack.

The change in k_{eff} due to the concrete change from the "reg-concrete" to the EPRI conservative concrete for the final model is shown on Table 17.2. As expected, the

impact of the concrete on the flooded case is small. Results in Table 17.2 show that the impact of the concrete on the low density model is significant. The model with the EPRI conservative concrete is used for the final results but some uncertainties of the fully flooded cases are based on the "reg-concrete" model.

Figure 17.1 New Fuel Storage Rack Room

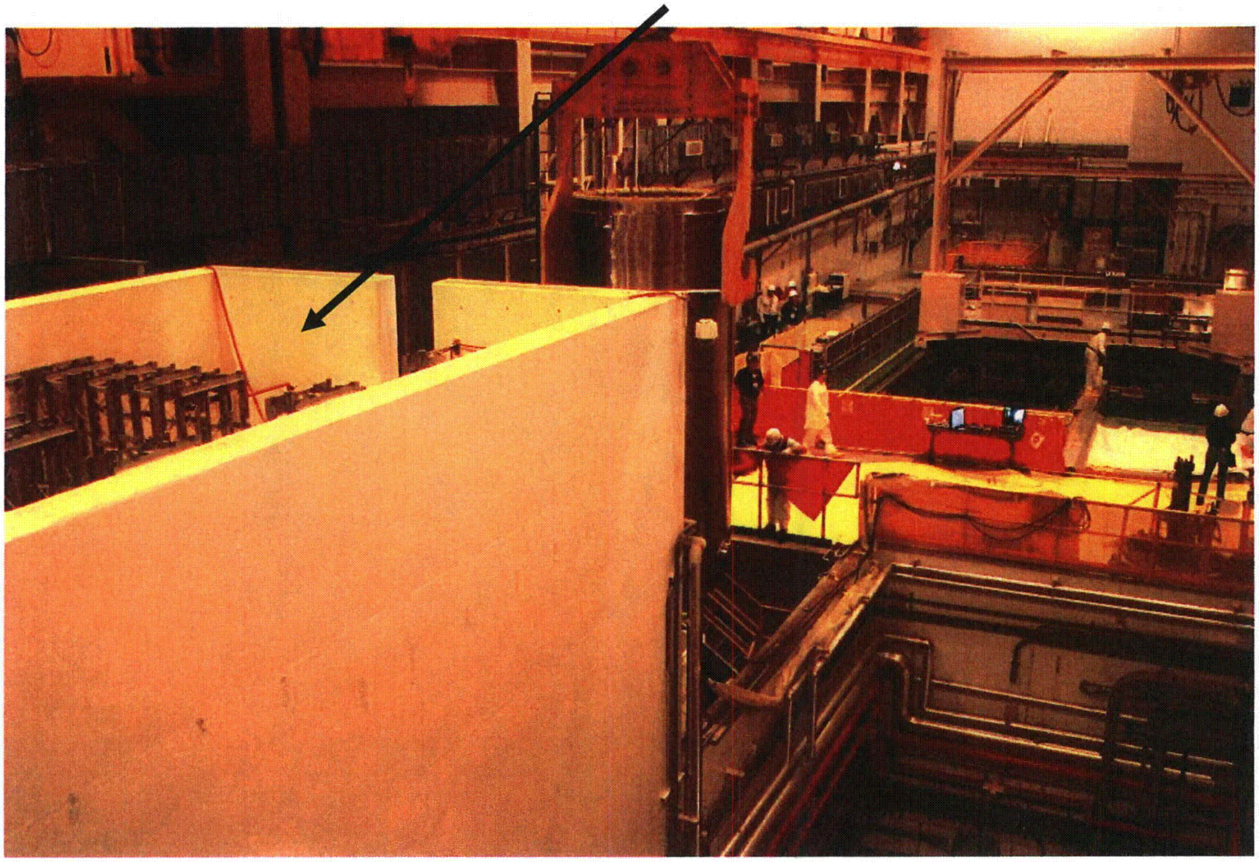


Table 17.2 Reactivity Impact of Concrete Composition with Optimum Moderation

Concrete	k_{eff}
EPRI dry	0.91204
Magnuson's	0.86374
Rocky Flats	0.84229
Oak Ridge concrete	0.85565

Reference:

17.1 *Sensitivity Analyses for Spent Fuel Pool Criticality*, EPRI Report 3002003073, Palo Alto, CA 2014.

RAI-18

The following deficiencies were noted with respect to the uncertainty analysis:

a. *Uncertainty analysis was not performed at the low-moderator density peak conditions.*

b. *Eccentric fuel location was handled as an uncertainty. This is not appropriate. The criticality calculations should be performed with the fuel at its most reactive approved location/arrangement.*

c. *Uncertainties associated with (1) spacing between assemblies and (2) spacing between rack modules and walls/floor/ceiling were not evaluated.*

Revise the analysis to perform a more complete uncertainty analysis and to evaluate eccentric fuel assembly placement as a bias rather than an uncertainty, or provide a justification for treating eccentric positioning as an uncertainty.

DNC Response

The uncertainty analysis for the NFSR has been redone at full and low-moderator density conditions. The base case uses the closest possible spacing of the fuel assemblies in the rack. Assemblies are eccentrically loaded in the cell locations and the assembly separation is the minimum possible when accounting for the manufacturing tolerances for the rack. Although the analysis is not very sensitive to the rack module separation, the minimum rack module separation was also used. The k_{eff} decreases as the fuel is lifted from the floor so the analysis assumes the fuel is on the floor. The ceiling is too high to have an effect. Since the base case includes the eccentricity and bounding rack dimensions, they do not appear in the uncertainty analysis. Tables 18.1 and 18.2 show the new calculation of total bias and uncertainty and Table 18.3 shows the new comparison to the regulatory limits.

Table 18.1 New Fuel Storage Racks Tolerance Calculations (100% Moderation)

Calculation Description	277 K			373 K		
	k_{eff}	σ	Δk_{calc}	k_{eff}	σ	Δk_{calc}
Nominal	0.91570	0.0002	N/A	0.91357	0.0002	N/A
Increased Fuel Enrichment	0.91741	0.0002	0.0022	0.91491	0.0002	0.0018
Increased Fuel Density	0.91795	0.0002	0.0023	0.91528	0.0002	0.0017
Fuel Pellet OD Increase	0.91641	0.0002	0.0017	0.91371	0.0002	0.0006
Decrease Cladding OD	0.91777	0.0002	0.0025	0.91505	0.0002	0.0019
Increase Cladding ID	0.91607	0.0002	0.0008	0.91358	0.0002	0.0005
Guide Tube OD Decrease	0.91642	0.0002	0.0012	0.91360	0.0002	0.0005
Guide Tube ID Increase	0.91655	0.0002	0.0013	0.91372	0.0002	0.0006
Increased Fuel Rod Pitch	0.91709	0.0002	0.0018	0.91429	0.0002	0.0012
Statistically Combined Uncertainties			**0.0052**			**0.0038**

Table 18.2 New Fuel Storage Racks Tolerance Calculations (4% Moderation)

Calculation Description	k_{eff}	σ	Max Δk_{calc}
Nominal	0.91204	0.0002	N/A
Increased Fuel Enrichment	0.91348	0.0002	0.0019
Increased Fuel Density	0.91334	0.0002	0.0018
Fuel Pellet OD Increase	0.91210	0.0002	0.0005
Decrease Cladding OD	0.91225	0.0002	0.0006
Increase Cladding ID	0.91209	0.0002	0.0005
Guide Tube OD Decrease	0.91206	0.0002	0.0005
Guide Tube ID Increase	0.91202	0.0002	0.0004
Increased Fuel Rod Pitch	0.91231	0.0002	0.0007
Statistically Combined Uncertainties			**0.0029**

Table 18.3 Revised Results for New Fuel Storage Rack KENO Calculations

Temperature (Kelvin)	**277**	**373**	**373**
Moderator Density (gm/cm^3)	**1.0**	**0.959**	**0.04**
Uncertainties			
KENO Code Bias Uncertainty	0.0060	0.0060	0.0060
KENO Calculation Statistics (95%/95%, 2σ)	0.0004	0.0004	0.0004
Calculated Tolerances	0.0052	0.0038	0.0029
Statistically Combined all Uncertainties	0.0080	0.0071	0.0067
Biases			
KENO Code Bias	0.007	0.007	0.007
SCALE Temperature Bias	0	0.0014	0.0014
NRC Administrative Margin	0.005	0.005	0.005
Sum of Biases and Uncertainties	0.0200	0.0205	0.0201
Calculated KENO k_{eff}	0.9165	0.9138	0.9196
k_{eff} including biases and uncertainties	**0.9365**	0.9343	0.9397
Regulatory Limit	0.95	0.95	0.98

<u>RAI-19</u>

From the results presented in Table 5.3-1, it looks like a higher optimum moderation peak k_{eff} value may occur between 4 and 2.5 % water density. Perform additional calculations to ensure the peak k_{eff} value has been identified.

<u>DNC Response</u>

Additional calculations have been performed for low water densities.

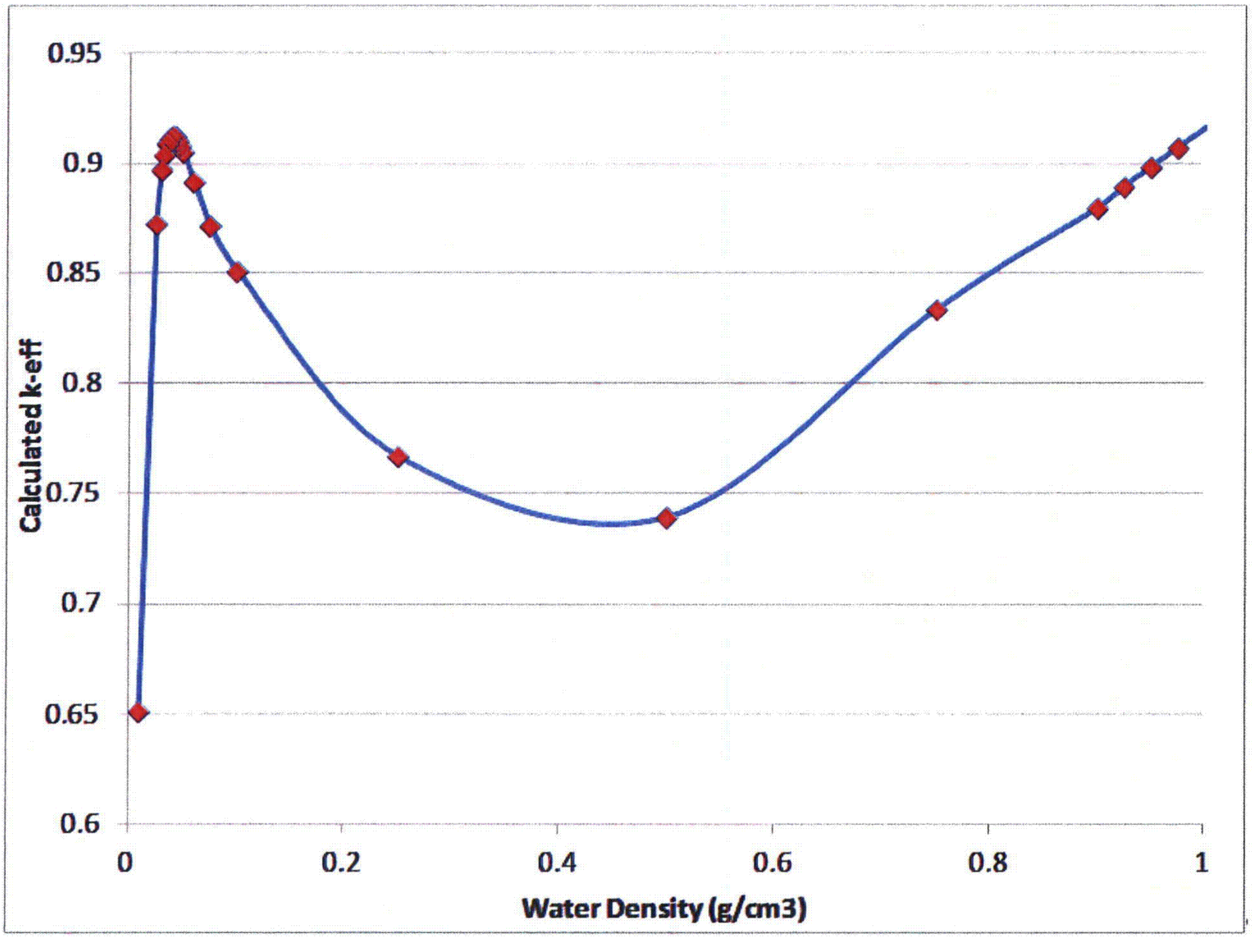


Figure 19.1 New Fuel Storage Rack k_{eff} as a function of Water Density

Table 19.1 New Fuel Storage Racks Interspersed Moderation Effects Results

Water Density (g/cm^3)	k_{eff}
0.0100	0.6510
0.0250	0.8722
0.0300	0.8968
0.0325	0.9036
0.0350	0.9087
0.0375	0.9109
0.0400	**0.9120**
0.0425	0.9117
0.0450	0.9099
0.0475	0.9075
0.0500	0.9048
0.0600	0.8913
0.0750	0.8713
0.1000	0.8507
0.2500	0.7664
0.5000	0.7389
0.7500	0.8332
0.9000	0.8793
0.9250	0.8890
0.9500	0.8980
0.9700	0.9068
1.000	**0.9157**

RAI-20

Provide the EALF of the low water density optimum moderation point for the new fuel storage analysis. This will be compared with the validation study to ensure these calculations are adequately validated.

DNC Response

The EALF value for the peak low-density moderation point is 0.93 eV. The critical experiments cover a range of EALF from 0.06 eV to 0.85 eV. Since the extrapolation needed is only about 10% of the range, the extrapolation is reasonable. The bias and uncertainty has been extrapolated to an EALF of 1.0. At this EALF, the bias is 0.007 and the uncertainty is 0.0060.

RAI-21

From the descriptions provided in Sections 4 and 6 of Ref. 2, it appears that what is referred to as a poison box or Boraflex box was included in all new Region 1 and 2 calculations. Section 6.1.1.1 explicitly notes that they are removable. Poison box dimensions and some tolerances are provided in Table 6.1-1. The poison box is visible in Figure 6.1-2.

a. *Provide a better description of the poison box model.*

b. *Expand the Regions 1 and 2 uncertainty analyses to address poison box dimensional tolerances.*

c. *The text in Section 4.2.1 states the poison boxes are "centered" in the open stainless steel boxes. What forces them to be centered? What is the uncertainty on the location of the box within the storage cell? What sensitivity studies were performed to address variation in k_{eff} with poison box location?*

d. *If nothing centers the poison box, revise the analysis to use the most reactive arrangement of storage cell, poison boxes and fuel assemblies to calculate the maximum k_{eff} values.*

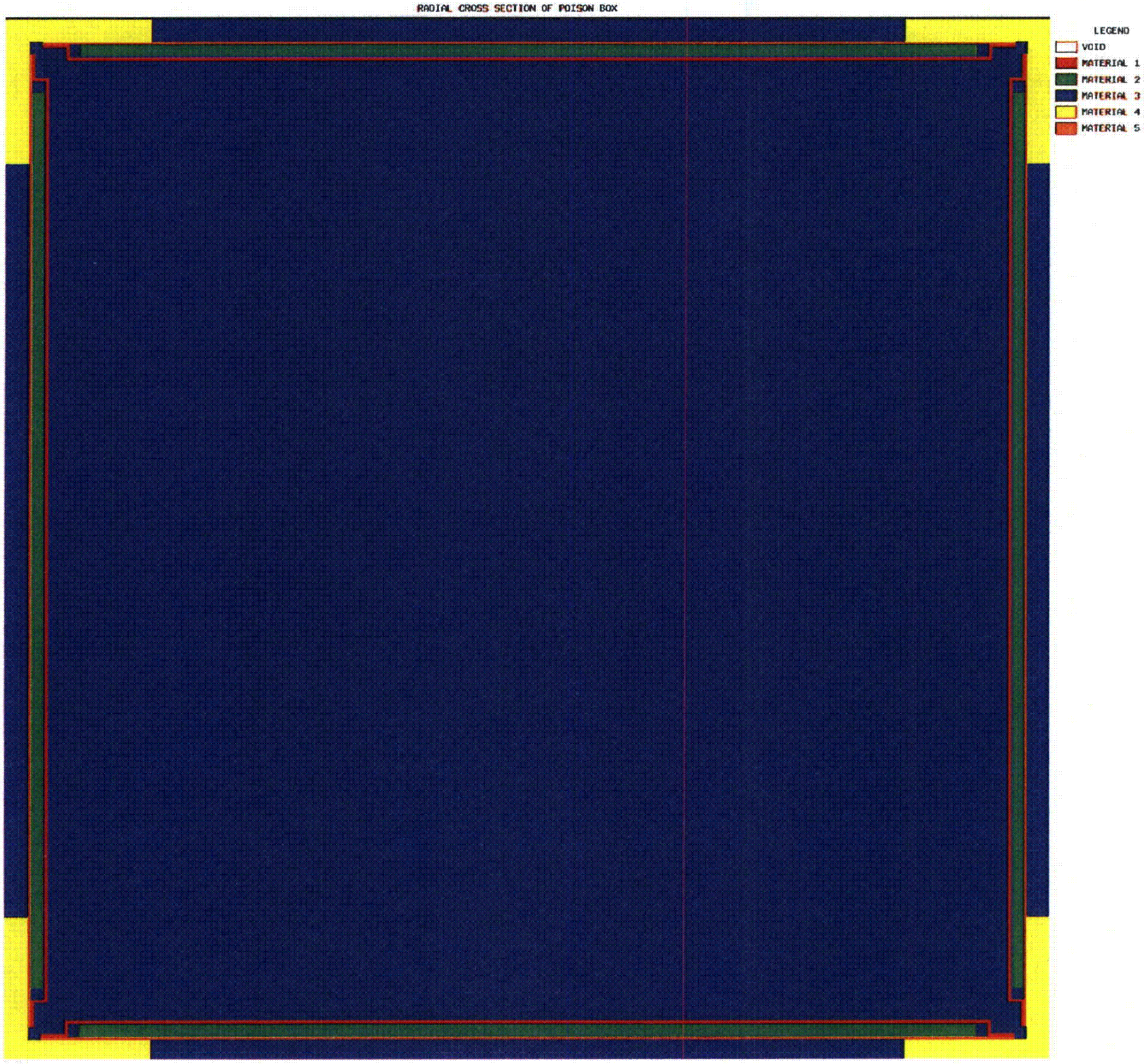
e. *From the text in Section 4.2.1, there should be a [ ]^{a,c} thick steel plate on both the inside and outside of the poison gap in the poison box. From Figure 6.1-6, it looks like the cover sheet is missing off of the outside of the poison box. Review the Region 1 and 2 models to confirm the models are correct. If they are not correct, either revise the analysis or provide an evaluation of the impact of the modeling error.*

DNC Response

a. The poison box is a structure designed to hold the Boraflex absorber panel a fixed distance from the cell wall. It is comprised of four stainless steel corner braces, four sheets of stainless steel welded to the corner braces at the back of the Boraflex panels, four Boraflex panels, and four stainless steel sheets welded to the corner braces at the front of the Boraflex panels. The stainless steel sheets (wrappers) on both sides of the Boraflex panels are [ ]^{a,c} thick. Boraflex is modeled as water in the [ ]^{a,c} gap between wrapper sheets. Above the wrappers, a stainless steel sheet "funnel" is welded to the corner brackets and is flared outward at the top. The flare has tabs that lock into the top of the rack structure, thereby holding the poison box in the center of the cell. Removal of the poison box is accomplished using special tools.

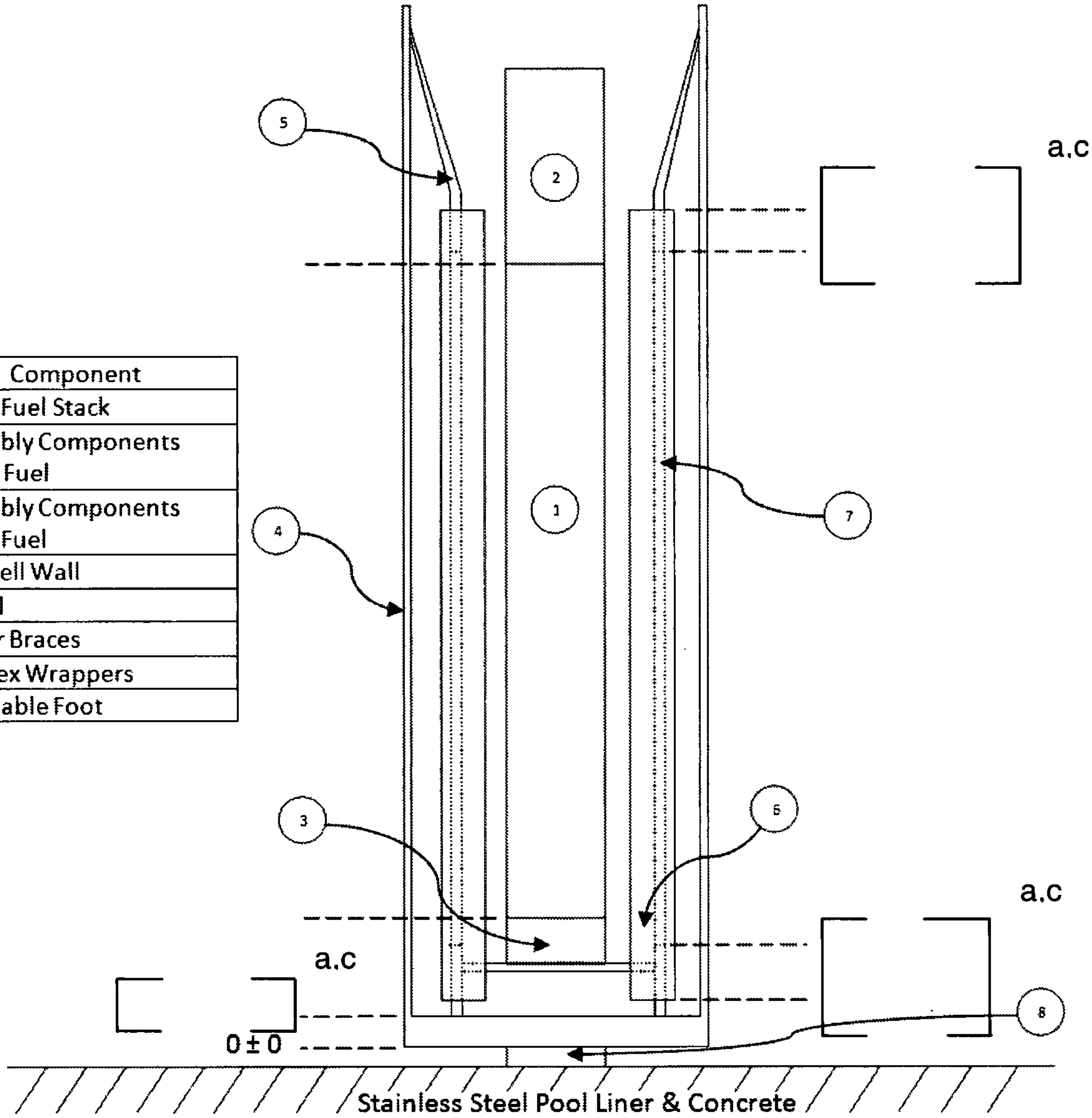
Figure 21.1 is an x-y cut of a poison box at the active fuel level. Figure 21.2 provides the axial features of the poison box in the rack cell with fuel. Figure 21.3 features two photographs of the top of a poison box.

Figure 21.1 Radial Cut of the Poison Box



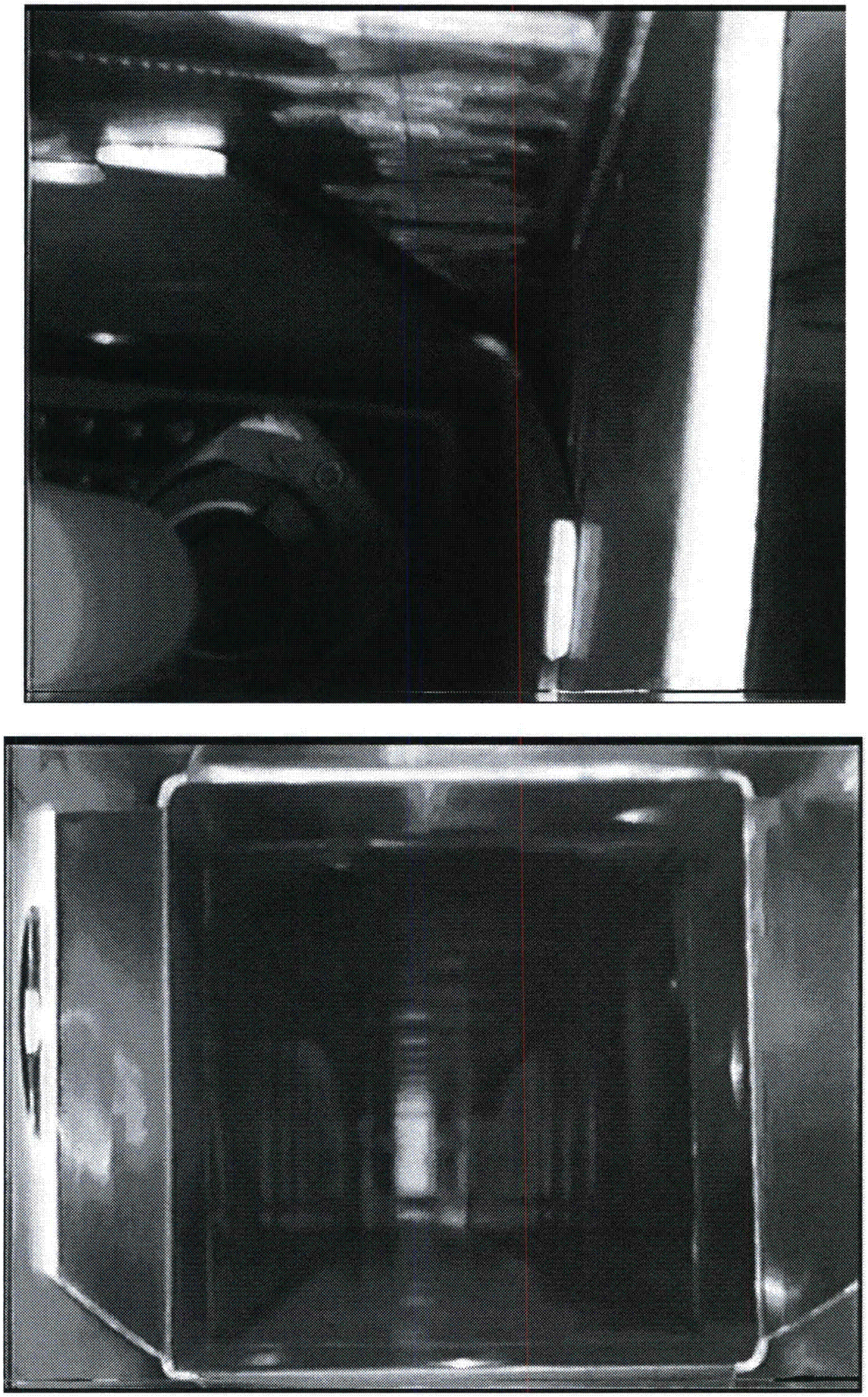
Key:
Material 1 (red) is the Boraflex Cover, Material 2 (green) is the Boraflex, Material 3 (blue) is empty space
Material 4 (yellow) is the corner brace, Material 5 (brown) is the back plate for the Boraflex

Figure 21.2 Axial Features of the Poison Box



ID	Component
1	Active Fuel Stack
2	Assembly Components Above Fuel
3	Assembly Components Below Fuel
4	Rack Cell Wall
5	Funnel
6	Corner Braces
7	Boraflex Wrappers
8	Adjustable Foot

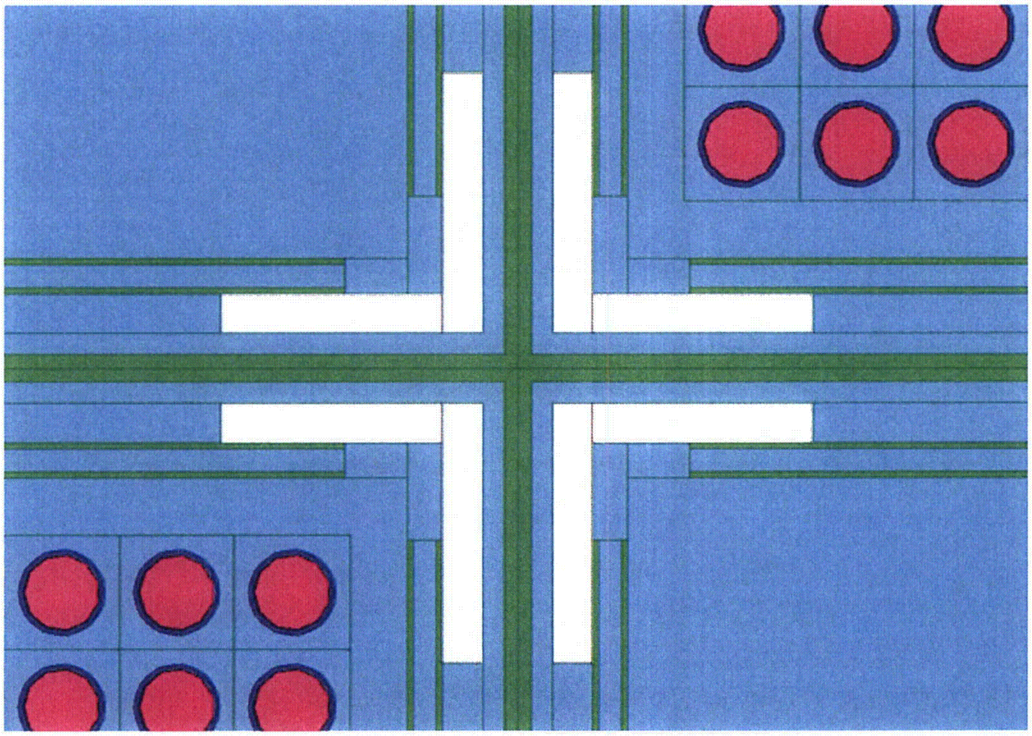
Figure 21.3 Pictures of the Poison Box
(First view with fuel in the cell, Second view is an empty cell with the poison box)



b. In the active region of the fuel the poison box structure consists of two components (stainless steel wrappers and corner braces). The ASTM standard tolerance on stainless steel sheet thickness is 0.002 inches for thicknesses between 0.02 and 0.035 inches. [Ref. 21.1] A conservative 0.003 inch tolerance has been added to the analysis. Further, although the cover and back sheet are separate pieces, it is assumed they are both simultaneously either at the minimum or maximum thickness.

The stainless steel corner braces are [ ]a,c wide, [ ]a,c thick, and have a thickness tolerance of [ ]a,c. Wrapper thickness cases show that increasing stainless steel in Regions 1 and 2 decreases k_{eff} with 0 ppm soluble boron. With 2000 ppm boron, the wrapper thickness tolerance effect is too small to affect the total uncertainty calculation. Therefore, only the [ ]a,c inch tolerance is of interest. This tolerance is ignored because in the Region 1 and 2 KENO models the portion of the stainless steel wrappers extending beyond the Boraflex region is not modeled (2 thicknesses of [ ]a,c thick stainless steel approximately [ ]a,c long). This portion of the wrappers may be visualized by comparing the Boraflex wrappers in Figure 21.4 (as modeled) and Figure 21.1 (idealized). In addition, the wrapper tolerance used is 0.003 rather than 0.002 inch, which provides additional conservatism to adequately cover the corner brace thickness uncertainty.

Figure 21.4 Region 1 KENO Model Poison Box Detail



c & d. The poison boxes are centered by the funnel section of the poison box which is compressed and snapped into a slot in the rack cell walls. See Figure 21.3 for the funnel sections. A Region 1 calculation was performed with the poison boxes shifted toward the corner of the rack cell such that the corner brace contacts the rack cell wall. The reactivity effect was 0.0002 dk which is too small to have an effect after the statistical combination of the uncertainties.

e. Although not easily visible in Figure 6.1-6 of the December 2012 LAR, both the inside and outside panels of stainless steel were in the model. Figure 21.4 is an expanded view of the model that shows both panels.

Reference:

21.1 *Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip*, ASTM A480/A480M-13b, ASTM International, West Conshohocken, PA, November 2013.

RAI-22

The following issues are related to the fuel assembly model used.

a. The text in Section 6.1.1 notes that the lower rack structure, lower tie plate, and upper tie plate are modeled as 30% stainless steel and 70% water. Are these volume percentages? Is the water and steel a homogenized mixture? Were the total steel and water masses conserved? Provide a justification for these modeling simplifications and for the steel to water ratio used.

b. The effects of fuel rod growth and clad creep are not addressed. Evaluate and incorporate the impacts of fuel rod growth and clad creep. Note these phenomena are not uncertainties as they affect every assembly in a similar way.

c. From the text in the numbered list on page 49 of Ref. 2, fuel rod end plugs and upper plenum are apparently modeled. Confirm that conservative end plug dimensions were used. This likely means the shortest end plug design. Also, describe and justify how the fuel rod upper plenum is modeled.

DNC Response

a.& c. The fuel assembly axial regions above and below the fuel are modeled using the nominal attributes of the limiting assembly design. The level of detail chosen is intended to add a reasonable amount of reality to the axial reflectors without placing too high a modeling burden for relatively low neutron importance regions.

At the bottom of the assembly, the end plug region is modeled as solid zircaloy rods and water filled guide thimbles surrounded by water. The lower Inconel grid is conservatively neglected. The bottom nozzle region is homogenized water (70% volume fraction) and stainless steel (30% volume fraction) with volume fractions determined using the mass and height of the lower tie plate. Therefore, the mass of the water and steel is preserved. The lower rack structure is far enough from the fuel to be unimportant and is approximated with the same mixture as the bottom nozzle region.

The fuel rod upper plenum region is modeled as voided fuel clad and water filled guide thimbles. The upper grid is neglected. Plenum springs are neglected. The top nozzle region uses the same 70/30 mixture as the bottom nozzle. The top nozzle region is unimportant neutronically because it is roughly 20 cm above the top of the fuel. The region above the top nozzle is modeled as water.

To demonstrate the adequacy of the reflector model, KENO cases were run with the top and bottom nozzle regions replaced by water. Table 22.1 demonstrates that the axial reflector model described ("base" model) and the water-only nozzle models provide essentially the same k_{eff} in Region 1. K_{eff} is insensitive to the choice of nozzle material. Four cases of each model (base model, water top nozzle, water top and bottom nozzle) were run with different random number seeds and averaged to obtain a better estimate of nozzle effect on k_{eff} because the effect is so small. Small variations in the zircaloy end plug region (conservative end plugs) do not need to be considered at the top due to the insensitivity and at the bottom due to insensitivity and the conservatism associated with ignoring the bottom Inconel grid. The final case in Table 22.1 replaces the plenum region, nozzle regions, end plug regions and rack base region modeling with water. Even using a simple water reflector above and below the fuel has a trivial effect on k_{eff}.

Table 22.1: Reflector Model Sensitivity with Fresh Fuel in Region 1 (0 ppm)

Case	Enrichment (wt% U-235)	k_{eff}	Sigma	Notes
Base 2x2 (1)	5.0	0.90873	0.00011	Base default random number start (DRN)
Base 2x2 (2)	5.0	0.909	0.00011	Base 1st alternate random number start (A1RN)
Base 2x2 (3)	5.0	0.90893	0.00012	Base 2nd alternate random number start (A2RN)
Base 2x2 (4)	5.0	0.90872	0.00011	Base 3rd alternate random number start (A3RN)
Water top1	5.0	0.90887	0.00012	Top nozzle water DRN
Water top2	5.0	0.90883	0.00012	Top nozzle water A1RN
Water top3	5.0	0.90866	0.00011	Top nozzle water A2RN
Water top4	5.0	0.90876	0.00011	Top nozzle water A3RN
Water both1	5.0	0.90876	0.00012	Both nozzles water DRN
Water both2	5.0	0.9088	0.00012	Both nozzles water A1RN
Water both3	5.0	0.90858	0.00011	Both nozzles water A2RN
Water both4	5.0	0.9088	0.00011	Both nozzles water A3RN
Base 2x2	5.0	0.90885		4 case average
Water top	5.0	0.90878		4 case average
Water both	5.0	0.90874		4 case average
Water reflector	5.0	0.90855	0.00011	All water reflector above and below active fuel

A pair of cases were also run for highly burned fuel to confirm that the reflector model is acceptable when a strong "end effect" is present. Table 22.2 shows the results of the nominal Region 3 case with depleted fuel (5.0 wt% 50 GWd/MTU) and the same case with 100% water in the nozzle regions. There is no significant reactivity difference.

Table 22.2: Reflector Model Sensitivity with Depleted Fuel (0 ppm)

Case	Enrichment (wt% U-235)	Burnup (GWd/MTU)	Regio n	k_{eff}	Sigma	Notes
Base	5.0	50	3	0.96263	0.00009	Base
Water nozzles	5.0	50	3	0.96268	0.00009	Water nozzles

b. To assess fuel rod growth, a Region 2 fresh fuel KENO case was run with 1% longer fuel and 1% lower fuel density. K_{eff} declined roughly 0.001 dk. Therefore, fuel stack growth is not of concern for SFP criticality when there is no strong absorber axial position fuel coverage issue involved. The approved testing material (ATM) 103, 104, and 106 measurements of Calvert Cliffs fuel (a sister plant for MPS2) [Refs. 22.1, 22.2, and 22.3] show that fuel growth is about 1% or less. A 1% change in active fuel length does not result in any movement of fuel across an axial absorber boundary in any of the regions or configurations. Specifically, the CEAs and borated stainless steel rodlets used in Region 3 have absorber material that is sufficiently above the active fuel to accommodate growth of the fuel.

Creep is a change in the fuel clad diameter. The timing and amount of clad creep is a complex function of multiple fuel design and operation variables. However, several references are available to determine a conservative creep down. Reference 22.4 (Figure 10) suggests that Zirc-4 clad creep down is less than 0.005 cm after one cycle. Reference 22.5 (Figure 3-18) indicates that for PWR fuel, it is conservative to assume maximum creep occurs by the end of the first cycle of depletion. The maximum amount of creep (diameter reduction) is roughly 0.014 cm in that reference, however, this is for a very high Nb clad. The Zirc-4 creep down from the same figure is 0.007 cm, which is applicable to current MPS2 fuel. Reference 22.4 points out that the creep down for Zirlo is less than for Zirc-4 and creep down is greater for high Nb alloys.

The change in reactivity due to creep down is due to increased moderation. Along with creep down is the development of an oxide layer that increases the clad outside diameter (OD) and partially offsets the decrease due to creep. This oxide layer grows with time in the reactor at power and can reach 0.003-0.007 cm. [Ref. 22.6] The net decrease in the effective clad OD is therefore much smaller than the bounding creep value of 0.014 cm. Sensitivity cases for depleted fuel show that creep increases k_{eff} at 0 and 2000 ppm. Therefore, depleted fuel KENO cases will include creep geometry (0.014 cm OD reduction) as part of the KENO model.

Depleting with creep geometry will result in a softer neutron spectrum, which mitigates part of the creep k_{eff} increase. To evaluate the magnitude of the isotopic effect, 18 node TRITON depletions for 5.0 wt% fuel to 40 GWd/MTU were run using fuel clad OD reduced 0.01 cm. Depletion power, soluble boron, time steps and temperatures were not changed from the reference case. K_{eff} at 0 and 2000 ppm was calculated for Region 4 with 5 wt% U-235 fuel with 40 GWd/MTU burnup using both the nominal clad depletion and creep down depletion compositions. Although the depletion calculations assumed the creep down was 0.01 cm (average amount of creep over the entire depletion), the Region 4 k_{eff} calculations assumed a 0.014 cm creep down. The results are shown on Table 22.3.

Table 22.3 Creep and Creep Isotopics Affect on k_{eff} (Region 4, 5 wt% U-235, 40 GWd/MTU)

Isotopics	Clad Dimension	Soluble Boron (ppm)	k_{eff}	Worth (dk)	Notes
Nominal	Nominal	0	0.96511	-	Base Case 0 ppm
Nominal	-0.014 cm	0	0.96807	0.0030	Change in dimension only
With 0.01 cm Creep	-0.014 cm	0	0.96786	0.0028	Change in dimension + isotopics
Nominal	Nominal	2000	0.72048	-	Base Case 2000 ppm
Nominal	-0.014 cm	2000	0.72115	0.0007	Change in dimension only
With 0.01 cm Creep	-0.014 cm	2000	0.72027	-0.0002	Change in dimension + isotopics

Results of these cases demonstrate that depletion effects only slightly offset the effect of creep geometry for the 0 ppm condition. For simplicity, the effect of creep down on fuel isotopic content will be conservatively ignored. To conservatively bound creep effects, depleted fuel KENO cases will include clad inside diameter (ID) and OD reduced by 0.014 cm with no oxide layer credit. The clad manufacturing tolerance is 0.005 cm. Since the conservative creep down is nearly three times the manufacturing tolerance and the creep down is treated as a bias rather than an uncertainty, no clad dimension uncertainty will be assessed for depleted fuel cases.

For all regions at zero ppm, the reactivity worth of decreasing the clad OD and ID is positive. However, for Region 3 (rodlets) the creep worth (k_{eff} change with reduced clad ID and OD) is slightly negative with 2000 ppm soluble boron. Rather than change the base model, the reactivity due to creep down was calculated for Region 3 (rodlets) at 2000 ppm and a small bias is added in the calculation of the total bias and uncertainty.

This analysis conservatively covers the dimensional changes with depletion. However, it is not clear that this is required. The creep down used was selected conservatively using a clad that creeps more than the clad actually used at MPS2. The maximum creep of all burnups was used. The fuel growth was conservatively ignored. The oxide layer that displaces water was conservatively ignored. An analysis integrating these effects that does not take a bounding approach to each variable would likely demonstrate that the effect of dimensional changes is small.

References:

22.1 R. J. Guenther, et al., *Characterization of Spent Fuel Approved Testing Material – ATM-103*, Pacific Northwest Laboratory, PNL-5109-103 (UC-70), April 1988.

22.2 R. J. Guenther, et al., *Characterization of Spent Fuel Approved Testing Material – ATM-104*, Pacific Northwest Laboratory, PNL-5109-104 (UC-802), December 1991.

22.3 R. J. Guenther, et al., *Characterization of Spent Fuel Approved Testing Material – ATM-106*, Pacific Northwest Laboratory, PNL-5109-106 (UC-70), October 1988.

22.4 G. P. Sabol, G. Schoenberger, M. G. Balfour, “Improved PWR Fuel Cladding,” *Materials for advanced water cooled reactors*, Proceedings of a Technical Committee Meeting held in Plzen, Czechoslovakia, May 14-17, 1991, IAEA-TECDOC-665, International Atomic Energy Agency, Vienna, Austria, pp 122-130, September 1992.

22.5 F. Garzarolli, "Available data on in-reactor creep and deduced correlations," chapter in R. Adamson, F. Garzarolli, and C. Patterson, ZIRAT14 Special Topic Report, In-Reactor Creep of Zirconium Alloys, Advanced Nuclear Technology International, Skultuna, Sweden, September 2009.

22.6 AREVA 57-TR-FS-07-72-000, "Fuel Assembly Cause of Failure Examinations, Millstone 2 EOC17," January 2007.

RAI-23

Eccentric fuel placement was evaluated as an uncertainty throughout the analysis. A relatively small number of assemblies grouped in the most reactive arrangement will result in the maximum keff value. Even if assembly placement is truly random, the large number of sets of assemblies that do occur in a SFP significantly increases the probability of occurrence of one of the small sets having the maximum keff value. It is not appropriate to simply assume that there are no mechanical or operational drivers that may result in systematic (i.e. non-random) assembly location in the storage cells. The maximum keff value should be calculated with the fuel in the most reactive approved configuration. This may be accomplished by using the most reactive assembly location in the analyses or by incorporating a conservative bias term. Revise the analysis to calculate the maximum keff values using the most reactive arrangements or incorporate a conservative bias term to cover the keff increase due to asymmetric placement.

DNC Response

Small numbers of eccentrically placed assemblies (hereafter referred to as collocated assemblies) can raise the calculated k_{eff} and this would be an expected condition in a large SFP that should be handled as a bias rather than an uncertainty. The credible number of such collocated assemblies is not clear.

To address a reasonable number for collocated assemblies, a very simple model in which an assembly may only occupy one of the four quadrants of a cell was considered. Each quadrant represents the most eccentric fuel position possible within the storage cell. For a SFP region in which collocating assemblies increases k_{eff}, this is a very conservative model because in reality, the assembly could occupy any number of intermediate less limiting positions within the storage cell. With only four possible and equally probable locations for each fuel assembly, having 16 assemblies (a 4x4 set of storage locations within the SFP) that are simultaneously collocated with each assembly in the correct quadrant has a probability of $(1/4)^{16}$ or 2×10^{-10}.

Region 3 has 795 cell positions, which contains fewer than 795 unique 4x4 subregions. This means the probability of having 16 assemblies properly collocated in Region 3 with

4-out-of-4 storage geometry is <2 x 10^{-7}. The fuel is moved periodically. Assuming all fuel assemblies are moved 2 times per year for 100 years, the probability that 16 assemblies are collocated in Region 3 any time in the year is <4 x 10^{-5}. Because this configuration has a probability of occurrence < 5% over the lifetime of the SFP, it is sufficiently conservative to determine asymmetry bias for Region 3 using 16 collocated fuel assemblies. Figure 23.1 shows how the KENO model is configured for the collocated 4x4 region in the middle of a 6x6 rack model with periodic boundary conditions. The outer row of fuel is centered in the rack cells.

The above argument was made for Region 3. Since the number of cells is different for the other regions and some regions have empty cells, the number of collocated assemblies that are adequate varies from region to region. Table 23.1 shows the probability that a given set of the assemblies are collocated during the life of the plant for each region.

Figure 23.1

Region 3 with 16 Collocated Assemblies in a 6x6 Model

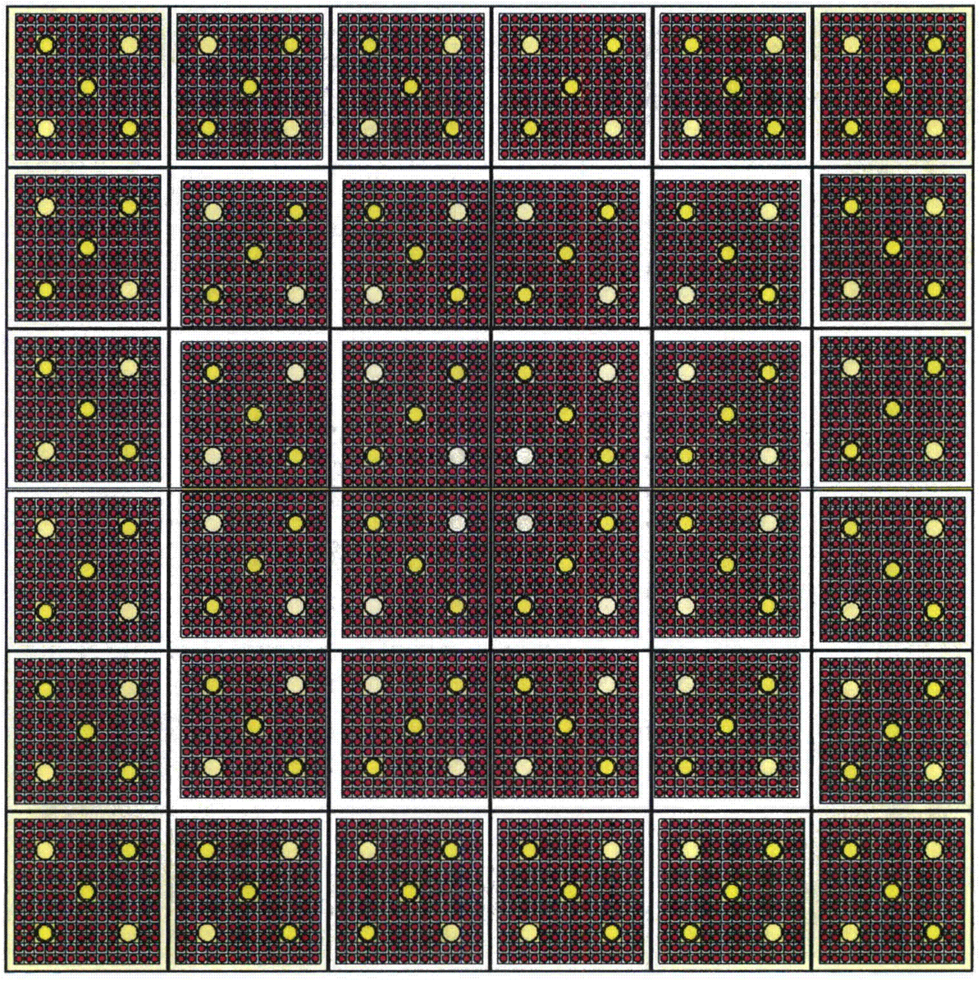


Table 23.1: Probability of Collocation by Region

	Region 1	Region 2	Region 3	Region 4
Number of Cells (A)	80	168	795	105
Collocation Array	6x6	4x4	4x4	4x4
Number of Assemblies Collocated (B)	18	12	16	12
Probability for one Region Loading ($A \times .25^B$)	1.2E-09	1.0E-05	1.9E-07	6.3E-06
Loadings per year	2	2	2	2
Life of Plant (yr)	100	100	100	100
Probability of the Collocation over life of plant ($200 \times A \times .25^B$)	2.3E-07	0.0020	3.7E-5	0.0013

To cover the possible increase in reactivity due to collocated assemblies, analysis of each rack was performed. For Region 1 an 8X8 model was analyzed where the central 6x6 assemblies are positioned as close as possible to the model center. Surrounding this set of assemblies is a row of assemblies centered in the rack cell. The model employs a periodic boundary condition so the rack is modeled as sets of 6x6 assemblies collocated to a central point separated by two rows of centered assemblies. The models for the other regions are similar but they use a 6x6 model with 4x4 sets being collocated toward a central point. If the calculated k_{eff} is greater than the reference model with centered assemblies, the increase in k_{eff} (including 2 x RSS KENO uncertainty) is used as a bias rather than an uncertainty.

The above arguments assume that the quadrant placement is random. To address the issue of randomness, a December 23, 1998 detailed video of a 15 x 27 rack cell region of the MPS2 SFP was reviewed visually. Each location was assessed visually with fuel assigned to equally spaced X and Y dimension bins of -1, -0.5, 0, +0.5, or +1 with ±1 representing proximity to or contact with a rack cell wall. Table 23.2 shows the position assignment matrix used. As an example of part of the data, Table 23.3 shows the placement of the assemblies in the northeast corner of rack module N12. The top number is the assembly identifier and beneath that is the placement observed for the assembly. A "T" after the placement notes that the assembly is twisted in the cell.

Table 23.2: Assembly Position Assignment Matrix

(-1,1)	(-0.5,1)	(0,1)	(0.5,1)	(1,1)
(-1,.5)	(-0.5,.5)	(0,0.5)	(0.5,0.5)	(1,0.5)
(-1,0)	(-0.5,0)	(0,0)	(0.5,0)	(1,0)
(-1,-.5)	(-0.5,-.5)	(0,-0.5)	(0.5,-0.5)	(1,-0.5)
(-1,-1)	(-0.5,-1)	(0,-1)	(0.5,-1)	(1,-1)

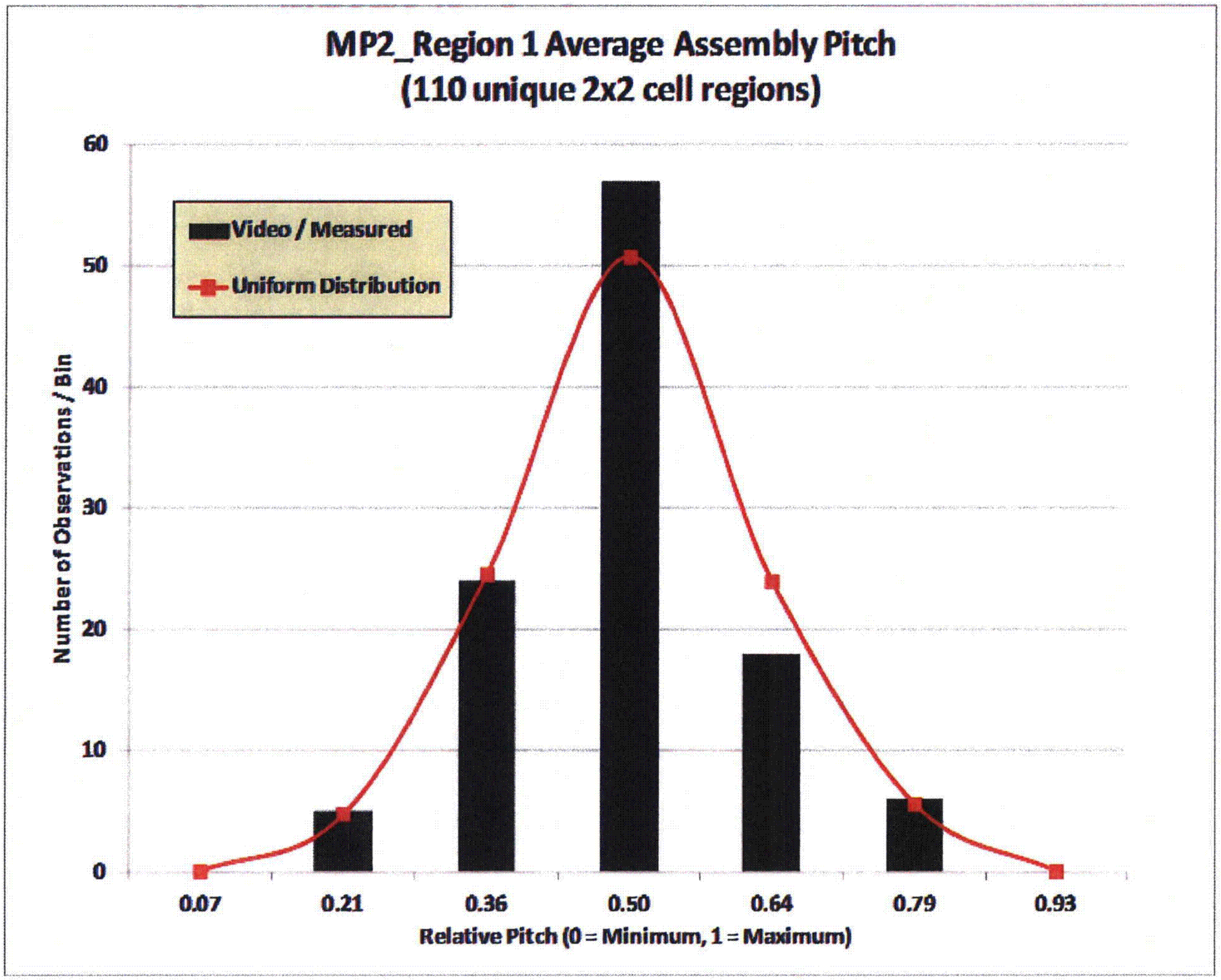
Table 23.3: Assembly Placement in Northeast Corner of Rack Module N12

N-06 (-.5,+.5)	N-43 (+1,+1)	P-38 (+1,-1)	P-68 (+.5,+.5)**T**	P-71 (+1,-1)	P-61 (-.5,-.5)	P-44 (+1,-1)	N-52 (0,0)	L-50 (+1,+1)
N-02 (+.5,+.5)	P-10 (+.5,+.5)**T**	P-64 (+.5,+1)**T**	N-20 (0,+1)	P-33 (+.5,-.5)	P-05 (0,+.5)	N-55 (-.5,+.5) **T**	N-65 (-.5,+.5)	P-21 (+1,-.5)
N-42 (+.5,+.5)	N-51 (0,-1) **T**	N-16 (+.5,+.5)**T**	N-34 (+.5,0) **T**	N-23 (+.5,+.5)	N-14 (+.5,-.5)	P-29 (-.5,+.5) **T**	P-37 (+1,-1)	N-07 (+.5,-.5)
P-13 (-.5,-1)	N-46 (+.5,+.5)**T**	P-12 (+1,-1)	N-44 (+.5,+1) **T**	N-48 (+1,-.5)	N-26 (+1,+1)	P-30 (+.5,-1)	P-51 (0,+.5) **T**	N-05 (+.5,-1)
N-12 (+.5,+1)	P-08 (+1,0)	P-50 (+1,+.5)	P-22 (0,+.5)	R-60 (+1,+1)	N-41 (0,-.5)	P-59 (0,0)	P-20 (+.5,0)	P-53 (0,+1)
P-23 (+.5,-1)	P-55 (+.5,+.5)	P-41 (+.5,0)	P-40 (-.5,+1)	P-70 (+1,+1)	P-24 (0,-1)	N-15 (0,0)	N-60 (+.5,+1)	P-15 (0,-1)
N-30 (+1,+.5)	N-09 (+.5,-.5)**T**	N-18 (+.5,+.5)**T**	N-35 (-1,-1)	N-17 (+.5,+.5)	P-46 (+1,+1)	N-21 (+1,+1)	P-69 (-.5,+1)	N-10 (+1,+.5)

Using the binned coordinates, the four assembly average pitch was calculated for 110 unique 2x2 clusters (four fuel assemblies per cluster). An average pitch of -1 represents minimum possible pitch for four assemblies and +1 represents maximum separation of fuel assemblies. Figure 23.2 shows the distribution of the average separation in the 110 observed 2x2 clusters using seven equal size histogram bins. The line on Figure 23.2 is the distribution if the placement in the cell were random with an equal probability of being placed in any of the 25 possible locations defined by the video coordinate system. As shown in Figure 23.2, the distribution appears nearly random and does not support an assumption of systematic adverse assembly position distribution.

Figure 23.2

Comparison of Observed Separation of Assemblies to Random Separation of Assemblies



Although no mechanism has been determined that would systematically place the assembly in a particular quadrant, it is conceivable that an East-West or North-South bias in placement could exist. The regions were analyzed assuming a constant position bias such that all the assemblies are in the corner. For these cases, the distance between the center of the assemblies is still the nominal rack pitch. It was observed that placing the assemblies in the corner can increase k_{eff}. In the final calculation of biases and uncertainties, the maximum of the corner placement or the collocated fuel bias is used as the "off center placement" bias.

Tables 23.4 and 23.5 show the calculations of the off center placement biases for each region.

Table 23.4: Off Center Location Bias Calculations (zero soluble boron)

	Region	Enrichment (wt% U^{235})	Burnup (GWd/T)	k	Sigma	Delta k
Reference (Centered)	1	5	0	0.90873	0.0001	-
8x8 with 6x6 Collocated	1	5	0	0.90947	0.0001	0.0010
All in corner	1	5	0	0.90835	0.0001	-0.0001
Reference (Centered)	2	2.9/1.9	0	0.96355	0.0001	-
6x6 with 4x4 Collocated	2	2.9/1.9	0	0.96541	0.0001	0.0022
All in corner	2	2.9/1.9	0	0.96229	0.0001	-0.0010
Reference (Centered)	2	4.85	16/33	0.97767	0.0001	-
6x6 with 4x4 Collocated	2	4.85	16/33	0.97973	0.0001	0.0024
Reference (Centered)	3 Rods*	1.6	0	0.96431	0.0001	-
6x6 with 4x4 Collocated	3 Rods*	1.6	0	0.96223	0.0001	-0.0018
All in corner	3 Rods*	1.6	0	0.96445	0.0001	0.0004
6x6 with 4x4 Collocated	3 Rods	1.6	0	0.96090	0.0001	-0.0032
All in corner	3 Rods	1.6	0	0.96298	0.0001	-0.0011
Reference (Centered)	3 CEAs	2.2	0	0.96045	0.0001	-
6x6 with 4x4 Collocated	3 CEAs	2.2	0	0.95787	0.0001	-0.0023
All in corner	3 CEAs	2.2	0	0.96207	0.0001	0.0019
Reference (Centered)	4	1.7	0	0.96318	0.0001	-
6x6 with 4x4 Collocated	4	1.7	0	0.96293	0.0001	0.0000
All in corner	4	1.7	0	0.96361	0.0001	0.0007

*Alternating rodlet orientations

Table 23.5: Off Center Location Bias Calculations (2000 ppm)

	Region	Enrichment (wt% U^{235})	Burnup (GWd/T)	k	Sigma	Delta k
Reference (Centered)	1	5	0	0.68994	0.0001	-
8x8 with 6x6 Collocated	1	5	0	0.68941	0.0001	-0.0002
All in corner	1	5	0	0.68811	0.0001	-0.0015
Reference (Centered)	2	2.9/1.9	0	0.65755	0.0001	-
6x6 with 4x4 Collocated	2	2.9/1.9	0	0.66082	0.0001	0.0036
All in corner	2	2.9/1.9	0	0.65494	0.0001	-0.0023
Reference (Centered)	2	4.85	16/33	0.72803	0.0001	-
6x6 with 4x4 Collocated	2	4.85	16/33	0.73197	0.0001	0.0043
Reference (Centered)	3 Rods	1.6	0	0.63745	0.0001	-
6x6 with 4x4 Collocated	3 Rods	1.6	0	0.64013	0.0001	0.0029
All in corner	3 Rods	1.6	0	0.63431	0.0001	-0.0030
Reference (Centered)	3 CEAs	2.2	0	0.68507	0.0001	-
6x6 with 4x4 Collocated	3 CEAs	2.2	0	0.68558	0.0001	0.0007
All in corner	3 CEAs	2.2	0	0.68183	0.0001	-0.0030
Reference (Centered)	4	1.7	0	0.61710	0.0001	-
6x6 with 4x4 Collocated	4	1.7	0	0.61439	0.0001	-0.0025
All in corner	4	1.7	0	0.61888	0.0001	0.0020

RAI-24

The last paragraph in Section 6.1.1.2 states that "Sensitivity values treated as a bias are calculated as K2-K1. Significance is defined as k2-k1>k1sd." The goal of bias and uncertainty calculations is to generate an accurate or conservative estimate for the biases and uncertainties. When Monte Carlo calculations are used to calculate biases and uncertainties, these values are to be calculated to include the appropriate Monte Carlo uncertainties. It is not appropriate to discard Monte Carlo uncertainties. If necessary, the analyst may reduce these Monte Carlo uncertainties by running more neutron histories. It is also inappropriate to discard biases or uncertainties as not being significant based on comparison with the Monte Carlo calculation uncertainties. All biases and uncertainties should be calculated using an equation similar to that provided at the bottom of page 57 of Ref. 2. Revise the analysis to properly incorporate accurate or conservative biases and uncertainties.

DNC Response

The uncertainty and bias values included in the calculation of Region 1-4 total bias and uncertainty are now calculated using K2-K1 + 2* RSS (Sigma K1, Sigma K2) and values greater than 0 are considered significant. Some sensitivity cases used to support RAI responses may use K2-K1.

Because of the small magnitude of KENO uncertainty in this analysis (~0.0001 – 0.0002 dk) and the much larger magnitude of RSS total uncertainty for each Region (~0.008 – 0.025 dk), changing the definition of significance and the method of calculating the biases and uncertainties has no meaningful impact on the RSS total uncertainty.

RAI-25

Table 6.1-2 is a list of "Specific Bias and Uncertainty Values."

a. *The following items appear to be missing from the table:*

   i. *B-SS rodlet length*

   ii. *Material, dimension, and location information, and associated tolerances/uncertainties for CEAs used in Region 3*

   iii. *Dimensional tolerances and location information on "poison boxes" used in Regions 1 and 2*

   iv. *Bias and uncertainty associated with elevated fuel temperature calculations*

v. Fuel stack height, height of the bottom of the active fuel above the bottom of the cell, and associated uncertainties.

Justify leaving out the above information, or provide the missing information and, where appropriate, incorporate the information into the analysis.

b. It does not look like the nominal dimensions for the Region 1 and 2 cells add up. With a nominal cell pitch of [ ]^{a,c} and a single wall thickness of [ ]^{a,c} cm, the cell inner dimension is [ ]^{a,c} cm, which is larger than the [ ]^{a,c} stated in Table 6.1-2. The text in Section 4.2.1 states the cell ID is [ ]^{a,c} or [ ]^{a,c}. What dimensions were used in the base model and were the tolerance uncertainty calculations adjusted to be consistent with the base model?

c. A spent fuel pool temperature bias term is included. Did this term include both temperature and the associated water density variation? If not, please explain.

<u>DNC Response</u>

a.i The B-SS rodlets fully cover the fuel stack region on both ends of the fuel pins. Rodlet length uncertainty does not result in an un-poisoned fuel region and no analysis of rodlet length uncertainty is needed. The B-SS rodlet length uncertainty has no effect on k_{eff} and was not included in Table 6.1-2 of the December 2012 LAR. The B-SS rodlet length and tolerance is found on Table 6.1-1 and is 387.35+/- 0.16 cm.

a.ii Section 6.1.1.3 and Table 6.1-2 in the December 2012 LAR were to address items that were handled as biases or uncertainties to the reference model. One of the items in the table, "CEA absorber content," refers to the reduced absorber content used to model the CEA in the reference model. Section 6.1.4.2.1 addresses the conservative modeling of the discharged CEAs but does not address how this conservatism covers the uncertainties. This is addressed here but will not result in a change to Table 6.1-2.

Table 6.1-1 in the December 2012 LAR did not include the specifications for the CEAs. The requested specifications are shown on Table 25.1. Uncertainty of the axial position of the bottom of the CEA absorber is primarily determined by the uncertainty of the length of the CEA clad.

The CEA specifications are very conservative due to the large reduction in the B_4C %TD. This B_4C density was selected to match the maximum allowed CEA bank worth error in the startup measurements. In old CEA designs (not in the MPS2 SFP and not credited here) the B_4C extended to the tips of the CEA fingers. Fluence related failures occurred with B_4C depletion of about 20%. CEA design was changed to include Ag/In/Cd absorber near the CEA rodlet

tips to reduce the B_4C depletion. The analysis assumes the entire B_4C length is depleted 65% even though actual B_4C depletion is small.

To confirm that uncertainties and small design details of the CEA are conservatively covered, analyses have been performed assuming 20% depletion of the B_4C. Table 25.2 shows the reactivity due to the tolerances in the limiting CEA design and shows the reactivity margin available if the depletion assumption were changed from 65% to 20%. The difference in k_{eff} obtained by relaxing just the B_4C depletion assumption is roughly -0.012 dk. By comparison, CEA dimensional tolerances are small.

These cases confirm that the overall conservatism of the CEA model is many times larger than the tolerance and uncertainty values. Therefore, no additional allowance for CEA uncertainty is needed.

Table 25.1 MPS2 Specification of CEAs

Region	Design Feature	Value
3	CEA Clad Material	Inconel 625
3	CEA Clad ID (cm)	[ ]A
3	CEA Clad OD (cm)	2.408 ± [ ]A
3	CEA B4C OD (cm)	[ ]A
3	CEA B4C % Theoretical Density	[*]A
3	CEA Ag/In/Cd ID (cm)	[ ]A
3	CEA Ag/In/Cd OD (cm)	[ ]A
3	Length of B4C Stack (cm)	[ ]A
3	Length of Ag/In/Cd Stack (cm)	[ ]A
3	CEA Clad Length (cm)	[ ]A

* Reduced to 24.5% for criticality analysis

Table 25.2: Sensitivity Calculations for the CEAs in Region 3

Initial Enrichment (wt% U235)	Burnup (GWd/ MTU)	KENO K_{eff}	Keno Sigma	Sensitivity (dk)	Case Type
2.20	0	0.96045	0.00009		Base
2.20	0	0.96035	0.00009	0.0002	Reduce CEA clad OD
2.20	0	0.96029	0.00009	0.0001	Increase CEA clad ID
2.20	0	0.96050	0.00009	0.0003	Reduce CEA B4C OD
2.20	0	0.96056	0.00009	0.0004	Reduce CEA AIC OD
2.20	0	0.96055	0.00009	0.0004	Increase CEA AIC annulus ID
2.20	0	0.96188	0.00009	0.0017	CEA shifted up 1 cm
2.20	**0**	**0.94835**	**0.00010**	**-0.0124**	**B4C depleted 20% rather than 65%**

a.iii. The response to RAI 21 provides more detail on the poison boxes. The dimensional tolerance for the stainless steel panels has been added to the analysis. The dimensional tolerance for the corner braces is insignificant as discussed in the response to RAI 21. The poison box's position is held in the center by the spring force created by the funnel section. The poison box position has an insignificant impact on reactivity so no location uncertainty is included in the calculation of uncertainties.

a.iv. The SFP Temperature is currently in Table 6.1-2 in the December 2012 LAR. The temperature is a bias since the reference calculations are done at 20°C. The temperature is handled as a limiting condition rather than nominal with an uncertainty. The maximum bias for the temperature range of 32 to 210 °F is included in the total uncertainty and bias calculation tables. RAI 42 addresses a change in the code validation bias and uncertainty with temperature. The validation bias related to temperature is included in revised calculation of burnup credit, margin, and boron required for normal and accident conditions. Although the maximum normal operating temperature of the MPS2 SFP is 150 °F, Region 1-4 total bias and uncertainty, margin, and burnup credit curve calculations cover a range from 32 to 210 °F.

a.v. The response to RAI 22a and b shows that the uncertainties in axial positioning do not affect k_{eff}. Region 1 stack height was increased 0.2 cm (about 5 times the uncertainty in the fuel stack height) and the calculated k_{eff} was 0.9087 compared to the nominal stack height k_{eff} of 0.9087. The Monte Carlo uncertainty in these two runs is 0.0001. The elevation uncertainties are not significant and do not need to be included in Table 6.1-2.

b. The Region 1 and 2 rack cells are "developed" from a checkerboard arrangement of storage cans welded at the corners such that the nominal pitch for the rack cells is slightly larger than the pitch calculated from a can inner diameter [ ]^{a,c} and nominal cell wall thickness. The cans have rounded corners. If not, the cell pitch would have to be the inner diameter [ ]^{a,c} plus 2 cell wall

thicknesses (2 x [ ]^{a,c}) or [ ]^{a,c}. The cell pitch is taken from the rack drawings which properly take into account the rounding of the can wall and the space for the weld material. In the modeling of the rack, the cell pitch and cell wall thickness are preserved so that the cell ID used is actually [ ]^{a,c}.

c. Yes. With each temperature change the water density was also changed.

RAI-26

Confirm the 0.0056 value provided for the "2 x KENO std. dev." uncertainty for 0 ppm. In general, Monte Carlo style calculations are run to standard deviations that are much smaller than 0.0028. If the 0.0056 value is correct, identify the cases where such large Monte Carlo uncertainties were used in the analysis.

DNC Response

The 0.0056 value was incorrect. There was an error on the KENO uncertainty value (a leading 0 was omitted) used in the total uncertainty calculation which has been corrected.

RAI-27

In Section 6.1.3.2, the text on page 66 appears to be stating that burnup dependent fission product and minor actinide worth for Region 2 will be based on Region 3 calculations. Region 3 is poisoned with either CEAs or borated steel rods. These components will impact the calculated worth of the FP&MAs. Justify that Regions 2 and 4 are bounded by the Region 3 calculations.

DNC Response

Fission product and minor actinide worth is calculated for each region (Regions 2, 3 with rodlets, 3 with CEA, and 4) as part of the revised bias and uncertainty calculations provided with this letter in Attachment 5.

RAI-28

In Section 6.1.3.2, the text on page 66 appears to be stating some of the uncertainties calculated for Region 1 will be applied to Region 2. Since Region 1 is 2-out-of-4 storage and Region 2 is 3-out-of-4 storage, the sensitivity of the k_{eff} value to some

parameters will be different. Identify the specific uncertainties that were not recalculated for each region and provide the logic for why the uncertainties will not vary from region to region. That the racks are of identical design is of course part of the logic for Regions 1 and 2, but the variation in storage configuration and minimum burnup limits also affects the uncertainty calculations.

DNC Response

Bias and uncertainty cases are calculated for each region (including two sets for Region 3 which uses two loading curves - rodlets and CEAs). Each set is done at both 0 and 2000 ppm. The uncertainty and bias cases are performed for the maximum fresh fuel enrichment that meets the loading requirements and the highest burnup case that meets the loading requirement. For enrichment/burnup pairs between the high burnup and zero burnup, the maximum bias or uncertainty from the high or low burnup condition is used. The exceptions to this are 1) the burnup worth uncertainty (5% of the delta k of burnup), 2) the burnup record uncertainty (3.5% of the delta k of burnup), 3) the bias for minor actinide and fission product worth (1.5% of the delta k of minor actinides and fission products) and 4) the enrichment uncertainty (taken as the fresh fuel uncertainty multiplied by the ratio of the fresh fuel enrichment divided by the burned fuel enrichment). These four items are calculated for each enrichment/burnup pair on the loading curve.

Due to the conservative modeling of clad creep, the uncertainty for clad dimensions is taken as zero for the burned fuel. Some added uncertainties appear with the new calculations, for example the poison box and rodlet dimensions.

No fuel pellet OD sensitivity is provided for depleted fuel. Comparison of the fresh fuel pellet OD sensitivity cases and fresh fuel density tolerance cases shows that pellet OD sensitivity case is effectively a much smaller version of the pellet density tolerance case, with the reactivity effect of each primarily due to the amount of uranium dioxide (UO_2) mass change. In addition, the density tolerance is sufficiently large to account for the UO_2 mass uncertainty due to pellet density manufacturing tolerance, pellet dishing and chamfer manufacturing tolerance, and pellet diameter manufacturing tolerance after combining these three independent tolerances in quadrature.

These exceptions are used in the uncertainty calculations for practical reasons:

- Sufficient fuel density change cases were run for depleted fuel to demonstrate that the fuel density effect is essentially the same as for fresh fuel, so the depletion fuel cases were generally not run for the fuel density uncertainty.

- For 2000 ppm burnup worth uncertainty calculations, 0 ppm burnup worth was used for simplicity in some cases to reduce the number of KENO cases required. A maximum burnup credit case for total burnup worth and for minor actinide and fission product worth confirms that burnup worth is substantially lower with 2000

ppm boron than with 0 ppm boron. Use of the 0 ppm burnup worth for 2000 ppm uncertainty calculations is conservative.

RAI-29

The proposed Region 3 would permit storage of assemblies in which either B-SS rodlets or CEAs have been installed, provided they meet the burnup credit acceptance limits for that component. Analyses are performed for CEAs and for B-SS rods. The proposed TS would permit mixing of assemblies loaded with CEAs with assemblies loaded with B-SS pins. Because geometric effects of the rodlets would impact the calculations analysis should have been performed demonstrating that mixing assemblies with these components will not result in higher Region 3 k_{eff} values. Provide analysis demonstrating that mixtures of assemblies with CEAs and assemblies with B-SS rodlets is bounded by the existing analysis.

DNC Response

Table 29.1 contains results of Region 3 2x2 cases with all CEA, all rodlets and mixed CEA/rodlet configurations. Uniform cases (all rodlets and all CEAs) are selected to have nearly the same $k_{eff.}$ The mixed case k_{eff} (two assemblies with CEAs and two assemblies with rodlets in a checkerboard orientation) is compared to the average of the uniform case k_{eff}'s. Two sets of cases indicate a negative effect on k_{eff} and two sets indicate neutral or indeterminate effect. The all fresh fuel case has a very small positive effect. The fresh fuel case is not of concern because the magnitude is very small, the CEA's are very conservatively modeled, and storage of very low enrichment fresh fuel assemblies in Region 3 is not expected to occur. One additional mixed rodlet/CEA case was run to consider the effect of a uniform axial burnup shape for the depleted fuel. The last case in Table 29.1 shows that there is a positive effect on k_{eff} using a uniform shape rather than the NUREG/CR 6801 axial shape. However, the case k_{eff} is still significantly lower than the average of the infinite single region k_{eff}'s. No interference effect is apparent.

Table 29.1: Region 3 with CEA and Rodlets in the Same 2x2

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Difference from avg. base (dK)	Value
1.6 PP	0	0.96217	0.00005	N/A	Fresh with rodlets for fresh fuel mix
2.21 CEA	0	0.96177	0.00006	N/A	Fresh with CEA for fresh fuel mix
1.6 PP / 2.21 CEA	0	0.96211	0.00006	**0.0001**	Mixed rodlets/CEA, fresh/fresh
2.34 CEA	0	0.97902	0.00009	N/A	Fresh with CEA for fresh / depl mix
4.85 PP	50	0.97786	0.00010	N/A	28 Major Nuclides depl with rodlets
4.85 PP / 2.34 CEA	50/0	0.96216	0.00009	**-0.0163**	Mixed rodlets/CEA, depl/fresh
4.85 CEA	33	0.97586	0.00009	N/A	28 Major Nuclides CEA
4.85 PP	50	0.97786	0.00010	N/A	28 Major Nuclides rodlets
4.85 PP / 4.85 CEA	50/33	0.97681	0.00009	**0.0000**	Mixed rodlets/CEA, depl/depl
1.66 PP	0	0.97476	0.00008	N/A	Fresh with rodlets for fresh / depl
4.85 CEA	33	0.97615	0.00009	N/A	28 Major Nuclides CEA
1.66 PP / 4.85 CEA	0/33	0.96776	0.00009	**-0.0077**	Mixed rodlets/CEA, fresh/depl NUREG shape
1.66 PP / 4.85 CEA	0/33U	0.97108	0.00008	**-0.0044**	Mixed rodlets/CEA fresh/depl uniform shape

RAI-30

The analysis results presented in Table 6.1-26 and the text provided in Section 6.1.4.2 do not address uncertainties associated with the CEAs. While the degree of boron depletion in the CEA is admittedly conservative, it is still appropriate to check the uncertainties for the CEA dimensions and materials. In particular, the uncertainties for the B_4C pellet density, ID, and OD, clad OD and thickness, B_4C axial location and extent should be calculated. Provide analysis of the uncertainties associated with CEA manufacturing tolerances.

DNC Response

The uncertainties associated with the CEAs have been addressed and have been found to be covered by the conservatism in the depletion assumed for the B_4C. The response to RAI 25.a.ii provides the details of the analysis performed.

RAI-31

Confirm that the Region 3 k_{eff} values are insensitive to the location of the CEAs and B-SS rods within the guide tubes. For example, is k_{eff} higher if the B-SS rod is moved such that it is in-contact with the GT inner surface rather than centered? If there is a significant uncertainty associated with the positions of the CEA or B-SS rods in the guide tubes, review the designs of these components to determine whether or not the locations are truly random. If they are random they can then be handled as uncorrelated uncertainties. However, if the positions are not random and the systems are sensitive to the rod locations, develop and incorporate a bias term to cover CEA and B-SS rod locations.

DNC Response

Off-center rodlet cases are included in the Region 3 bias and uncertainty calculations. Three cases were considered, as illustrated in Figures 31.1 through 31.3. The calculated sensitivity to position is very small (-0.0005 dk to 0.0006 dk, including 2x RSS KENO uncertainty). The reactivity of each of the three off-center placements were calculated at zero burnup, 1.6 wt% U-235 enrichment and 50 GWd/MTU, 4.85 wt% U-235. The highest sensitivity of the three cases for each burnup was used as an uncertainty for that burnup in the calculation of total Region bias and uncertainty. Then the higher of the sensitivities was used for all of the intermediate burnups. The calculation was repeated at 2000 ppm.

Figure 31.1 Off-center Rodlets Case 1

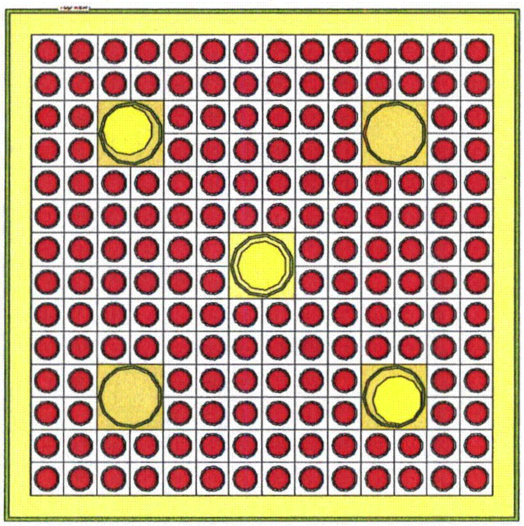


Figure 31.2 Off-center Rodlets Case 2

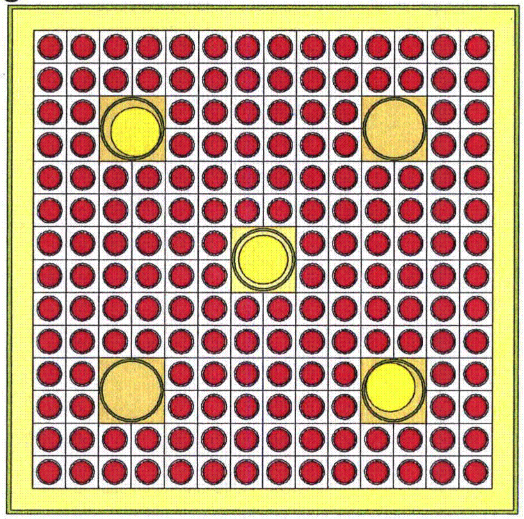
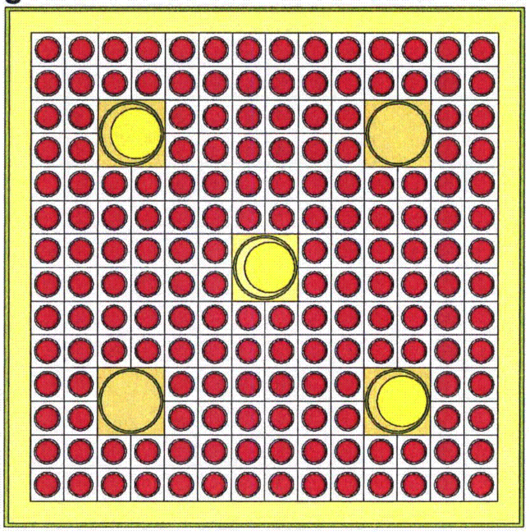


Figure 31.3 Off-center Rodlets Case 3



Two off-center CEA cases were considered, as illustrated in Figures 31.4 and 31.5. The calculated sensitivity to position (-0.0002 dk to 0.0005 dk, including 2x RSS KENO uncertainty) is at least a factor of 20 less than the CEA depletion conservatism. Therefore, it is not included in the calculation of total bias and uncertainty.

Figure 31.4 Off-center CEA Case 1

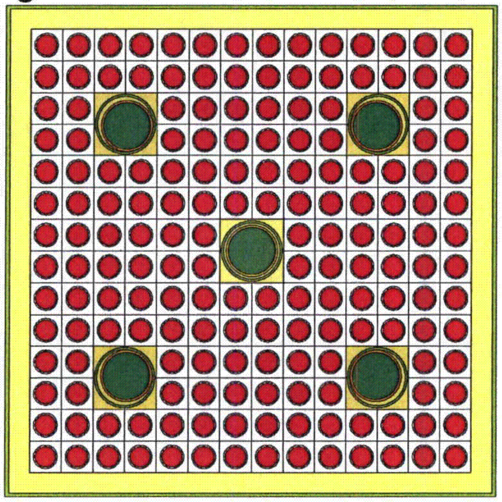
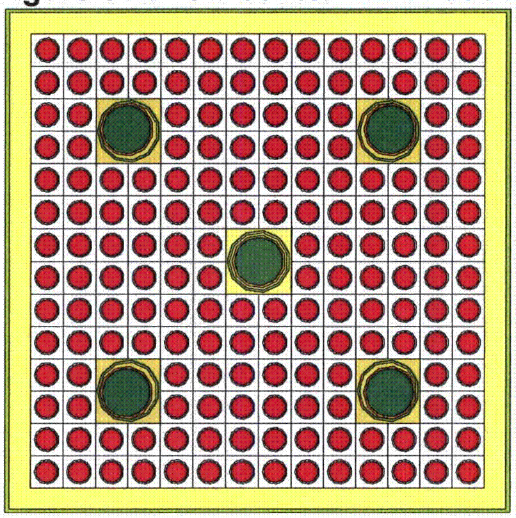


Figure 31.5 Off-center CEA Case 2



RAI-32

The text in the final paragraph on page 88 notes that uncertainty analysis for Region 4 with soluble boron is not provided because Region 4 has analogous trends and is the same rack design. The 3-out-of-4 storage in Region 4 versus 4-out-of-4 storage in

Region 3 and the presence of the CEAs or B-SS rodlets in the Region 3 analysis may cause some of the uncertainties calculated with soluble boron present to vary significantly from the Region 3 analysis. Provide uncertainty analysis for Region 4 calculations with soluble boron.

DNC Response

Biases and uncertainty were calculated for Region 4 with soluble boron for the revised total bias and uncertainty calculation. The new biases and uncertainties are provided with the new burnup credit curve analysis (Attachment 5 of this letter).

RAI-33

Describe the lateral "full spent fuel pool model" details, including distance to the wall, materials and dimensions, sensitivity of the model to these parameters, and comparison with the actual SFP.

DNC Response

The requirement to consider multiple misloads has removed the need to have a full pool model for accident analysis. Further, soluble boron requirements are no longer calculated, rather the k_{eff} (including biases and uncertainties) for normal operations is shown to be less than 0.95 using a conservative minimum soluble boron following a boron dilution accident. Likewise the k_{eff} of accident conditions is shown to be less than 0.95 using the proposed TS minimum soluble boron concentration. The interface analysis no longer relies on a full pool model (see RAI 34 response). No full pool model is used in the revised analysis (see RAI 35 response).

RAI-34

The final sentence in Section 6.2.1, on page 97 is:

> Therefore, it can safely be concluded that there are no detrimental boundary effects with respect to pool reactivity because the overall pool Keff is less than the maximum regional Keff value.

Insufficient basis is provided for this conclusion. It does not look like the impacts of burned fuel, asymmetric fuel placement optimized to maximize region-to-region interaction, optimal rotation of assemblies with B-SS rodlets were considered. Please evaluate the impacts of modeling burned fuel, Region 3 B-SS bundle rotations, and

asymmetric bundle locations on the full pool k_{eff} value without soluble boron, particularly between the interfaces of the different rack regions.

DNC Response

A revised interface analysis which includes burned fuel, Region 3 rodlet consideration and asymmetric fuel placement is described below. Due to the complexity of the full pool model, the revised analysis does not rely on the full pool model. Alternate methods of addressing interface effects are used.

Region interfaces are evaluated to ensure that they do not have the potential to cause SFP k_{eff} to be higher than the analysis k_{eff} of the individual regions. Each region is initially modeled independently using reflective or periodic X and Y dimension boundary conditions, resulting in zero net neutron leakage across the X and Y problem boundaries. For the actual SFP, dissimilar adjacent regions introduce a change in the region boundary condition assumption. Region boundary effects that can impact SFP k_{eff} include axial shape differences, spectral effects, proximity of higher or lower reactivity fuel, spacing between storage racks, increased neutron absorption in rack structural materials (two rack cell walls between fuel assemblies instead of one shared wall), and flux trap effects.

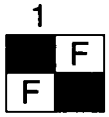
Adverse and Benign Interfaces

An interface occurs at the common boundary of two different regions. The k_{eff} of a system composed of multiple reasonably large regions will be similar to the highest k_{eff} individual region. An interface effect is adverse if k_{eff} of the system, including biases and uncertainties, is higher than the highest k_{eff} of the individual regions, including biases and uncertainties. An interface is benign if the system k_{eff}, including biases and uncertainties, is less than or equal to the highest individual region k_{eff}, including biases and uncertainties. MPS2 region interfaces are designed to be benign.

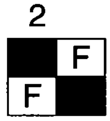
The following examples show how an interface between two regions can increase k_{eff} over the k_{eff} of the isolated regions (adverse interface) or have no effect (benign interface).

Assume there are two large identical regions (1 and 2) with checkerboard 2-out-of-4 storage for fresh fuel (F):

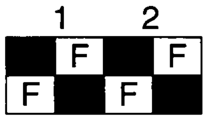
1



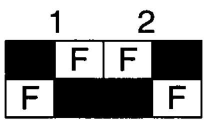
2



When Regions 1 and 2 are brought together, the result is the same as the individual Regions. There is a benign interface effect because the pattern (as well as k_{eff}, bias, uncertainty and margin) is unchanged:



If Region 2 orientation is reversed, there is no change to the individual Region 1 or Region 2 analyses, but there is an adverse interface effect for the coupled Regions because two fresh fuel assemblies are brought together. The k_{eff} of the coupled system will be higher than either isolated Region k_{eff} and margin is reduced:



There are three ways to show that an interface is benign:
1. By inspection
2. By separation
3. By direct calculation

Disposition by Inspection

Interfaces between regions with the same rack design and with rack cells aligned across the interface can be dispositioned qualitatively. In the diagram below, regions A and B are comprised of 2x2 unit cells of approximately equal reactivity.

A		Hybrid		B	
2	0	0	1	1	1
0	2	2	0	0	1

The hybrid region in the center exists at the interface of regions A and B. With fuel assembly reactivity ranked from low to high (0 = empty cell, 1 = low reactivity, and 2 = high reactivity) it is clear by inspection that the interface 2x2 is significantly less reactive than the region A 2x2.

- If region A has the highest analysis k_{eff}, the interface is benign because the hybrid region is less reactive than region A.

- If region B has the highest analysis k_{eff}, the interface is benign because the hybrid region is less reactive than region A, which is less reactive than region B.

Disposition by Separation

A second disposition method is to demonstrate sufficient neutronic separation. If adjacent racks are far enough apart, no interaction will occur.

To determine the rack interface gap size required to neutronically separate fuel, a 4x2 Region 2 KENO model (Figure 34.1) was created with a rack boundary at the center of the 4 assembly dimension. Using periodic boundary conditions, this model represents two adjacent rack modules each effectively infinite in the Y dimension and 4 rows wide in the X dimension. For simplicity, Region 2 3-out-of-4 storage geometry was used with 2.5 wt% fresh fuel assemblies. Results of the model are presented in Table 34.1 and Figure 34.2. Modeling the full cell wall thickness on the interface side of each rack decreases k_{eff} by ~0.001 dk. Neutronic coupling (defined as change in k_{eff} / change in separation distance) declines more than an order of magnitude for each 10 cm of separation.

Figure 34.1: KENO Region 2 Interface Gap Model

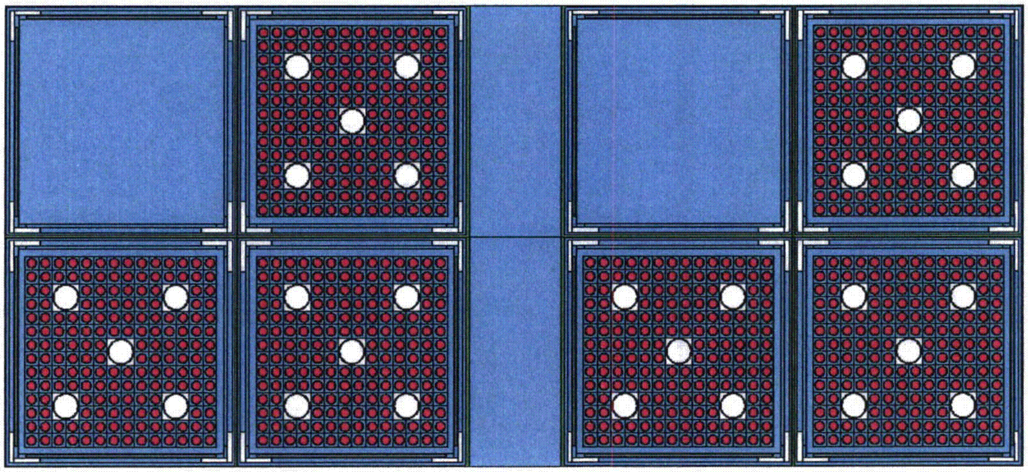
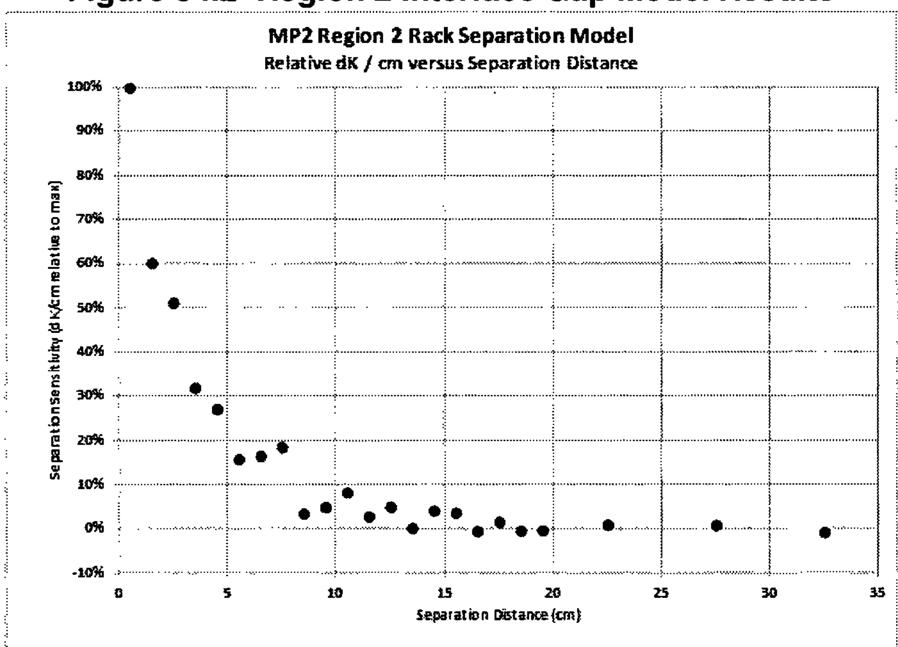


Table 34.1: Region 2 Interface Gap Model Results

Rack Separation (cm)	k_{eff}	k_{eff} uncertainty	dk from reference	dk/cm	Case
0	0.97143	0.00006	N/A	N/A	Infinite region
0	0.97038	0.00006	N/A	N/A	Reference: Two adjacent racks
1	0.96612	0.00007	-0.0043	-0.0043	1 cm separation
2	0.96356	0.00006	-0.0068	-0.0026	2 cm separation
3	0.96137	0.00007	-0.0090	-0.0022	3 cm separation
4	0.96001	0.00006	-0.0104	-0.0014	4 cm separation
5	0.95885	0.00006	-0.0115	-0.0012	5 cm separation
6	0.95817	0.00006	-0.0122	-0.0007	6 cm separation
7	0.95747	0.00006	-0.0129	-0.0007	7 cm separation
8	0.95667	0.00007	-0.0137	-0.0008	8 cm separation
9	0.95653	0.00006	-0.0139	-0.0001	9 cm separation
10	0.95632	0.00007	-0.0141	-0.0002	10 cm separation
12	0.95584	0.00007	-0.0145	-0.0002	12 cm separation
14	0.95562	0.00007	-0.0148	-0.0001	14 cm separation
15	0.95545	0.00007	-0.0149	-0.0002	15 cm separation
20	0.95528	0.00007	-0.0151	0.0000	20 cm separation
25	0.95509	0.00007	-0.0153	0.0000	25 cm separation
30	0.95491	0.00007	-0.0155	0.0000	30 cm separation
35	0.95509	0.00006	-0.0153	0.0000	35 cm separation

Figure 34.2 Region 2 Interface Gap Model Results



Disposition by Direct Calculation of Interface Effects

If a region interface cannot be dispositioned by inspection or separation, a direct calculation can be used.

Each Region is initially analyzed as an infinite array. Each Region has a calculated k_{eff} representing the "base case" configuration. Allowance for bias and uncertainty ensures that the infinite Region k_{eff} will not exceed the regulatory limit including the effect of analytical, material, and geometric biases and tolerances. The region 95/95 k_{eff} is the region calculated k_{eff} plus total Region bias and uncertainty.

Bias and uncertainty is calculated independently for each Region. For a coupled system of dissimilar Regions, it is not clear what the appropriate bias and uncertainty should be. NRC Interim Staff Guidance DSS-ISG-2010-01 Rev. 0 [Ref. 34.1] states: "*Absent a determination of a set of biases and uncertainties specifically for the combined interface model, use of the maximum biases and uncertainties from the individual storage configurations should be acceptable in determining whether the keff of the combined interface model meets the regulatory requirements.*"

This approach can be unnecessarily conservative as shown by the following example. Assume Region 1 has 0.02 dk bias and uncertainty and Region 2 has 0.04 dk bias and uncertainty and both regions have the same 95/95 k_{eff}:

Region	Calculated k_{eff}	Bias and Uncertainty	95/95 k_{eff}
1	0.97	0.02	0.99
2	0.95	0.04	0.99

If we assume there is a benign interface, the interface evaluation using a "base case" Region 1 / Region 2 model will have $k_{eff} \leq 0.97$. System k_{eff} will be dominated by the more reactive Region 1 but will not be higher than 0.97. If the Region 2 bias and uncertainty is added to the coupled system k_{eff} as suggested in the 2010 ISG, the interface analysis k_{eff} would be ~1.01 (≤0.97 + 0.04 bias and uncertainty). The analyzed k_{eff} is over the limit by 0.01 dk *even though the interface is benign.* In this case, applying the higher bias and uncertainty for the coupled system is overly conservative. Bias and uncertainty calculations for the system using a "base case" model would be dominated by Region 1 (base case k_{eff} = 0.97) and would underweight Region 2 (base case k_{eff} = 0.95) because the system k_{eff} is dominated by the higher importance Region 1.

As suggested in the 2010 ISG, bias and uncertainty for the system could be directly calculated. An alternative is to use 95/95 region models rather than base case region models to construct the coupled system model. In the example, the coupled 95/95 system k_{eff} with a benign interface will be ≤ 0.99. Since the interface does not cause a

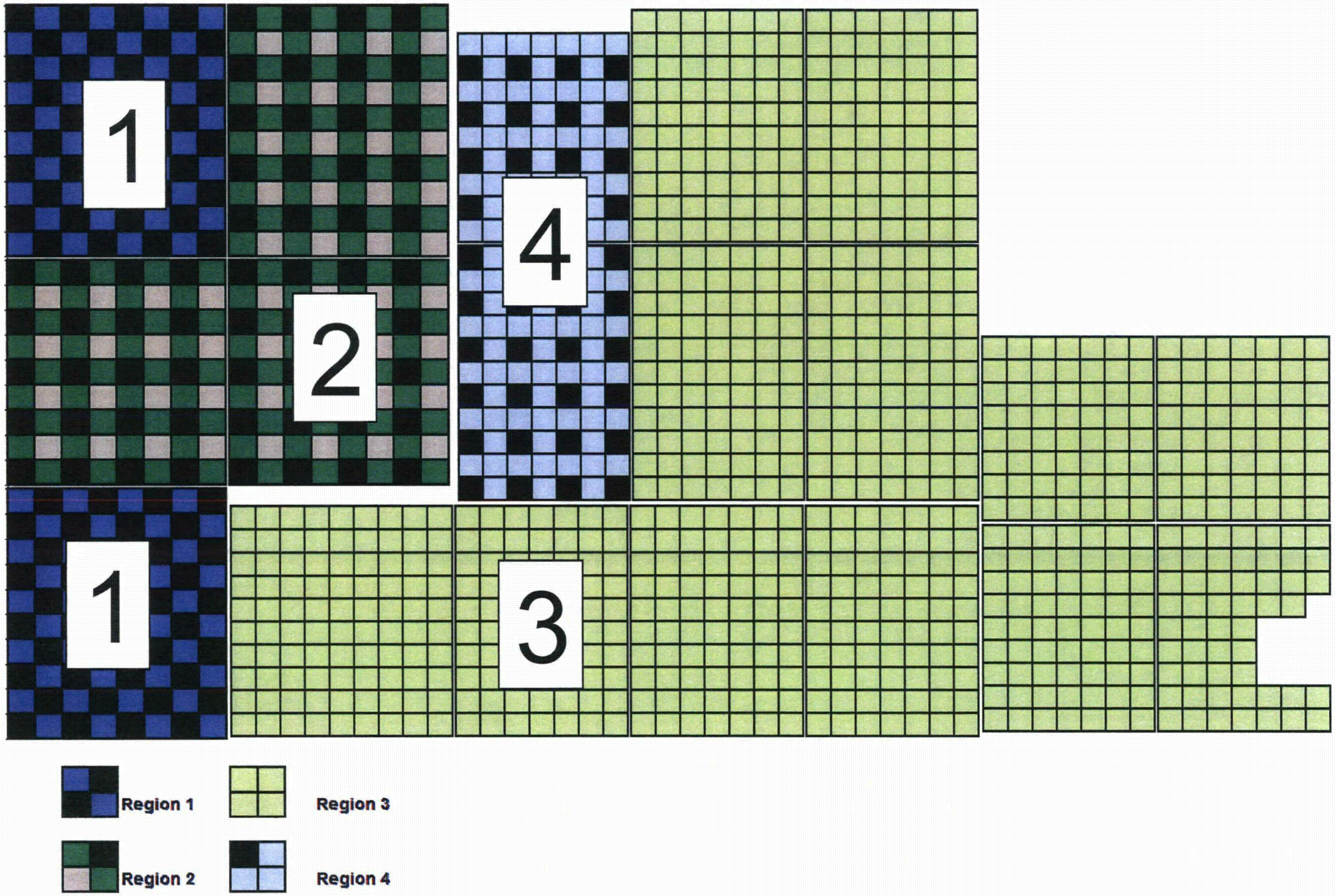
higher k_{eff} than highest 95/95 region model k_{eff}, the interface is confirmed as benign. The interface evaluation confirms that the coupled system has at least the amount of margin to the k_{eff} limit as the region with the highest infinite lattice 95/95 k_{eff} (margin to the limit for the 0 ppm normal configuration is 1.0 – 95/95 k_{eff}).

It is not necessary to perform the 95/95 interface evaluation with true 95/95 models. The key to the 95/95 interface analysis approach is using region models that have the same infinite lattice k_{eff} difference (region 2 – region 1) as the 95/95 k_{eff} difference (region 2 – region 1). The correct region k_{eff} difference can be obtained by arbitrarily increasing the reactivity of the less reactive region or arbitrarily decreasing the reactivity of the more reactive region. A benign interface will have system k_{eff} less than or equal to the maximum of the infinite lattice region k_{eff}'s. An adverse interface will have system k_{eff} greater than the maximum of the infinite lattice region k_{eff}'s.

Dispositioning of MPS2 Region Interfaces

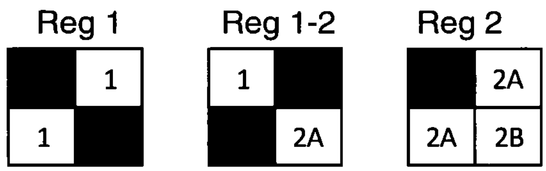
The MPS2 SFP Region interfaces are designed to be benign (Figure 34.3). Region 1 has empty cells in a 2-out-of-4 checkerboard. The checkerboard 2-out-of-4 configuration is very low reactivity. Region 2 has every other cell empty on the faces except at the Region 4 interface. Region 4 has every other cell empty along the interfaces. Benign interface effects will be confirmed for each interface.

Figure 34.3: Region Assignments in MPS2 Pool



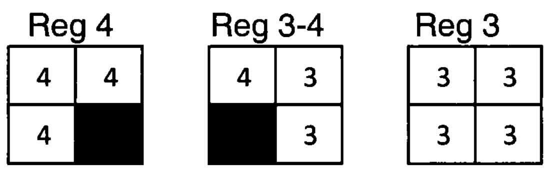
Disposition of MPS2 Region 1-2 and 3-4 Interfaces

Figure 34.3 shows the Region layout for the MPS2 SFP. Region interfaces for Regions 1-2 and 3-4 can be dispositioned by inspection. The Region 1-2 interface can be treated as a 2x2 hybrid composed of one Region 1 fresh 4.85 wt% assembly, one Region 2A depleted assembly, and two empty cells in a checkerboard arrangement.



The gap between Region 1 and Region 2 is slightly more than 2 inches, so treating the interface as a contiguous 2x2 region is conservative. The hybrid Region 1-2 2x2 is less reactive than the Region 1 2x2 because the 2A depleted fuel assembly is less reactive than a fresh fuel assembly. Region 1 is also less reactive than Region 2 due to the 2-out-of-4 geometry. Therefore, the interface region is less reactive than either Region 1 or Region 2. The Region 1-2 interface is benign.

The Region 3-4 interface can be treated as a 2x2 subregion composed of one Region 4 assembly, two adjacent Region 3 assemblies, and one empty cell.



The gap between regions is 2 inches, so treating the interface as a contiguous 2x2 region is conservative. The two Region 3 assemblies in the interface 2x2 are far less reactive (higher burnup requirement in addition to 3 rodlets or a CEA) than two Region 4 assemblies in the same position in a Region 4 2x2. Therefore the Region 3-4 interface 2x2 is much less reactive than the Region 4 2x2, which is similar in reactivity to the Region 3 2x2 (see region margin calculations). In addition, interface reactivity is reduced by the effect of the finite rack size (full cell wall thickness on both sides of the region interface) and by the minimum 2 inch rack separation. The Region 3-4 interface is benign.

Disposition of MPS2 Region 2-3 Interface

There is a 10 inch (25.4 cm) gap at the Region 2-3 interface. The 10 inch gap is sufficient to preclude any interface effect. The Region 2-3 interface is benign.

Disposition of the MPS2 Region 1-3 Interface

Region 1 contains only fresh fuel. Region 3 can have a range of enrichment (low to high) and burnup (low to high). Region 3 may have borated stainless steel rodlets or CEAs. The Region 1 infinite lattice k_{eff} is much lower than the Region 3 infinite lattice k_{eff}. Bias and uncertainty is higher for Region 3. Therefore, for simplicity, the 2010 ISG conservative approach of applying the higher Region 3 bias and uncertainty to the coupled system "base case" k_{eff} will be used for the Region 1-3 interface analysis.

If the coupled system calculated k_{eff} is less than the Region 3 infinite model then the interface is benign and the coupled system margin to the k_{eff} limit is greater than or equal to the Region 3 infinite lattice margin.

Both low enrichment fresh fuel and high enrichment depleted fuel is considered for Region 3. The calculated infinite model k_{eff} and margin to the limit come from Attachment 5 of this letter.

The interface model consists of a 10x10 Region 1 rack, an 11x11 Region 3 rack, a 2 inch gap between racks, a 1 inch gap between racks at the interface, and periodic boundary conditions. This model is infinite in the X and Y dimensions and larger than the MPS2 racks. Minimum installed gap between racks is 2 inches. The interface gap is reduced to 1 inch to eliminate consideration of asymmetric placement at the interface.

Region 1-3 interface analysis with fresh fuel:

Region 1 infinite model calculated k_{eff}:	0.9087	(5.0 wt% fresh)
Region 3 rodlet infinite model *calculated* k_{eff}:	0.9643	(1.6 wt% fresh, rodlets)
Coupled system Region 1-3 k_{eff}:	0.9562	
Difference (system k_{eff} – max region k_{eff}):	**-0.0081**	

The coupled Region 1-3 model k_{eff} is 0.0081 lower than the Region 3 infinite model case indicating a benign interface.

Region 1-3 interface analysis with depleted Region 3 fuel (Rodlets, NUREG axial shape):

Region 1 infinite model calculated k_{eff}:	0.9087	(5.0 wt% fresh)
Region 3 infinite model calculated k_{eff}:	0.9552	(4.85 wt% 50 GWd/MTU, rodlets)
Coupled system Region 1-3 k_{eff}:	0.9477	
Difference (system k_{eff} – max region k_{eff}):	**-0.0075**	

The coupled Region 1-3 model k_{eff} is 0.0075 lower than the Region 3 infinite model case indicating a benign interface.

Region 1-3 interface analysis with depleted Region 3 fuel (CEA, uniform axial shape):

Region 1 infinite model calculated k_{eff}:	0.9087	(5.0 wt% fresh)
Region 3 infinite model calculated k_{eff}:	0.9408	(4.85 wt% 33 GWd/MTU, CEA)
Coupled system Region 1-3 k_{eff}:	0.9328	
Difference (system k_{eff} – max region k_{eff}):	**-0.0080**	

The coupled Region 1-3 model k_{eff} is 0.0080 lower than the Region 3 infinite model case indicating a benign interface.

Region 1-3 interface analysis with depleted Region 3 fuel (CEA, NUREG axial shape):

Region 1 infinite model calculated keff:	0.9087	(5.0 wt% fresh)
Region 3 infinite model calculated keff:	0.9596	(4.85 wt% 33 GWd/MTU, CEA)
Coupled system Region 1-3 k_{eff}:	0.9518	
Difference (system k_{eff} – max region k_{eff}):	**-0.0078**	

The coupled Region 1-3 model k_{eff} is 0.0078 lower than the Region 3 infinite model case indicating a benign interface.

The Region 1-3 coupled system k_{eff} is less than the Region 3 infinite lattice k_{eff}. Region 3 has the higher bias and uncertainty of the two regions. The interface analysis indicates the coupled system margin to the k_{eff} limit is greater than or equal to the Region 3 infinite lattice margin to the limit. The Region 1-3 interface is benign.

Disposition of the MPS2 Region 2-4 Interface

Both low enrichment fresh fuel and high enrichment depleted fuel is considered for Regions 2 and 4. The interface model consists of a 10x10 Region 2 rack, an 11x11 Region 4 rack, a 2 inch gap between racks, a 1 inch gap between racks at the interface, and periodic boundary conditions. This model is infinite in the X and Y dimensions and larger than the MPS2 racks. Minimum installed gap between racks is 2 inches. The interface gap is reduced to 1 inch to eliminate consideration of asymmetric placement at the interface.

The 95/95 interface evaluation method is used to avoid the complexity of an interface model-specific bias and uncertainty calculation and to avoid unnecessary excess

conservatism that could occur using the 2010 ISG maximum region bias and uncertainty approach.

Fresh fuel only Region 2-4 interface analysis:

Region 2 infinite model calculated k_{eff}:	0.9636	(2.9 and 1.9 wt% fresh)
Region 4 infinite model calculated k_{eff}:	0.9632	(1.7 wt% fresh)
K_{eff} difference (Region 4 – Region 2):	-0.0004	
Region 2 infinite model margin to limit:	0.0091	(Attachment 5)
Region 4 infinite model margin to limit:	0.0118	(Attachment 5)
95/95 model k_{eff} difference target (4-2):	-0.0027	
Coupled system Region 2-4 k_{eff}:	0.9570	
Difference (system k_{eff} – max region k_{eff}):	**-0.0066**	

For this case, the base case models may be used. For the 95/95 model approach, Region 4 infinite lattice model k_{eff} should be 0.0027 lower than the Region 2 infinite lattice model k_{eff}. Using base case models, the Region 4 k_{eff} is 0.0004 lower than Region 2 k_{eff}. Use of the base case models is therefore conservative because Region 4 k_{eff} is higher than required. No changes to alter the reactivity of the base case models are required. The coupled system k_{eff} will be compared to the Region 2 infinite model k_{eff}.

The coupled Region 2-4 model k_{eff} is 0.0066 lower than the Region 2 infinite model case indicating a benign interface.

Region 2-4 interface analysis with depleted Region 4 fuel (NUREG axial shape):

Region 2 infinite model calculated k_{eff}:	0.9581	(2.85 and 1.85 wt% fresh)
Region 4 infinite model calculated k_{eff}:	0.9569	(4.85 wt% 41 GWd/MTU)
K_{eff} difference (Region 4 – Region 2):	-0.0012	
Region 2 infinite model margin to limit:	0.0091	(Attachment 5)
Region 4 infinite model margin to limit:	0.0077	(Attachment 5)
95/95 model k_{eff} difference target (4-2):	0.0014	
Coupled system Region 2-4 k_{eff}:	0.9515	
Difference (system k_{eff} – max region k_{eff}):	**-0.0056**	

The Region 2 model fresh fuel enrichment is reduced by 0.05 wt%. For the 95/95 model approach, the Region 2 infinite lattice model k_{eff} should be 0.0014 lower than the Region 4 infinite lattice model k_{eff}. With Region 2 enrichment reduced 0.05 wt%,

Region 2 k_{eff} is 0.0012 higher than Region 4 k_{eff}. Region 2 k_{eff} is conservatively high. The coupled system k_{eff} will be compared to the Region 4 infinite model k_{eff}.

The coupled Region 2-4 model k_{eff} is 0.0056 lower than the Region 4 infinite model case indicating a benign interface.

Region 2-4 interface analysis with depleted Region 2 fuel (NUREG axial shape):

Region 2 infinite model calculated k_{eff}:	0.9650	(4.85 wt%, 16 and 33 GWD/MTU)
Region 4 infinite model calculated k_{eff}:	0.9632	(1.7 wt% fresh)
K_{eff} difference (Region 4 – Region 2):	-0.0018	
Region 2 infinite model margin to limit:	0.0051	(Attachment 5)
Region 4 infinite model margin to limit:	0.0118	(Attachment 5)
95/95 model k_{eff} difference target (4-2):	-0.0067	
Coupled system Region 2-4 k_{eff}:	0.9589	
Difference (system k_{eff} – max region k_{eff}):	**-0.0061**	

For the 95/95 model approach, the Region 4 infinite lattice model k_{eff} should be 0.0067 lower than the Region 2 infinite lattice model k_{eff}. Using base case models, the Region 4 k_{eff} is 0.0018 lower than Region 2 k_{eff}. Use of the base case models is therefore conservative because Region 4 k_{eff} is higher than required. No changes to alter the reactivity of the base case models are required. The coupled system k_{eff} will be compared to the Region 2 infinite model k_{eff}.

The coupled Region 2-4 model k_{eff} is 0.0061 lower than the Region 2 infinite model case indicating a benign interface.

Region 2-4 interface analysis with depleted Region 2 fuel (Uniform axial shape):

Region 2 infinite model calculated k_{eff}:	0.9632	(4.2 / 10 and 4.85 / 33)
Region 4 infinite model calculated k_{eff}:	0.9632	(1.7 wt% fresh)
K_{eff} difference (Region 4 – Region 2):	0.0000	
Region 2 infinite model margin to limit:	0.0067	(Attachment 5)
Region 4 infinite model margin to limit:	0.0118	(Attachment 5)
95/95 model k_{eff} difference target (4-2):	-0.0051	
Coupled system Region 2-4 k_{eff}:	0.9569	
Difference (system k_{eff} – max region k_{eff})	**-0.0063**	

For the 95/95 model approach, the Region 4 infinite lattice model k_{eff} should be 0.0051 lower than the Region 2 infinite lattice model k_{eff}. Using base case models,

the Region 4 k_{eff} is the same as the Region 2 keff. Use of the base case models is therefore conservative because Region 4 k_{eff} is higher than required. No changes to alter the reactivity of the base case models are required. The coupled system k_{eff} will be compared to the Region 2 infinite model k_{eff}.

The coupled Region 2-4 model k_{eff} is 0.0063 lower than the Region 2 infinite model case indicating a benign interface.

Region 2-4 interface analysis depleted Region 2 and 4 fuel (Mixed axial shapes):

Region 2 infinite model calculated k_{eff}:	0.9632	(4.2 / 10 and 4.85 / 33 uniform)
Region 4 infinite model calculated k_{eff}:	0.9569	(4.85 wt% 41 GWd/MTU, NUREG)
K_{eff} difference (Region 4 – Region 2):	-0.0063	
Region 4 infinite model calculated k_{eff}:	0.9615	(4.85 wt% 40 GWd/MTU, NUREG)
K_{eff} difference (Region 4 – Region 2):	-0.0017	
Region 2 infinite model margin to limit:	0.0067 (Attachment 5)	
Region 4 infinite model margin to limit:	0.0077 (Attachment 5)	
95/95 model k_{eff} difference target (4-2):	-0.0010	
Coupled system Region 2-4 k_{eff}:	0.9567	
Difference (system k_{eff} – max region k_{eff}):	**-0.0065**	

For the 95/95 model approach, the Region 4 infinite lattice model k_{eff} should be 0.0010 lower than the Region 2 infinite lattice model k_{eff}. Using base case models, the Region 4 k_{eff} is 0.0063 lower than Region 2 k_{eff}. Reducing the Region 4 burnup by 1 GWd/MTU increases Region 4 k_{eff} nearly the desired amount, such that a valid interface conclusion may be drawn from the coupled system case. The coupled system k_{eff} will be compared to the Region 2 infinite model k_{eff}.

The coupled Region 2-4 model k_{eff} is 0.0066 lower than the Region 2 infinite model case indicating a benign interface.

Consideration of Change in Rack Spacing

A seismic event could shift the racks in such a way as to reduce the spacing between racks and increase k_{eff}. Rack spacing changes within each Region are not of concern because each Region is analyzed as an infinite array of storage cells. Two cases were run to confirm that the seismic event is easily bounded by misload events. The Region 1-3 and Region 2-4 interface models with fresh fuel were re-run with no space between racks. The change in k_{eff} is very small (< 0.0006 dk).

Region Interface Conclusions

Evaluation of region interfaces and gaps between racks shows that none of the region interfaces result in loss of analyzed margin to the regulatory limit. There are five interfaces in the MPS2 SFP:

Region 1-2
Region 1-3
Region 2-3
Region 2-4
Region 3-4

Interfaces 1-2, 2-3, and 3-4 have been dispositioned without need of a calculation. Interfaces 1-3 and 2-4 have been shown to be benign by direct calculation.

References:

34.1 NRC Interim Staff Guidance (ISG) DSS-ISG-2010-01, "Staff Guidance Regarding the Nuclear Criticality Safety Analysis for Spent Fuel Pools," 2011.

RAI-35

Please provide clarification and justification for Section 6.2.1.1. For example, why are the region specific target k_{eff} values so low and why did they need to be adjusted lower? How was the Region 3 with B-SS rods target k_{eff} value determined? How was the Region 4 target k_{eff} value determined? Note that Region 3 with B-SS rods and Region 4 "target k_{eff}" values appear to be 0.8998, which does not include the adjustments used to determine the target k_{eff} for Region 2 and Region 3 with CEAs. How was the full pool model target k_{eff} value determined?

The last paragraph of Section 6.2.1.1 describes full pool model calculations and appears to indicate that full pool calculations were performed with only fresh fuel. Perform similar full pool calculations with all non-restricted fuel locations filled with the most highly burned fuel combinations on the loading curves and for both Region 3 with B-SS rodlets and Region 3 with CEAs. Alternatively, perform these calculations for each region to demonstrate that for the infinite array k_{eff} with biases and uncertainties will be no greater than 0.95 when the required soluble boron is present.

DNC Response

As discussed in the response to RAI 33, the requirement to consider multiple misload events has removed the need to have a full pool model for accident analysis. Section 6.2.1.1 of the December 2012 LAR has been replaced by a simpler alternative approach that addresses specific target k_{eff} values. Using infinite array models for each region, k_{eff} is calculated using a soluble boron concentration (550 ppm) that is bounded by the acceptable value in the boron dilution analysis (600 ppm). Each region k_{eff} is shown to be less than 0.95 after adding the appropriate bias and uncertainty.

Infinite lattice region models for all regions were run with 550 ppm using the highest and lowest analyzed enrichment and burnup combinations. Region 1 does not require any soluble boron to meet the 0.95 criterion. Table 35.1 shows the results of the analysis. The bias and uncertainties shown on Table 35.1 come from the analysis maximum of either the borated total bias and uncertainty analysis (2000 ppm) or the unborated total bias and uncertainty analysis. These cases confirm that 550 ppm is more than sufficient to achieve $k_{eff} < 0.95$ including maximum bias and uncertainty, and that this requirement is less than the 600 ppm value assumed in the MPS2 SFP dilution analysis.

Table 35.1: Boron Requirement Verification Infinite Array Cases

Region	k_{eff}	Sigma	Enrichment (wt% U^{235})	Burnup (GWd/MTU)	Total bias and uncertainty (max, dk)	k_{eff} with bias and uncertainty	Notes
1	0.8274	0.0001	5.0	0	0.023	0.851	With poison boxes, 550 ppm
1	0.8255	0.0001	5.0	0	0.023	0.849	No poison boxes in empty cells, 550 ppm
2	0.8463	0.0001	2.90 / 1.90	0 / 0	0.035	0.881	Poison box in all cells, 550 ppm boron
2	0.8740	0.0002	4.85 / 4.85	16 / 33	0.038	0.912	Poison box in all cells, 550 ppm boron
2	0.8450	0.0001	2.90 / 1.90	0 / 0	0.035	0.880	No poison boxes in empty cells, 550 ppm
2	0.8728	0.0002	4.85 / 4.85	16 / 33	0.038	0.911	No poison boxes in empty cells, 550 ppm
3 rodlets	0.8391	0.0001	1.6	0	0.034	0.873	550 ppm boron
3 rodlets	0.8733	0.0001	4.85	50	0.045	**0.919**	550 ppm boron
3 CEA	0.8664	0.0001	2.25	0	0.026	0.892	550 ppm boron
3 CEA	0.8860	0.0001	4.85	33	0.033	**0.919**	550 ppm boron
4	0.8257	0.0001	1.7	0	0.032	0.858	550 ppm boron
4	0.8636	0.0001	4.85	41	0.039	0.903	550 ppm boron

RAI-36

The last paragraph on page 99 states:

> Should the removed fuel rod be replaced by another fuel rod, the assembly average bumup must be recomputed and the fuel assembly must be prequalified according to the revised burnup, which will be bounded by the criticality safety analysis.

It is not obvious that simply recalculating the assembly average burnup will adequately bound the replacement of a burned fuel pin with another fuel pin. Provide additional justification for this fuel assembly reconstitution procedure.

DNC Response

An analysis of reconstitution is included in Attachment 4 of this letter.

RAI-37

Section 6.2.1.3 includes a list of accident scenarios analyzed Several misleading scenarios appear to be missing from the list, For the following scenarios, please either provide an analysis showing acceptable results or provide a justification for no performing the analysis. If administrative controls are credited, please demonstrate how multiple independent actions would be necessary to put the SFP in an unanalyzed condition. Include a detailed description of the controls in place (for example independent qualified software to check move sheets, locking devices to prevent movement of assemblies, etc.):

a. *Misplacement of multiple fresh fuel assemblies*
b. *Use of incorrect loading curves*
c. *Placement of fuel assemblies into Region 3 without the required CEAs or B-SS rods (note that it is not clear from the description whether the Region 3 misloads are with or without the required CEAs or B-SS rods)*
d. *Missing multiple poison boxes in Regions 1 or 2.*

DNC Response

Multiple misload events were not considered in the December 2012 LAR, however for the revised accident analysis, multiple misloads are considered. For Regions 1 and 2, the rack cells (including Restricted Locations) are assumed to contain a fresh 4.85

wt% U-235 assembly with no burnable absorbers. With this loading, it is shown that the k_{eff} is less than 0.95 with the TS soluble boron. This requires the TS minimum SFP soluble boron to be raised to 2100 ppm.

A multiple misload with fresh fuel in Regions 3 and 4 is not modeled due to the existence of multiple and independent error barriers:

- TS prohibit storage of reload new fuel[1] in Regions 3 and 4
- Move sheet preparation is an administratively controlled process
  - Governed by procedures
  - Requires training and qualifications
  - Requires independent review
  - Uses SHUFFLEWORKS QA software
    - TS requirements are coded into SHUFFLEWORKS
- Fuel movement requires independent verification
  - 3 person verification of correct selection of fuel and storage locations
    - Fuel handler
    - Independent verification (spotter)
    - Additional independent oversight
- Operator training is independent of move sheets[2]
  - Fresh fuel is only stored in Region 1 (currently Region B, future Region 1)
    - TS limitations
  - Fresh fuel is never stored in Regions 3 and 4 (currently Region C)
    - TS limitations
    - New and depleted fuel have different appearance
    - Rack alignment, size and design is different than Region 1
  - Human performance tools
    - Questioning attitude
    - Stop when unsure

Notes:

1) Reload fresh fuel assemblies have enrichments higher than allowable in Regions 3 and 4
2) Existing training is to be augmented to emphasize fresh fuel may only be placed in Region 1 and to stop fuel movement if a move sheet directs fresh fuel to another Region.

Reload new fuel is not stored in the Regions 3 and 4 racks due to burnup credit requirements. New fuel appears shiny in the SFP and is noticeably different than used fuel, which appears dull. This difference in appearance provides a visual indication that is a human performance barrier against inadvertent multiple misloads of fresh fuel (shiny) in Regions 3 and 4 (dull) that is independent of administrative controls. Fuel handler training will reinforce that new fuel is not permitted in Regions 3 and 4 (currently Region C) regardless of move sheet instructions.

A single misload of a fresh fuel assembly and a multiple misload of high reactivity depleted fuel in Regions 3 and 4 are included in the analysis. The misloaded fuel is conservatively assumed to contain no inserts (rodlets or CEAs). The reactivity of the Region 2A burned fuel assemblies misloaded into Regions 3 and 4 is higher than all expected once-burned MPS2 fuel. Region 2A is intended to comfortably satisfy storage requirements for all re-use once-burned fuel temporarily placed in the SFP during refueling outages and allows storage of higher reactivity depleted fuel than is expected at MPS2.

For questions a through c of RAI 37:

Multiple Misload Analysis of Regions 1 and 2 with 4.85 wt% U-235 Fresh Fuel

For Regions 1 and 2, the multiple fresh fuel assembly misload analysis bounds all misload events including those outside the racks and along the rack boundaries. An assembly placed outside the rack couples with at most two faces of normally stored rack fuel assemblies. An assembly placed in a rack location intended to be empty couples the misloaded assembly on three or four sides. An assembly placed on top of the rack is far enough away from the active fuel due to the length of the upper plenum, end plug, top nozzle and rack structure as to be uncoupled. The multiple misload event in Region 1 effectively produces a nearly infinite lattice of fresh fuel, coupling assemblies of the highest reactivity in the SFP on all sides. The Region 1 multiple misload analysis applies to Region 2, which has the same rack design.

Since the full misload in Region 1 at 2100 ppm may affect the Region biases and uncertainties, calculations for the misload case were rerun at 2100 ppm and with every cell containing fresh fuel. The results of these calculations are found on Table 37.1. The final cases are run at 150 °F, with and without zircaloy grids, and with some fuel asymmetrically located in the rack cells and are therefore not shown in Table 37.1 as biases. The multiple misload analysis used a periodic 8x10 rack model with 2 inch spacing between racks. Minimum measured rack spacing in the MPS2 SFP is 2 inches.

The first full fresh misload case assumes the assemblies are centered in each cell location and poison boxes are in each cell. When the spent fuel pool is at 2100 ppm, removing the cell boxes decreases k_{eff}. The next case includes fuel asymmetry (a 4x4 group of assemblies positioned toward a central point).

The Region 1 analysis allows for removal of the poison boxes in the Restricted Locations. With half of the Region 1 poison boxes removed, asymmetry effects with misloaded fuel could be worth more than the negative worth of the removing poison boxes. An asymmetric case was run with half of the poison boxes removed. The asymmetry analysis, however, was adjusted to be consistent with size and frequency possible for the misload of fresh fuel.

The misload analysis for the half poison box case was run with 6 assemblies asymmetrically loaded toward the middle of the rack. The basis for use of 6 assemblies follows the same logic as presented in the response to RAI 23. The key differences for the multiple misload cases are:

1) The number of storage locations involved is smaller. The fresh fuel multiple misload scenario is limited to the number of fresh fuel assemblies on-site, normally less than 80. The RAI 23 premise that the SFP is so large that a small region of maximally asymmetric fuel storage likely exists somewhere in the SFP is far less likely to be true for a small number of storage locations.

2) The multiple misload is analyzed for only one event, not two per cycle for 50 cycles of plant life.

Using the asymmetric placement model discussed in the response to RAI 23 of one out of four chance of fuel being stored fully displaced into one corner of each cell, the probability of occurrence for six adjacent fuel assemblies to be collocated is $(1/4)^6$ x 42 (unique 3x2 regions in the 8x10 rack), or 1.0%. This calculation further assumes that all 80 fuel assemblies are 4.85 wt% with no gadolinia. MPS2 fuel management requires use of gadolinia in most fuel assemblies, and most fuel assemblies have U-235 enrichment well below 4.85 wt%. Therefore, using a region of six collocated asymmetrically loaded assemblies in the misload model is sufficiently conservative for the Region 1 fresh fuel multiple misload.

The final results for the analysis of Region 1 and 2 multiple misload of fresh 4.85 wt% fuel with no burnable poison are presented in Table 37.2. With 2100 ppm soluble boron, the maximum k_{eff}, including bias and uncertainty (0.0192 dk) is 0.9422. The Region 1 and 2 multiple fresh assembly misload analysis with 2100 ppm boron credit meets the $k_{eff} < 0.95$ regulatory requirement.

No consideration of region boundary effects is required because the model used is a repeating array of Region 1 and 2 racks all loaded with fresh fuel. Regions 1, 2, 3 and 4 correctly loaded are much lower reactivity boundaries and would reduce k_{eff}.

Table 37.1: Uncertainties and Biases for Region 1/2 Full Misload

Case Type	Case	2100 ppm boron (dk)
Uncertainty	Increase fuel density	0.0032
Uncertainty	Increase enrichment	0.0027
Uncertainty	Increase pellet OD	0.0006
Uncertainty	Reduce cell pitch	0.0050
Uncertainty	Increase cell wall thickness	0.0012
Uncertainty	Reduce clad OD	0.0002
Uncertainty	Reduce clad ID*	0.0004
Uncertainty	Increase pin pitch	0.0013
Uncertainty	Reduce GT OD*	0.0003
Uncertainty	Reduce GT ID*	0.0004
Uncertainty	Reduce wrapper thickness*	0.0006
Uncertainty	Code uncertainty	0.0052
Uncertainty	2 x KENO std. dev.	0.0003
Uncertainty	NUREG 7109 Structural Materials	0.0008
	TOTAL UNCERTAINTY	**0.0086**
Bias	Code bias	0.0048
Bias	NRC administrative margin	0.0050
Bias	High Temperature Validation Bias	0.0008
	TOTAL BIAS	**0.0106**
	TOTAL BIAS AND UNCERTAINTY	**0.0192**

*Due to low impact these values were not recalculated but taken from Region 1

Table 37.2: Final k_{eff} For the Region 1/2 Full Misload*

Enrichment (wt% U235)	Poison Box	Eccentric Assemblies	Boron	k_{eff}	Sigma	Max k_{eff} with bias and uncertainty
4.85	All	0	2100	0.9066	0.0001	0.9258
4.85	All	16	2100	0.9194	0.0001	0.9386
4.85	All**	16	2100	0.9198	0.0001	0.9390
4.85	Half	0	2100	0.9022	0.0001	0.9214
4.85	Half	6	2100	0.9224	0.0001	0.9417
4.85	Half**	6	2100	0.9229	0.0001	0.9422

*All calculations are done at 150 °F. **No grids.

<u>Misloads for Regions 3 and 4</u>

A single fresh fuel misload case and a multiple depleted fuel misload case (wrong burnup curve, no rodlets or CEAs) will be analyzed for Regions 3 and 4, which have the same rack design.

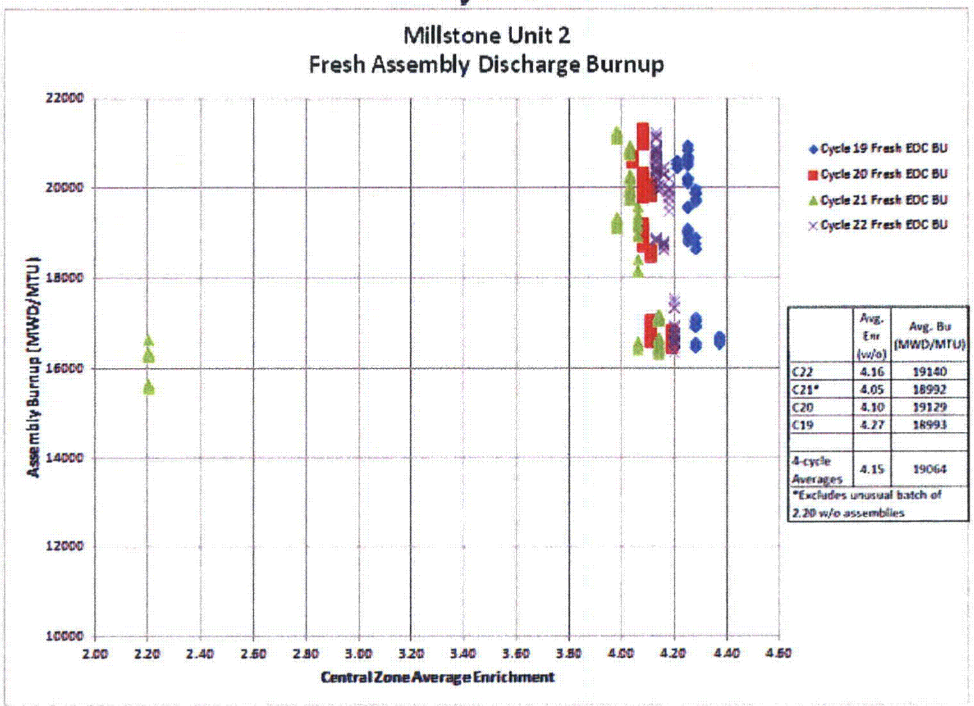
Modeling of the multiple depleted fuel misload case assumes:

1) Use of the wrong TS burnup credit curve.

2) TS requirements regarding neutron poisons (Region 3 rodlets or CEAs) and/or geometry constraints (3-out-of-4 storage in Region 4) are ignored.

For the Region 3 and 4 multiple depleted fuel misload, the limiting case is obtained assuming the highest reactivity depleted fuel (Region 2A). Region 2A fuel with 4.2 wt% initial enrichment and 10 GWd/MTU burnup is used for the Regions 3 and 4 depleted fuel multiple misload case. Figure 37.1 demonstrates that 4.2 wt% is a typical batch enrichment for modern MPS2 reload designs and that 10 GWd/MTU is conservatively lower than the typical end of cycle fresh batch burnup by > 6 GWd/MTU.

Figure 37.1: First Cycle Discharge Burnup versus Enrichment for Recent MPS2 Cycles



	Avg. Enr (w/o)	Avg. Bu (MWD/MTU)
C22	4.16	19140
C21*	4.05	18992
C20	4.10	19129
C19	4.27	18993
4-cycle Averages	4.15	19064
*Excludes unusual batch of 2.20 w/o assemblies		

The analysis of the multiple misload of Regions 3 and 4 uses a 9x10 rack model with periodic X-Y boundaries. The largest rack module in the MPS2 SFP is 9x10. The minimum measured inter-gap spacing (2 inches) is used. This model eliminates the

need to consider edge and boundary effects. Any normally loaded rack adjacent to the misload rack would represent a far lower reactivity boundary condition than the periodic boundary represents. Multiple misload cases are run at 150 °F (with corresponding water density), the maximum normal operating temperature of the SFP. Unlike the Regions 1and 2 multiple misloads, grids and asymmetric fuel are not part of the base model and a bias for those effects was calculated.

The biases and uncertainties are recalculated for the Regions 3 and 4 multiple misload cases and are found on Table 37.3. The temperature bias is set to 0.0008 dk (due to the KENO benchmarking temperature bias of 0.000017 dk / C). The calculated total bias and uncertainty is 0.0286. Table 37.4 shows the multiple misload k_{eff} calculation results using uniform and NUREG/CR-6801 axial burnup distributions.

With 2100 ppm soluble boron, the maximum k_{eff} including the bias and uncertainty is 0.9451 which is less than the 0.95.

Table 37.3: Uncertainties and Biases for Regions 3 and 4 Full Misload

Case Type	Case	2100 ppm boron (dk)
Uncertainty	Increase fuel density	0.0035
Uncertainty	Increase pellet OD	N/A**
Uncertainty	Increase enrichment	0.0040
Uncertainty	Reduce cell pitch	0.0053
Uncertainty	Increase cell wall thickness	0.0005
Uncertainty	Burnup worth (5%)	0.0042
Uncertainty	Burnup record (3.5%)	0.0030
Uncertainty	Increase pin pitch	0.0015
Uncertainty	Increase GT OD*	0.0004
Uncertainty	Increase GT ID*	0.0003
Uncertainty	Code uncertainty	0.0052
Uncertainty	2 x KENO std. dev.	0.0002
Uncertainty	NUREG 7109 Structural Materials	0.0008
	TOTAL UNCERTAINTY	**0.0107**
Bias	Code bias	0.0048
Bias	1.5% minor actinides and FP	0.0005
Bias	Temperature from Validation	0.0008
Bias	Zr grid worth at 2100 ppm	0.0009
Bias	Creep correction (base model includes creep)	0.0023
Bias	Asymmetric fuel placement	0.0024
Bias	Use of assembly average enrich.	0.0010
Bias	NRC administrative margin	0.0050
	TOTAL BIAS	**0.0177**
	TOTAL BIAS AND UNCERTAINTY	**0.0284**

*Due to low impact these values were not recalculated but taken from Region 3
**Set to zero as part of dimension changes with burnup. See RAI 28.

Table 37.4: Regions 3 and 4 Multiple Depleted Fuel Assembly Misload

Region	Soluble boron (ppm)	Enrichment and Burnup (wt% U^{235} / GWD/MTU)	k_{eff}	sigma	Bias and Uncertainty (dk)	Max k_{eff}	Axial Burnup Profile
3/4	2100	4.2/10	0.9165	0.00008	0.0284	**0.9449**	Uniform
3/4	2100	4.2/10	0.9134	0.00008	0.0284	**0.9418**	NUREG/CR

The bounding single fresh assembly misload in Region 3 or 4 is misloading of a fresh fuel assembly in the empty cell of a Region 4 2x2 model with periodic boundary conditions. This case is more limiting than misloading a fresh assembly in Region 3 without a CEA or rodlets because the three correctly loaded assemblies in the Region 4 2x2 are more reactive than the three correctly loaded assemblies in the Region 3 2x2.

Modeling of the Region 4 single fresh fuel misload is conservative due to these considerations:

1) Use of higher reactivity fuel than permitted by the Region 4 burnup curve. To reduce run time, 4.85 wt% 40 GWd/MTU fuel (1 GWd/MTU less than required) with reduced isotopic content (28 major nuclides) was used. This simplification conservatively increases k_{eff}.

2) The Region 4 misload model is 2x2 with periodic boundary conditions. Use of an infinite lattice model represents multiple fresh assembly misloads and places a more reactive 2x2 boundary on all four faces of the misload 2x2 than any of the normally loaded region boundaries. This eliminates the need to consider boundary effects on the Region 2-4 boundary.

3) The infinite lattice model bounds misplacement of a fresh assembly between Region 3 or Region 4 and the SFP wall because it provides neutronic coupling on 4 sides of the fresh assembly rather than one.

4) The maximum 2000 ppm boron Region 4 total bias and uncertainty is used. The presence of the fresh misload assembly would significantly reduce burnup uncertainty of the model.

With 2100 ppm soluble boron, the regulatory requirement for $k_{eff} < 0.95$ is met with large margin for the fresh fuel misload in Regions 3 and 4.

Table 37.5: Regions 3 and 4 Single Fresh Fuel 4.85 wt% U-235 Assembly Misload

Region	Soluble boron (ppm)	Rack Enrichment and Burnup (wt% U^{235} / GWD/MTU)	k_{eff}	sigma	Bias and Uncertainty (dk)*	Max k_{eff}	Axial Burnup Profile
4	2100	4.85/40	0.8744	0.00009	0.0394	**0.9138**	NUREG/CR
4	2100	4.85/40U	0.8741	0.00008	0.0394	**0.9135**	Uniform
4	2100	1.74/0	0.8136	0.00009	0.0394	**0.8530**	Uniform
3 (CEA)	2100	4.85/33	0.8435	0.00009	0.0327	**0.8762**	NUREG/CR
3 (CEA)	2100	4.85/33U	0.8446	0.00009	0.0327	**0.8773**	Uniform

***Maximum Region 4 2000 ppm boron value of Region 3 (CEA) 2000 ppm value used.**

d. At 2100 ppm soluble boron, removing poison boxes reduces k_{eff} due to the large negative worth of borated water. Table 37.2 shows that removing half the poison boxes decreases k_{eff} by 0.004. Removing Restricted Location poison boxes has been evaluated in RAI 35 and RAI 37 responses as well as in Attachment 5 of this letter. Special tools are required for poison box removal. Poison boxes are required in cells where fuel is stored in Regions 1 and 2.

RAI-38

The fourth item in the bulleted list on page 102 is:

- *Misplacement of a 5.0 wt% U-235 fresh fuel assembly between Region 3 and the new fuel elevator, with a fresh 5.0 wt% U-235 fuel assembly in the new fuel elevator.*

Unless there are controls that are intended to prevent this configuration, fuel handling should be treated as a normal condition. Describe why this is treated as an abnormal condition rather than a normal condition. If the analysis is revised to treat it as a normal condition, include a bias term in the calculation of maximum k_{eff} values.

DNC Response

Controls are in place to prevent this configuration. With fuel in the new fuel elevator, station procedure OPS-FH 216 requires that the fuel elevator be in the full down position prior to movement of any fuel with the platform crane. In addition, there is a general restriction on fuel spacing that requires at least 12 inches between fuel assemblies unless the fuel assembly being handled is being lowered into an approved storage location (OPS-FH 210). Therefore, placement of a fuel assembly between a storage rack and the new fuel elevator with fuel in the elevator is an abnormal condition.

RAI-39

Table 6.2-3 provides the full pool model results for many single assembly misloads. Please justify the following:

a. *The Region 1 misloads of assemblies placed into a required empty location along the Region 3 boundary is missing.*

b. *Was the Region 1 misload along the Region 2 boundary along the flat or in the corner?*

c. *The Region 2 misloads along the Regions 3 and 4 boundaries are missing.*

d. *Were the Region 3 misloads that were along the Region 1, 2 and 4 boundaries next to a Region 1/2/4 assembly or a required empty location? Describe the analysis performed to ensure the most reactive misload position was identified.*

e. *For the assembly placed between Region 3 and the new fuel elevator, was a range of locations considered? Note that a small spacing between two assemblies frequently yields a higher k_{eff} than two assemblies that have no separation. Describe the analysis performed to ensure that the most reactive location was identified.*

f. *Was the Region 4 misload along the Region 2 boundary in a position adjacent to a high reactivity assembly?*

g. *Region 4 misloads along the Region 3 boundary are missing.*

h. *For the misloading of a fresh 5 wt % assembly into the SFP, were various burned fuel enrichment/burnup combinations considered for the burned fuel already in the rack? The peak axial fission density distribution for fresh fuel is near the axial mid-plane of the assembly. Due to similar axial fission density profiles, use of the zero burnup maximum enrichment point will likely maximize reactivity of the misload.*

DNC Response

The response to RAI 37 addresses the change of the misload criterion from single misloads to multiple misloads. The multiple misload event is more limiting than the single misload event.

For questions a. through d., f. and g. of RAI 39:

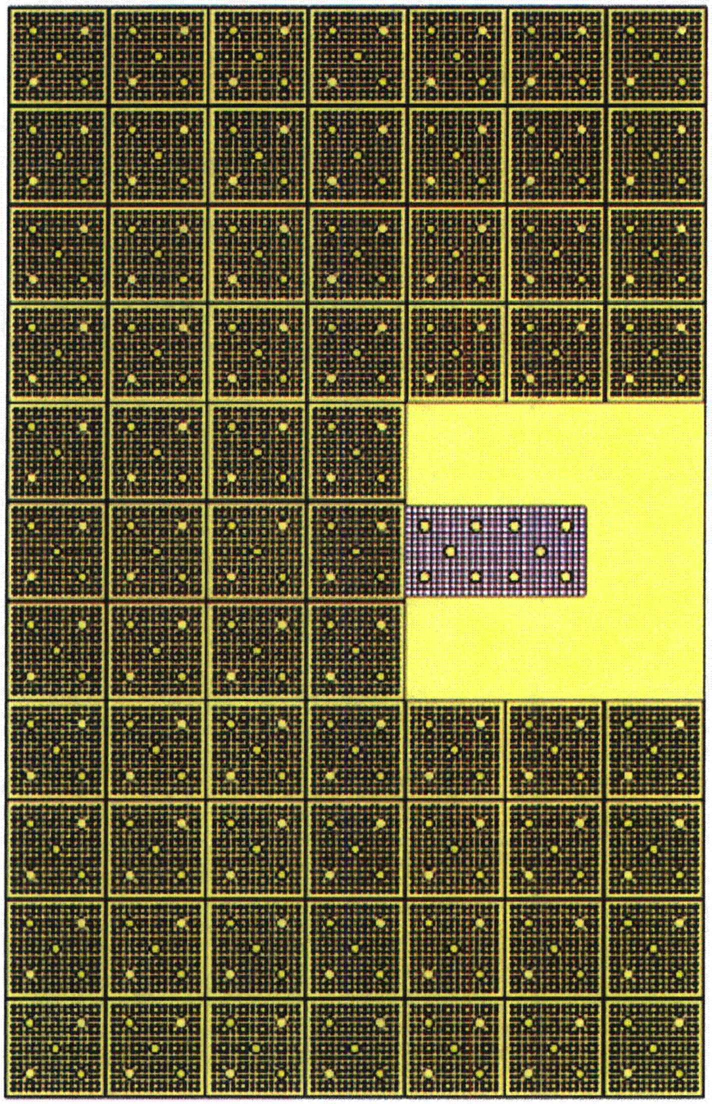
The multiple misload of fresh assemblies in Regions 1 and 2 is an infinite array of misloaded modules. The adjacent misloaded module is more reactive than any properly loaded region so the multiple misload analysis addresses concerns about misloading a single assembly near a boundary.

e. The case of a fresh assembly accidentally placed between the new fuel elevator and Region 3 produces a low k_{eff} when the soluble boron is 2100 ppm; however, a few cases were performed where the distance between the two fresh assemblies were varied as well as the distance between the assemblies and Region 3. None of the cases produce a k_{eff} above 0.90 which leaves 5% in k_{eff} margin to address any concerns in the analysis. The results of the cases analyzed are found on Table 39.1. Figure 39.1 shows the model used. Reflective boundary conditions were assumed on all faces.

Table 39.1: Misload of a Fresh 4.85 wt% U-235 Assembly Near the New Fuel Elevator Containing a Fresh 4.85 wt% U-235 Assembly

Distance from Region 3 (cm)	Distance between Fresh Assemblies (cm)	Soluble Boron (ppm)	k_{eff}	sigma	Bias and Uncertainty (dk)	Max k_{eff}
0	0	2100	0.7855	0.00010	0.0454	**0.8309**
1	0	2100	0.7829	0.00011	0.0454	0.8283
1	1	2100	0.7784	0.00010	0.0454	0.8238
2	2	2100	0.7602	0.00010	0.0454	0.8056
3	3	2100	0.7387	0.00011	0.0454	0.7841

Figure 39.1: Model for Misload Near the New Fuel Elevator



h. The analysis of the single fresh 5 wt% fuel misloaded into Region 4 was addressed in the response to RAI 37. Two different enrichment/burnup pairings were used in the analysis. In both cases a large margin to the 0.95 criteria was observed.

RAI-40

The analysis of the soluble boron required for the bounding misload is described on Page 106. There a couple of questions concerning this analysis.

a. *Justify that using the most highly burned fuel approved for use in Region 4 is conservative. The 1.74 wt % fuel with zero burnup will yield an axial fission density profile more similar to that of the misloaded 5 wt % new fuel assembly. Was the zero burnup fuel also considered in analysis? If not, why not?*

b. *The analysis showed that the Region 4 misload yielded the highest k_{eff} at zero soluble boron. However, the soluble boron worth for a Region 3 misload may be significantly lower due to the reliance on the CEAs and B-SS rods. Consequently, the amount of soluble boron required for a Region 3 misload may be higher than what appears to be required for the Region 4 misload. Either evaluate the soluble boron requirements for other misloads or provide justification for not doing so.*

c. *The analysis utilizes the Region 4 target k_{eff} value to determine the required soluble boron concentration. Depending on the responses to the RAIs provided above, it may be necessary to rework the analysis of soluble boron required for misload accidents.*

DNC Response

The revised misload calculation does not determine a required soluble boron concentration to address accidents but rather uses the new TS soluble boron (2100 ppm) and shows that k_{eff} is less than 0.95 after adding biases and uncertainties. Addressing multiple misload events means that the single misload events are no longer limiting. A 1.74 wt% enrichment case was used in the new analysis and the results are shown on Table 37.5. A case with a single misload of a fresh assembly in Region 3 has also been analyzed and is shown on Table 37.5. As shown in Table 37.5, the single assembly misloads have considerable margin to k_{eff} of 0.95.

RAI-41

The analysis of boundary misalignment is provided starting on page 107. The text and figures are not clear to support review of this analysis. Please clarify the boundary misalignment descriptions and provide clearer figures. Address the following questions/concerns:

a. *It does not look like a Region 2 misalignment was considered wherein the whole Region 2 pattern is shifted to the west one row, placing a full Region 2 row next to Region 1.*

b. *It is does not appear that the misalignment between Regions 3 and 4 were considered. This scenario might involve moving the Region 4 pattern one column to the east, thereby placing a full Region 4 row next to Region 3.*

c. *Figures 6.2-1 through 6.2-4 are of such low quality that it is not possible to see what was analyzed. For example;*

   i. *Region 3 shows up as solid gray blocks. Does this mean Region 3 was modeled as empty? Confirm that all fuel storage racks were modeled as fully loaded.*

   ii. *In Figure 6.2-1, it is not possible to see how the Region 1 misalignment was modeled. Also, it looks like the Region 2 pattern may have been shifted a row to the west. Check the base case full pool model to ensure it is consistent with Figure 6.1-1 (and the TS).*

   iii. *In Figure 6.2-2, it is not clear how the misalignment was modeled. It looks like only one Region 2 row may have been misaligned. If so, it seems more appropriate to shift the entire pattern because a break in the pattern would more likely be identified by operations as incorrect.*

   iv. *In Figure 6.2-3, it looks like the Region 4 pattern was shifted, but it appears that the Region 2 pattern was also shifted. Thereby avoiding a solid Region 2 row next to a solid Region 4 row.*

   v. *Using Figure 6.2-4, it is not possible to verify by the reviewer that the boundary misalignment has been properly modeled.*

DNC Response

a.&b. The multiple misload analysis addresses the boundary misalignment cases. Specifically, with the multiple misload analysis there is no boundary between Regions 1 and 2 or Regions 3 and 4. The full fresh fuel misload in Regions 1 and 2 with an infinite periodic boundary addresses any alignment with Regions 3 and 4 since fresh fuel is much more reactive than Region 3 or Region 4 fuel. The fuel loaded in Regions 3 and 4 in the multiple misload case is Region 2A fuel, so the multiple misload assumption is more limiting that any misalignment concern with Region 2. The Region 3 and Region 1 boundary cannot be misaligned since Region 3 has equivalent assemblies in every cell.

c. Since the boundary misalignment case is less limiting than the multiple misload analysis, Figures 6.2-1 through 6.2-4 are no longer relevant.

RAI-42

The following RAIs are provided concerning the validation study provided in Appendix A and the use of the validation study results.

a. Some of the limiting calculated k_{eff} values were at 100C. Elevated temperature calculations have not been validated. Provide validation or adopt appropriate uncertainty to cover unvalidated elevated temperature calculations. An acceptable approach would be for the applicant to revise the validation study to include and use results from International Handbook of Evaluated Criticality Safety Benchmark Experiments evaluation LEU-COMP-THERM-046 (temperature variation from 14C to 85C) to estimate potential biases associated with nuclear data temperature adjustments.

b. MOX experiments are required to validate burned fuel k_{eff} calculations. The MOX experiments documented in Appendix A are restricted to the HTC experiments. The validation should be supplemented with additional non-HTC MOX experiments to ensure that an evaluation- or facility-specific bias is not built into the bias and 95/95 uncertainty generated by the validation study.

DNC Response

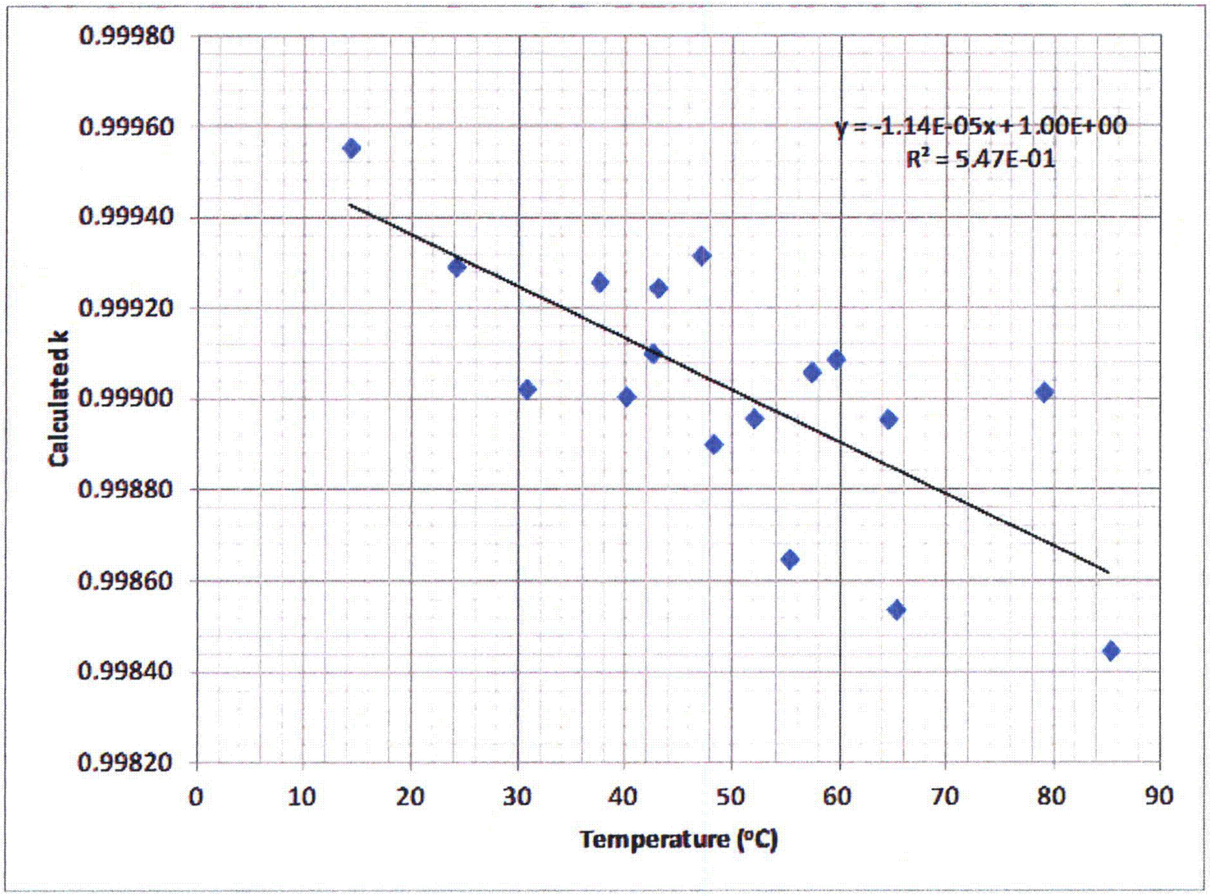
Seventeen cases of LEU-COMP-THERM-046 were analyzed and added to the validation. (The five cases with copper rods were excluded since copper is not in the spent fuel pool.) Table 42.1 shows the results of the analysis of the 17 cases. Note that the table shows the corrected k. The correction is needed since the experiments were not critical. The correction (divide by measured k) corrects the calculations to critical conditions. The critical experiments show a trend with temperature as shown on Figure 42.1. The maximum (95% confidence) change in k per degree Kelvin is -1.7E-05. For the spent fuel pool conditions above room temperature, a validation temperature bias of 1.7E-05 times the temperature difference (in °C) above room temperature is added to the calculated k_{eff}.

Table 42.1: LCT-046 with SCALE 6.0 and ENDF/B-VII

Case	Temperature (K)	Corrected SCALE k	SCALE sigma
1	297.05	0.998901	0.00007
2	310.41	0.998867	0.00007
3	315.43	0.998710	0.00007
4	319.96	0.998915	0.00007
5	324.93	0.998558	0.00007
6	332.53	0.998697	0.00007
7	287.22	0.999163	0.00007
8	315.91	0.998854	0.00006
9	330.27	0.998669	0.00007
10	337.44	0.998566	0.00007
11	351.99	0.998625	0.00007
12	303.60	0.998632	0.00007

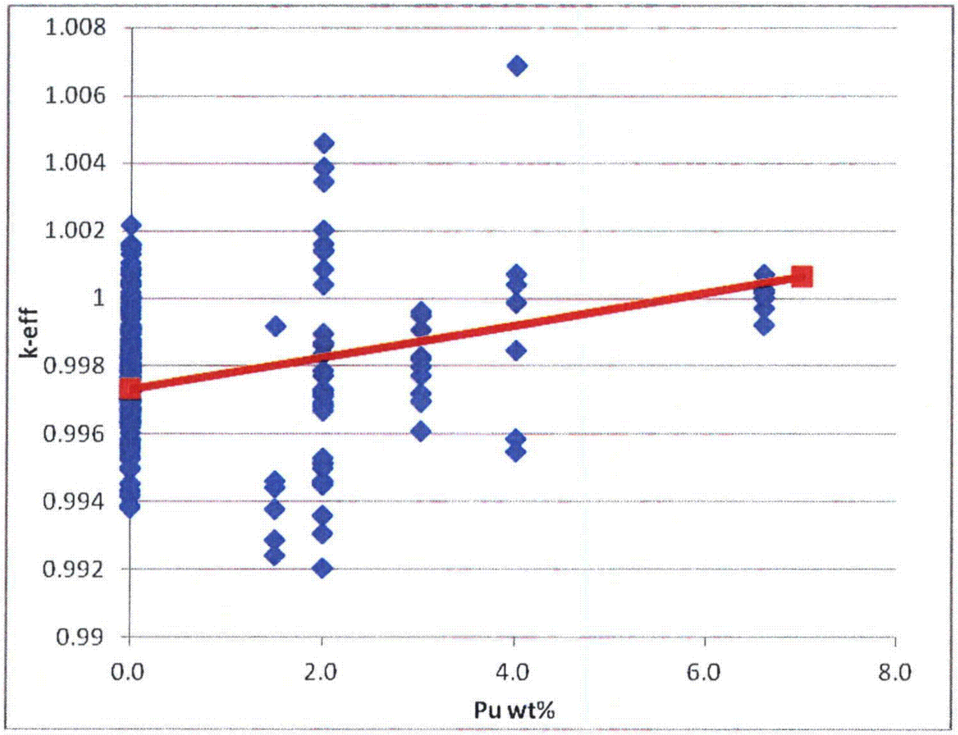
13	312.95	0.998616	0.00007
14	321.16	0.998511	0.00007
15	328.24	0.998258	0.00007
16	338.26	0.998147	0.00007
17	358.31	0.998057	0.00007

Figure 42.1: Calculated Benchmark k as a Function of Temperature



b. The low enriched mixed oxide fuel (MOX) pin critical experiments (63 critical experiments) in the International Handbook of Evaluated Criticality Safety Benchmark Experiments have been analyzed. ENDF/B-VII predicts a higher k for plutonium bearing experiments than for fresh UO_2 critical experiments. The uncertainty weighted mean k of the fresh UO_2 critical experiments is 0.9973. The uncertainty weighted mean of the MOX critical experiments is 0.9988. Since the bias is larger for UO_2 fuel than for MOX fuel, it would be non-conservative to add the MOX experiments to the validation set. This analysis is required since some of the plutonium content of the burned fuel is higher than the HTC critical experiments and without this analysis there is no certainty that the validation is conservative. Figure 42.2 confirms that as the plutonium content increases the calculated k of the critical system increases.

Figure 42.2: Predicted k_{eff} as a Function of the Plutonium Content



Although the MOX critical experiments analysis has been performed, the bias and uncertainty from the original LAR is maintained since it is more conservative than using the MOX data.

ATTACHMENT 3

DISCUSSION OF PROPOSED TECHNICAL SPECIFICATION CHANGES

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

1.0 Summary Description

By letter dated December 17, 2012 and supplemented by letters dated February 25, 2013, and May 28, 2013, Dominion Nuclear Connecticut, Inc. (DNC) submitted a license amendment request (LAR) for Millstone Power Station Unit 2 (MPS2). In response to the attached request for additional information from the Nuclear Regulatory Commission, DNC performed additional analyses. Based on the original December 2012 LAR and the additional analyses, DNC proposes to amend Operating License DPR-65 by incorporating the enclosed proposed changes into the Technical Specifications (TS) of MPS2. Note that for convenience the proposed changes to the TS and TS Bases supersede the changes proposed in the original December 2012 submittal. DNC is proposing to change or add the following Technical Specifications:

- TS 1.39 Storage Pattern
- TS 1.40 (New) Non-standard Fuel Configurations
- TS 3/4.9.17 Spent Fuel Pool Boron Concentration
- TS 3/4.9.18 Spent Fuel Pool – Storage
    - Figure 3.9-1A Minimum Required Average Fuel Assembly Burnup as a Function of Initial Enrichment to Permit Storage in Region 2A
    - Figure 3.9-1B Minimum Required Average Fuel Assembly Burnup as a Function of Initial Enrichment to Permit Storage in Region 2B
    - Figure 3.9-1C Minimum Required Average Fuel Assembly Burnup as a Function of Initial Enrichment to Permit Storage in Region 3 (with insertion of 3 Borated Stainless Steel Poison Rodlets)
    - Figure 3.9-1D Minimum Required Average Fuel Assembly Burnup as a Function of Initial Enrichment to Permit Storage in Region 3 (with insertion of a full length, full strength Control Element Assembly)
    - Figure 3.9-1E Minimum Required Average Fuel Assembly Burnup as a Function of Initial Enrichment to Permit Storage in Region 4
    - Figure 3.9-2 Spent Fuel Pool Arrangement
    - Figure 3.9-3 Minimum Required Fuel Assembly Exposure as a Function of Initial Enrichment to Permit Storage in Region C as Consolidated Fuel (to be DELETED)
    - Figure 3.9-4 Minimum Required Fuel Assembly Exposure as a Function of Initial Enrichment to Permit Storage in Region A (to be DELETED)
- TS 3/4.9.19 Spent Fuel Pool – Storage Pattern
- TS 5.3.1 Fuel Assemblies

- TS 5.6.1 Criticality
- TS 5.6.3 Capacity

The Bases for TS 3/4.9.17 through TS 3/4.8.19 are also being modified to address the proposed changes and are provided for information only. Changes to the TS Bases are controlled in accordance with the TS bases control program (TS 6.23).

The proposed changes to the above TS address the following objectives:

- Remove reactivity credit for Boraflex.
- Address recent spent fuel pool (SFP) concerns such as a multiple fuel assembly misload.
- Identify reactivity margin available to accommodate future issues.
- Remove requirements for cell blocking devices.
- Define "Non-standard Fuel Configurations" and permit storage in non-restricted SFP storage locations as supported by configuration-specific analyses.

In order to meet the spent fuel pool criticality requirements, the following changes are being proposed:

- Increase the number of regions in the SFP to four.
- Designate selected SFP storage locations as Restricted Locations in Regions 1, 2, and 4 (Revised TS Figure 3.9-2) which shall remain empty. Restricted Locations will be controlled administratively. Cell blocking devices will no longer be required.
- Replace existing burnup credit (enrichment/burnup) curves with five new burnup credit curves to meet the storage requirements in Regions 2, 3, and 4.
    - Region 1 does not have a burnup curve.
    - Region 2 has two curves, one for Region 2A and one for Region 2B.
    - Region 3 has two curves, one for fuel with 3 borated stainless steel rodlets (also referred to as rodlets or poison pins) and one for fuel with a Full Length, Full Strength Control Element Assembly (CEA).
    - Region 4 has one curve.
- Exempt some Non-standard Fuel Configurations stored in Region 3 from the requirement for a CEA or rodlets as demonstrated in configuration-specific analyses.
- Increase the minimum SFP boron concentration to 2100 ppm.
- Provide storage requirements for Regions 1 and 2 storage locations in which the Boraflex panel box has been removed.

The changes have been reviewed and confirmed to accommodate fuel currently in the spent fuel pool and potential future fuel designs.

2.0 Detailed Description of Proposed Technical Specifications Changes

Details of the analyses supporting the proposed changes are contained in the RAI responses herein.

2.1 TS 1.39 - Definitions

One definition is being updated to provide addition clarification.

Definition 1.39 – STORAGE PATTERN

Definition 1.39 is updated to clarify that a STORAGE PATTERN is a 2 x 2 storage array (encompassing four fuel storage rack locations), in which there is at least one location in which a fuel assembly is not to be stored. This definition is changed to improve clarity and to refer to Regions 1, 2, and 4 to which this definition applies.

2.2 TS 1.40 – Definitions (New)

A new definition is proposed:

Definition 1.40 - NON-STANDARD FUEL CONFIGURATIONS

This new definition defines Non-standard Fuel Configurations, which encompasses Consolidated Fuel Storage Boxes (CFSBs); TS 3.9.18, TS Figure 3.9-4, as well as other fuel configurations not specifically identified in TS.

2.3 TS 3/4.9.17 – Spent Fuel Pool Boron Concentration

TS 3/4.9.17 will be revised to increase the minimum SFP boron concentration to 2100 ppm. Also, “Consolidated Fuel Storage Boxes” is replaced with “Non-standard Fuel Configurations” since CFSBs are included as a Non-standard Fuel Configuration.

2.4 TS 3/4.9.18 – Spent Fuel Pool - Storage

TS 3.9.18 currently has 3 subparts (a), (b), and (c) which specify initial enrichment and burnup requirements for storage of spent fuel in Regions A and C and CFSBs in Region C. The proposed changes define new fuel pool storage Regions 1, 2, 3, and 4, replace the existing burnup credit curves, revise TS Figure 3.9-2 to account for the new regions, delete TS Figure 3.9-3 since a burnup credit curve for CFSBs is no longer required, and delete Figure 3.9-4 since Region 1 will not use a burnup curve.

The proposed changes follow:

LCO 3.9.18

Limiting Condition of Operation (LCO) 3.9.18(a), (b), and (c) are removed and replaced with new LCO 3.9.18(a), (b), (c), (d), and (e). The new items describe the burnup credit and poison insert requirements (a full length, full strength CEA or three rodlets in Region 3 fuel) to store fuel assemblies in each Region based on the updated spent fuel pool criticality analysis, and the storage requirements for Non-standard Fuel Configurations.

Region 1 does not have burnup requirements. Therefore, fuel assemblies meeting the TS enrichment requirement can be stored in Region 1. Regions 2, 3, and 4 have burnup credit requirements that must be met to allow storage in these regions.

Current Region C credits optional installation of three rodlets. The proposed Region 3, which is composed of all but two of the current Region C fuel storage racks, requires that each fuel assembly contain either three rodlets or a CEA. A footnote is added to this TS stating that the full-length, reduced-strength control element assemblies and the part-length control element assemblies stored in the MPS2 spent fuel racks cannot be used for reactivity control in Region 3.

The burnup credit requirements, poison insert requirements, and Restricted Locations (described in TS 3.9.18) ensure the following:

- under normal operating conditions k_{eff} will remain $\leq$ 0.95 with 600 ppm of soluble boron in the spent fuel pool, and will remain < 1.0 with 0 ppm of soluble boron in the spent fuel pool.
- under all postulated accident scenarios k_{eff} will remain $\leq$ 0.95 with 2100 ppm of soluble boron in the spent fuel pool.

"Consolidated Fuel Storage Boxes" is replaced with "Non-standard Fuel Configurations." Consolidated Fuel Storage Boxes is an example of a Non-standard Fuel Configuration. Attachment 4 summarizes the analysis demonstrating that Non-standard Fuel Configurations currently in the SFP can be stored in any non-restricted location and, with the exception of fuel assembly P-26, can also be stored in Region 3 without rodlets or a CEA.

The following is a discussion of new and updated figures. The values shown in these figures are supported by information provided in Attachment 5 of this RAI response.

TS Figure 3.9-1A

TS Figure 3.9-1A is revised. This figure shows the minimum required fuel assembly burnup as a function of initial planar average enrichment to permit storage of fuel assemblies in Region 2 within storage locations designated as Type 2A.

TS Figure 3.9-1B

TS Figure 3.9-1B is revised. This figure shows the minimum required fuel assembly burnup as a function of initial planar average enrichment to permit storage of fuel assemblies in Region 2 within storage locations designated as Type 2B. Region 2 Type 2A storage locations can store higher reactivity fuel assemblies than Region 2 Type 2B.

TS Figure 3.9-1C

TS Figure 3.9-1C is a new figure. This figure shows the minimum required fuel assembly burnup as a function of initial planar average enrichment to permit storage of fuel assemblies containing rodlets in Region 3.

TS Figure 3.9-1D

TS Figure 3.9-1D is a new figure. This figure shows the minimum required fuel assembly burnup as a function of initial planar average enrichment to permit storage of fuel assemblies containing a CEA in Region 3.

TS Figure 3.9-1E

TS Figure 3.9-1E is a new figure. This figure shows the minimum required fuel assembly burnup as a function of initial planar average enrichment to permit storage of fuel assemblies in Region 4.

TS Figure 3.9-2

TS Figure 3.9-2 is revised. This figure illustrates the new region definitions and storage patterns of the fuel storage racks. It also discusses the requirement that Restricted Locations are to remain empty.

TS Figure 3.9-3

Figure 3.9-3 is deleted because consolidated fuel is now considered a type of Non-standard Fuel Configuration. Non-standard Fuel Configurations are analyzed on an individual basis. Each Non-standard Fuel Configuration must have a criticality analysis which may allow storage in one or multiple regions, and which may or may not require rodlets or a CEA if stored in Region 3.

TS Figure 3.9-4

Figure 3.9-4 is deleted because Region 1 does not use an enrichment/burnup curve.

Surveillance Requirement 4.9.18

The surveillance requirement is updated to remove reference to consolidated fuel storage boxes, and to add the requirement to verify by administrative means that a Non-standard Fuel Configuration is qualified for a proposed storage region prior to storing it there.

2.8 TS 3/4.9.19 – Spent Fuel Pool – Storage Pattern

The TS 3/4.9.19 title is changed from "Storage Pattern" to "Storage Restrictions."

LCO 3.9.19

TS 3.9.19 currently has two subparts (1) and (2) which specify requirements for fuel assemblies stored in Region B when cell blocking devices are installed as shown in the current TS Figure 3.9-2, or when the blocking devices have been removed. The proposed change removes requirements for cell blocking devices, but adds two subparts. Subpart (1) states that Restricted Locations shall remain empty, and subpart (2) provides the storage restrictions on storage locations in which the Boraflex panel box has been removed (only non-fuel components can be stored in these locations). Regions 1, 2, and 4 contain Restricted Locations in the configuration shown in the proposed TS Figure 3.9-2.

The footnotes on this page (Page 3/4 9-26) are removed because the proposed changes will require that all fuel assemblies conform to the same burnup credit and poison insert requirements for SFP storage. Thus, Batch B must meet the storage requirements of the other fuel assemblies in the pool, and the current footnotes no longer apply.

Non-standard Fuel Configurations and non-fuel components are added to the "Applicability" portion of the LCO.

A new footnote is added describing the Boraflex panel boxes and states that the criticality analysis allows them to remain in or be removed from the Restricted Locations.

Surveillance Requirements 4.9.19

The existing surveillance requirement, which verifies that LCO 3.9.19 is satisfied prior to removing cell blocking devices, is changed since the new surveillance requires verification that LCO 3.9.19 is satisfied through the use of administrative means to assure that a fuel assembly, a Non-standard Fuel Configuration, or a non-fuel component will not be placed into a Restricted Location. Also, the LCO is satisfied through administrative means to assure that a fuel assembly or a Non-standard Fuel Configuration will not be placed into a Region 1 or 2 location in which the Boraflex panel box has been removed. It is permissible to store non-fuel components in a location without a Boraflex panel box if the location is not a Restricted Location.

Maintaining Restricted Locations empty, not allowing storage of fuel assemblies or Non-standard Fuel Configurations in non-restricted locations in which the Boraflex panel box has been removed, and using burnup curves will ensure that under normal operating conditions, k_{eff} will remain $\leq$ 0.95 with 600 ppm of soluble boron in the spent fuel pool, and will remain < 1.0 with 0 ppm of soluble boron in the spent fuel pool.

2.9 TS 5.3.1 – Fuel Assemblies

Design Feature 5.3.1

Design Feature 5.3.1 replaces the phrase "nominal average enrichment" with the phrase "initial planar average enrichment" which provides a more precise description of enrichment as it is treated in the criticality analysis.

2.10 TS 5.6.1 – Criticality

Design Feature 5.6.1

The following changes were made to Design Feature 5.6.1. These changes are supported by the information provided in Attachment 4 of the December 2012 LAR criticality safety analysis report, supplemented with the RAI responses, and described in Attachment 8 of this letter (the proposed criticality analysis).

- Paragraphs a) and b) - replaces the phrase "nominal average enrichment" with the phrase "initial planar average enrichment."
- Paragraphs c) and d) – deletes Westinghouse Report A-MP-FE-0011, Revision 1 which was not used in the proposed criticality analysis, which documents that the reactivity and soluble boron design requirements are met. These paragraphs also add that allowances were made for biases and uncertainties.
- Paragraph e) – replaces discussion of previous Region A enrichment burnup requirements with requirements for Region 1. Region 1 requirements include crediting Restricted Locations, specifying the initial planar average enrichment requirement of 4.85 weight percent U235.
- Paragraph f) - replaces discussion of previous Region B enrichment burnup requirements with requirements for Region 2. Region 2 requirements include crediting Restricted Locations, Type 2A and Type 2B storage locations, and a burnup credit curve for each Type.
- Paragraph g) - replaces discussion of previous Region C enrichment burnup requirements with requirements for Region 3. Region 3 requirements include a requirement that each fuel assembly contain either rodlets or a full length, full strength CEA. There are also two burnup credit curves for this region, one for fuel assemblies containing rodlets, and one for fuel assemblies containing a CEA.
- Paragraph h) – replaces discussion of Consolidated Fuel Storage Boxes with requirements for Region 4. Information provided is similar to the other paragraphs, including nominal center to center distance, Restricted Locations, and its burnup credit curve.
- Paragraph i) – new paragraph which provides the requirements for storage of Non-standard Fuel Configurations.
- Paragraph j) – new paragraph which describes that the Regions 1 and 2 rack locations have boxes that contain Boraflex panels. If a box is removed from a non-restricted location, that storage location shall not be allowed to store fuel assemblies or Non-standard Fuel Configurations. It is permissible to store non-fuel components in non-restricted locations, with or without the Boraflex panel box installed.

Paragraph d) boron concentration could be changed, but the current 600 ppm boron concentration is retained because it bounds the value used in the criticality analysis (550 ppm) and is the value used in the operator response time boron dilution analysis.

2.11 TS 5.6.3 – Capacity

Design Feature 5.6.3

Design Feature 5.6.3 updates the number of spent fuel pool storage locations (which includes Restricted Locations) for the proposed Regions 1, 2, 3, and 4.

3.0 Discussion

3.1 Introduction

DNC proposes to amend Operating License DPR-65 by incorporating the attached proposed changes into the TS of MPS2. DNC is proposing to change the following Technical Specifications described in Section 1.0 above.

The proposed amendment implements the following conditions associated with fuel storage at MPS2:

- Eliminate reactivity credit for Boraflex in current regions A and B of the spent fuel pool.

- Revise alphanumeric designation of spent fuel regions from A, B, C to 1, 2, 3, 4 to clearly distinguish from existing designations:
  - Regions 2, 3, and 4 will have new burnup credit curves. Regions 2 and 3 will each have two burnup credit curves.
  - Region 1 will not have a burnup credit curve. Any MPS2 fuel assembly can be stored in Region 1.

- Revise allowed storage patterns for fuel assemblies in the spent fuel pool to meet k_{eff} requirements under normal and accident conditions:
  - Restricted Locations will be required to remain empty. Restricted Locations may not contain fuel assemblies, Non-standard Fuel Configurations, or non-fuel components (proposed TS Figure 3.9-2).
  - Region 1 will allow fuel assemblies, Non-standard Fuel Configurations, and non-fuel components to be stored only in a 2 out of 4 storage pattern.
  - Regions 2 and 4 will allow storage in a 3 out of 4 storage pattern.
  - Region 3 is the only region that will allow storage in any location.

- Require use of a full length, full strength CEA or three rodlets in fuel assemblies stored in Region 3.

- Eliminate requirement to use spent fuel rack cell blocking devices.
  - Regions 1, 2, and 4 will have Restricted Locations that will be required to remain empty (proposed TS Figure 3.9-2).
  - Cell blocking devices are not credited in the fuel misload analysis.

- Allow storage of Non-standard Fuel Configurations in specifically analyzed non-restricted locations:
  - Each of the Non-standard Fuel Configurations must have a separate criticality analysis which may allow storage in one or multiple regions, and which may or may not require rodlets or a CEA if stored in Region 3.

- Prohibit storage of fuel assemblies and Non-standard Fuel Configurations in non-restricted locations in Regions 1 and 2 which do not contain a Boraflex box. Regions 1 and 2 racks are equipped with boxes that contain Boraflex panels. Boraflex will no longer be credited for neutron absorption, but the box structure is modeled as part of the non-restricted location design. Boraflex boxes can be physically removed from non-restricted and Restricted Locations. The criticality analysis permits removal of Boraflex boxes from Restricted Locations. If a Boraflex box is removed from a non-restricted storage location, the location will not be permitted to store fuel assemblies or Non-standard Fuel Configurations. It will be permissible to store non-fuel components in non-restricted locations with or without a Boraflex box.

- Increase the minimum SFP soluble boron concentration to 2100 ppm.

3.2 Current MPS2 Spent Fuel Pool Configuration

The MPS2 spent fuel pool currently consists of three regions of spent fuel storage racks, designated Regions A, B and C. Existing TS Figure 3.9-2 provides a schematic of the pool layout. Regions A and B racks contain Boraflex as the active neutron absorber in a flux trap design. Region C racks have an egg crate design with no fixed neutron absorber. Fuel may be stored in three types of configurations in Region C per current TS. Fuel assemblies stored in Region C may be stored with or without rodlets, and consolidated fuel storage boxes are also allowed to be stored in Region C. The consolidated fuel storage box has essentially the same dimensional envelope as a fuel assembly. Forty Region B fuel storage locations contain certain low reactivity fuel assemblies underneath cell blocking devices for added reactivity control.

Soluble boron is currently credited in the spent fuel pool for reactivity control for both normal and accident conditions.

The maximum initial planar average enrichment used is the currently licensed value of 4.85 weight percent U-235.

4.0 Technical Evaluation Summary

4.1 Introduction

The analyses and results summarized in this section are provided in the proposed criticality analysis. Boraflex will no longer be credited. Fuel storage loading requirements will continue to be maintained by administrative means. Use of the cell blocking devices will no longer be required. Cell blocking devices are not credited in the proposed criticality analysis as a means to preclude a fuel misload accident.

The MPS2 spent fuel pool has been analyzed to accommodate the following postulated scenarios (the fuel is assumed to contain no gadolinia or other burnable poison):

- Multiple misloads of 4.85 weight percent U-235 fresh fuel assemblies into Region 1 and 2 storage locations.
- Multiple misloads of higher than typical reactivity depleted fuel assemblies (initial enrichment of 4.20 weight percent U-235 and 10 GWD/MTU burnup) into Region 3 and 4 storage locations.
- Misload or dropping of a single 4.85 weight percent U-235 fresh fuel assembly into a Region 4 storage location.
- Dropping or misloading a 4.85 weight percent U-235 fresh fuel assembly between Region 3 and the new fuel elevator, with a 4.85 weight percent U-235 fresh fuel assembly in the new fuel elevator.
- Three 4.85 weight percent U-235 fresh fuel assemblies are allowed to touch edge to edge. This bounds a scenario in which two fresh fuel assemblies are in the fuel transfer cart and another fresh fuel assembly, by some undefined means, is allowed to come edge to edge with the fuel assembly in the transfer cart.
- Loss of pool cooling resulting in SFP temperature increase and voiding.
- Dropping of a fuel assembly or Non-standard Fuel Configuration which comes to rest on top of the racks in a horizontal position.
- Lateral rack movement due to a seismic event affecting the spacing between racks of any of the regions.

For reactivity control under normal storage conditions spent fuel pool soluble boron concentration of 550 ppm is credited in the proposed criticality analysis. Previous analysis (Amendment 274) has shown that there is adequate time for operators to respond to a SFP dilution event to prevent boron concentration from declining from 1720 ppm to below 600 ppm. Operator action time is greater for a dilution from 2100 ppm to 600 ppm than for a dilution from 1720 ppm to 600 ppm. Since 600 ppm boron is more than enough for criticality control, and since more operator time is available to respond to a dilution event,

assurance is provided that a spent fuel pool soluble boron dilution event will not result in loss of criticality control.

The proposed design changes do not result in any hardware changes to the plant. The cell blocking devices are of a removable design and not an integral part of the storage racks. There are no changes in how rodlets are used in Region 3 of the spent fuel pool, or how CEAs are placed and stored in fuel assemblies. There are no changes in how fuel, Non-standard Fuel Configurations, and non-fuel components are moved, or the process used to qualify and verify fuel storage in the pool other than the updated enrichment/burnup curves and not placing fuel assemblies or any other equipment in Restricted Locations in the fuel pool.

From an operational perspective, the proposed design changes are transparent except that the SFP's minimum soluble boron concentration requirements will increase from 1720 ppm to 2100 ppm. The changes in burnup credit curves lead to the proposed TS Figures 3.9-1A through 3.9-1E and the deletion of Figures 3.9.3 and 3.9-4. However, there are no changes in how fuel and other components are moved. Administrative means will continue to be used to ensure fuel and non-fuel components are not misloaded. Existing training will be augmented to emphasize that fresh fuel may only be placed in Region 1 and to stop fuel movement if a move sheet directs fresh fuel to another region.

The dropping of a fuel transfer cask was not analyzed because MPS2 has installed a single failure mode crane which is used for cask handling operations. However, TS 3/4.9.17 surveillance requirement to confirm proper boron concentration before commencing cask operations in the SFP will conservatively remain in this surveillance.

4.2 New Fuel Storage Rack Analysis

DNC performed the criticality analysis for the new fuel storage racks so that the analysis methods used are consistent with the methods used in the criticality analysis for the SFP (no TS changes are required for the new fuel storage racks). This new fuel storage rack criticality analysis assumes that the maximum reactivity fuel assembly is a fresh (no burnup) fuel assembly, with a maximum initial planar average enrichment of 5.0 weight percent U-235 (which is conservative vs. the licensed maximum of 4.85 weight percent). No credit is taken for any gadolinia burnable absorber loading, which typically exists in fresh fuel. The MPS2 fuel design is described in more detail in Section 4.3.

Two scenarios, flooding and optimized moderation, were analyzed. A tolerance and uncertainty analysis is provided for both scenarios. In both scenarios the analysis confirms that k_{eff} remains less than or equal to 0.95.

The criticality analysis bounds the possible water loss in the concrete reflector and the uncertainties due to fuel assembly placement/orientation. The analysis demonstrates that, for anticipated normal and abnormal configurations of fuel assemblies in the new fuel storage rack, k_{eff} is below the criticality design criteria of 0.95 at a 95 percent probability, 95 percent confidence level when the fuel racks are flooded with full density unborated water. The analysis also demonstrates the k_{eff} is less than 0.95 at a 95 percent probability, 95 percent confidence level assuming optimum moderation conditions.

Note that no TS changes associated with fuel storage in the new fuel storage racks are proposed.

4.3 Spent Fuel Pool Criticality Analysis - General

The criticality analysis to support the proposed changes was performed by DNC.

This criticality analysis assumes that the maximum reactivity fuel assembly in the SFP is a fresh (zero burnup) fuel assembly, with a maximum initial planar average enrichment of 4.85 weight percent U-235. No credit is taken for any gadolinia burnable absorber loading, which typically exists in fresh fuel. The most reactive normal spent fuel pool water temperature is used for each region. A tolerance and uncertainty analysis is provided.

MPS2 design of fuel assemblies typically has different fuel rod enrichments in the radial direction as well as axial blankets. The maximum initial planar average enrichment is 4.85 weight percent U-235 (maximum of any axial zone in a fuel assembly). Individual fuel rods may have enrichments as high as 5.0 weight percent U-235. The criticality analysis models the fuel assembly with fuel rods at the average radial enrichment. Modeling the average radial fuel rod enrichment is either conservative relative to modeling the distributed radial fuel rod enrichments, or a conservative bias is used. The criticality analysis bounds the use of reduced enrichment axial blankets.

In addition, DNC performed criticality analyses on the MPS2 Non-standard Fuel Configurations currently in the SFP for storage in the non-restricted SFP locations (Attachment 4), including storage in Region 3 without insertion of rodlets or a CEA. The items analyzed for storage in the MPS2 SFP are listed in Table 4.0-1, Attachment 4 of this letter.

4.4 Spent Fuel Pool Criticality Analysis - Normal Storage Conditions

Region 1 of the spent fuel storage pool is designed for normal conditions to ensure $k_{eff} < 1.0$ with no boron in the SFP, and $k_{eff} \leq 0.95$ with the spent fuel pool filled with water borated to a minimum concentration of 550 ppm. Fresh fuel assemblies stored in this region may have a maximum initial planar average enrichment of 4.85 weight percent U-235 (no gadolinia). This region contains Restricted Locations and stores fuel assemblies in a 2 out of 4 configuration as shown in proposed TS Figure 3.9-2.

Region 2 of the spent fuel storage pool is designed for normal conditions to ensure $k_{eff} < 1.0$ with no boron in the SFP, and $k_{eff} \leq 0.95$ with the spent fuel pool filled with water borated to a minimum concentration of 550 ppm. Region 2 contains two types of storage locations, Type 2A (higher reactivity) and Type 2B (lower reactivity), as shown in TS Figure 3.9-2. Fuel assemblies stored in this region must comply with Figure 3.9-1A (Type 2A) or Figure 3.9-1B (Type 2B) to be in the acceptable burnup domain. This region contains Restricted Locations and stores fuel assemblies in a 3 out of 4 configuration as shown in proposed TS Figure 3.9-2.

Region 3 of the spent fuel storage pool is designed to ensure a $k_{eff} \leq 0.95$ with the storage pool filled with water borated to a minimum concentration of 550 ppm for normal conditions. Fuel assemblies stored in Region 3 must contain either three rodlets or a full-length full strength CEA. Full-length reduced-strength and the part length CEAs existing in the fuel pool racks cannot be used to satisfy the CEA requirement for Region 3 (see proposed change to TS 3.9.18, including the TS Basis). Fuel assemblies stored in this region must comply with Figure 3.9-1C (containing three rodlets) or Figure 3.9-1D (containing a CEA) to be in the acceptable burnup domain. Non-standard Fuel Configurations are analyzed on a case-by-case basis and may not require rodlets or a CEA when stored in Region 3. The RAI responses show that Non-standard Fuel Configurations currently in the MPS2 SFP can be stored in any location where fuel assemblies can be stored and, with the exception of fuel assembly P-26, do not require rodlets or a CEA if stored in Region 3. This region does not contain Restricted Locations.

Region 4 of the spent fuel storage pool is designed to ensure a $k_{eff} < 1.0$ with no soluble boron, and $k_{eff} \leq 0.95$ with the storage pool filled with water borated to a minimum concentration of 550 ppm for normal conditions. Fuel assemblies stored in this region must comply with Figure 3.9-1E to be in the acceptable burnup domain. This region contains Restricted Locations and stores fuel assemblies in a 3 out of 4 configuration as shown in proposed TS Figure 3.9-2.

Non-standard Fuel Configurations currently in the SFP (see Attachment 4) and non-fuel components may be stored in all non-restricted locations in the SFP. Each Non-standard Fuel Configuration must have a criticality analysis which may allow storage in one or multiple regions, and which may or may not require rodlets or a CEA if stored in Region 3

The above analyses show that, for the regions of the SFP, 550 ppm of soluble boron is sufficient under normal conditions to assure that the spent fuel pool k_{eff} $\leq$ 0.95 (including biases and uncertainties). Also, the criticality analysis shows that with 0 ppm of soluble boron, under normal conditions the spent fuel pool k_{eff} is less than 1.00 (including biases and uncertainties).

4.5 Spent Fuel Pool Criticality Analysis - Accident Conditions

The spent fuel pool criticality analysis has analyzed the following postulated accident conditions listed in Section 4.1 using a 4.85 weight percent U-235 initial planar average enrichment and no gadolinia. For these accident conditions, credit for soluble boron is acceptable per the double contingency principle.

Based on the criticality analysis described in the response to RAI Question 37, the limiting accident is a multiple misload of fuel assemblies with a 4.20 weight percent initial enrichment and 10 GWd/MTU burnup in Regions 3 and 4. The analysis shows that a 2100 ppm boron concentration ensures that k_{eff} is $\leq$ 0.95, including the uncertainties and biases, for this postulated accident which bounds the other less limiting accidents.

The current TS require a minimum concentration of 1720 ppm soluble boron at all times that fuel is in the spent fuel pool. The proposed change would increase this concentration to 2100 ppm.

Analysis in Attachment 4 demonstrates that the reactivity of existing Non-standard Fuel Configurations is bounded by standard fuel assemblies. The probability and consequence of a misload of Non-standard Fuel Configurations is bounded by a misload of fuel assemblies.

4.6 Boron Dilution Analysis

An analysis of potential boron dilution scenarios was previously performed to demonstrate that sufficient time is available to detect and mitigate a boron dilution event prior to reaching the minimum soluble boron to maintain $k_{eff} \leq 0.95$ under normal storage conditions. That dilution analysis assumed a conservatively high final boron concentration of 600 ppm and an initial concentration of 1720 ppm.

The current TS minimum spent fuel pool soluble boron limit is 1720 ppm. The proposed change would increase this concentration to 2100 ppm. The proposed criticality analysis indicates that 550 ppm of soluble boron is sufficient under normal conditions to assure $k_{eff} \leq 0.95$ under normal storage conditions. With the initial boron increased from 1720 to 2100 ppm, there is more operator time available to respond to a dilution event than in the dilution analysis of record. Therefore, sufficient operator response time will continue to be available for the postulated boron dilution event with the proposed minimum TS requirement of 2100 ppm soluble boron.

4.7 Boraflex Material Monitoring

Regions 1 and 2 spent fuel racks contain Boraflex which will no longer be credited as a neutron absorber. Therefore, the Boraflex monitoring program will be discontinued.

4.8 Decreased Fuel Storage

The proposed change decreases the number of fuel assemblies that can be stored in the fuel pool due to implementation of Restricted Locations (there are a greater number of proposed Restricted Locations than current cell blocker locations). Since the spent fuel pool will be licensed to store fewer assemblies, the current mechanical and seismic analyses, as well as the current design basis heat load analysis, remain bounding.

4.9 Implementation

DNC will implement the revised TS within 120 days of NRC approval of the proposed changes.

4.10 Conclusions

Implementation of the proposed changes is safe and will have no effect on current plant operation. There are no hardware changes made to the plant due to these proposed changes. There are no changes in how fuel assemblies, Non-standard Fuel Configurations, or non-fuel components are handled whether in the new fuel storage rack or the SFP, or the process used to qualify and verify storage in the SFP.

The cell blocking devices are removable, and can be removed from the spent fuel racks. Cell blocking devices are not credited in the criticality analysis. Fuel

storage loading requirements will continue to be maintained by administrative means as they have throughout the unit's operations.

DNC's analysis supports the proposed modifications. MPS2 will increase the spent fuel pool minimum soluble boron concentration to 2100 ppm. Potential boron dilution events have been previously reviewed. Operator response time to detect and mitigate the postulated dilution event with a TS minimum TS boron concentration of 2100 ppm is greater than that previously analyzed.

The spent fuel racks were originally designed to store fuel in all rack locations, and the current design basis seismic/structural and heat load analyses already bound the proposed reduction in fuel storage capacity.

The proposed criticality analysis no longer credits Boraflex for neutron absorption. Thus, it will no longer be necessary to continue the Boraflex monitoring program.

Non-standard Fuel Configurations currently stored in the MPS2 SFP have been analyzed and qualified for storage in all locations in the SFP that fuel assemblies can be stored and, with the exception of fuel assembly P-26, do not require rodlets or a CEA if stored in Region 3.

If a Boraflex panel box is removed from a non-restricted Region 1 or 2 storage location, the location will not be allowed to store fuel assemblies or Non-standard Fuel Configurations. Non-fuel components may be stored in non-restricted locations with or without a Boraflex panel box.

Reanalysis of the new fuel storage rack using the updated methods (including computer codes) used for the SFP concludes that k_{eff} will remain less than or equal to 0.95 for both postulated flooding and optimized moderation scenarios.

5.0 Regulatory Evaluation

5.1 Applicable Regulatory Requirements and Criteria

Appendix A to Title 10 of the *Code of Federal Regulations,* Part 50 (10 CFR 50), General Design Criterion (GDC) 62, "Prevention of Criticality in Fuel Storage and Handling," states that "criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations."

10 CFR 50.68, "Criticality Accident Requirements," states in subpart (b)(4) that "if credit is taken for soluble boron, the k_{eff} of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity must not exceed 0.95, at a 95

percent probability, 95 percent confidence level, if flooded with borated water, and the k_{eff} must remain below 1.0 (subcritical), at a 95 percent probability, 95 percent confidence level, if flooded with unborated water."

5.2 No Significant Hazards Consideration

DNC has evaluated whether or not a significant hazards consideration is involved with the proposed amendment by addressing the three standards set forth in 10 CFR 50.92, "Issuance of Amendment," as discussed below:

1. Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

   Response: No.

   The proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

   The proposed change will not affect the physical plant, including the spent fuel pool (SFP), spent fuel racks, or fuel handling equipment. While there will be more regions to consider in the SFP, the administrative controls for identifying fuel storage locations will not change, however, the regionalization and burnup curves will be revised. Also, the administrative controls associated with fuel assemblies, Non-standard Fuel Configurations, and non-fuel components will not change. Thus, the probability of a fuel assembly or component misloading or drop will not significantly increase with the proposed change.

   Multiple postulated accidents were reviewed for the proposed change which included single and multiple fuel misloading scenarios as well as a fuel assembly drop (summarized in Section 4.1). Based on the response to RAI Question 37, the limiting accident is a multiple misload of fuel assemblies with a 4.20 weight percent initial enrichment and 10 GWd/MTU burnup in Regions 3 and 4. The analysis shows that with the proposed increased 2100 ppm boron concentration, k_{eff} is $\leq$ 0.95, including the uncertainties and biases, for this postulated accident.

   A boron dilution accident was reviewed. There are no changes to plant equipment or operations required by the proposed change. The increase in TS minimum SFP soluble boron results in the consequences of a dilution event that is bounded by the existing analysis. Thus, there is no increase in the probability or consequences of a boron dilution accident.

In the case of each accident, k_{eff} continues to be less than the licensing limit of 0.95. Thus, it is concluded that the consequences of a previously evaluated accident remains the same.

The probability and consequence of a misload of Non-standard Fuel Configurations is bounded by a misload of fuel assemblies.

The proposed change will not allow fuel assemblies or Non-standard Fuel Configurations to be stored in Regions 1 and 2 storage locations which have had Boraflex panel boxes removed. Non-fuel components may be stored in non-restricted locations with or without a Boraflex panel box. DNC will use the administrative controls discussed above to assure that this storage requirement is met.

Since the proposed change reduces the number of fuel assemblies that can be stored in the fuel storage racks, the current seismic/structural and heat load analyses bound the proposed change.

Storage in the new fuel storage rack is not affected by the proposed change. However, the analysis was updated using the same methods used for the SFP and concludes that k_{eff} will remain $\leq$ 0.95 for both the postulated flooding and the postulated optimized moderation scenarios.

2. Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?

   Response: No.

   The proposed change does not create the possibility of a new or different kind of accident from any accident previously evaluated.

   There is no change to the physical plant, including the equipment and procedures used to handle fuel assemblies, Non-standard Fuel Configurations, non-fuel components, or any heavy load over fuel storage racks. The accidents previously evaluated relate to fuel misload events and fuel handling events over the storage racks. As requested by the NRC, DNC analyzed additional fuel misload events concerning multiple misload scenarios listed in Section 4.1 and summarized in the response to RAI Question 37. $K_{eff} \leq 0.95$ (including uncertainties and biases) is maintained for the multiple misload scenarios. While this is the first time that DNC has analyzed multiple misload scenarios, the proposed change does not create the possibility of a multiple misload event. Thus, there are no new accidents created

over and above the existing postulated accidents of a fuel or component misload or drop onto the SFP racks.

Use of cell blocking devices will no longer be required. The cell blocking devices are removable and can be removed from the spent fuel racks. Fuel and component storage loading requirements will continue to be maintained by administrative means. Thus, removing the requirement to use cell blocking devices will not create a new accident over and above the existing postulated accidents of a fuel or component misload or drop onto the SFP racks.

Reducing the number of fuel assemblies that can be stored in the fuel storage racks will not create any new or different type of accident.

3. Does the proposed change involve a significant reduction in a margin of safety?

   Response: No.

   The proposed change does not involve a significant reduction in a margin of safety

   The licensing requirement for the SFP is that k_{eff} remain less than or equal to 0.95 under all postulated accident conditions (misloads, dropped fuel assembly or component, loss of cooling, and boron dilution). These accidents were analyzed for the proposed change and the $k_{eff} \leq 0.95$ requirement is met in all cases. In addition, the criticality analysis concluded that, under normal conditions, the SFP k_{eff} will remain < 1.0 with 0 ppm boron in the SFP, and $\leq$ 0.95 with 550 ppm boron in the SFP.

   Since the proposed change reduces the number of fuel assemblies that can be stored in the fuel storage racks, the current seismic, structural and heat load analyses' margin of safety bound the proposed change.

   There will be no change to the storage of fuel assemblies in the new fuel storage rack. However, the analysis for the new fuel storage racks was updated using the same methods used for the SFP and concludes that k_{eff} will remain $\leq$ 0.95 for both the postulated flooding and optimized moderation scenarios.

Based on the above information, DNC concludes that the proposed changes involve no significant hazards consideration under the criteria set forth in 10 CFR 50.92(c) and, accordingly, a finding of no significant hazards consideration is justified.

6.0 Environmental Considerations

DNC has reviewed the proposed license amendment for environmental considerations. The proposed license amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion from an environmental assessment as set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

7.0 References

1. NRC Letter to Dominion Nuclear Connecticut, Inc., "Millstone Power Station, Unit No. 2 – Issuance of Amendment RE: Spent Fuel Pool Requirements (TAC NO. MB3386)," April 1, 2003

ATTACHMENT 4

ANALYSIS OF NON-STANDARD FUEL CONFIGURATIONS AND NON-FUEL COMPONENTS

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

Analysis of Non-Standard Fuel Configurations and Non-fuel Components

4.0 Non-standard Fuel Configurations

A standard arrangement of fuel is a 14x14 array of fuel pins with five guide tubes. If any of the fuel pins have been removed or replaced this is a non-standard arrangement of fuel. Single fuel pins or collections of fuel pins in a consolidated fuel storage box or in a special container are non-standard arrangements of fuel.

The RAIs associated with storage of non-standard fuel configurations are as follows:

RAI	Subject summary
1	Provide supplementary analysis or justification for consolidated fuel storage boxes
3	Define non-standard fuel configurations (NSFC).
4	Remove discussion of new NSFC or provide full analysis
5	Correct statement on storage of NSFC in restricted locations
16	Evaluate the effects of NSFC including applicability of validation study, accident conditions, conservatism, neutronic interaction with fuel assemblies

Non-standard fuel configurations (NSFC) in the Millstone Power Station Unit 2 (MPS2) spent fuel pool (SFP) will be individually identified and analyzed. Table 4.0-1 provides a brief description of each NSFC.

Table 4.0-1

Non-Standard Fuel Configurations

Item	Enrichment (wt%)	Burnup (MWd/MTU)	Number of fuel pins / lattice	Description
G-56	≤3.3	≥7.4	30 / 14x14	Failed fuel storage cage. Normal MPS2 fuel lattice spacing.
B&W FRSC	≤3.84	≥7.7	16 and 5 fragments / 7x7	NUSCO 40 failed rod storage basket. Contains 16 failed fuel rods and a tube with five fuel pellet fragments.
CFSB	1.93	≥15.0	352 / close packed	Consolidated fuel from two depleted fuel assemblies in each basket.
IRSC	3.3	>20.1	1 / 14x14	Hollow stainless steel tube stored in a fuel assembly guide thimble with one failed fuel rod inside.
8FR	3.99 , 0.7	>39.1 , 0	52, 12 / 14x14	Donor cage has normal assembly pitch and lattice, 52 depleted fuel pins, 12 natural enrichment pins, 86 non-fuel filler rods, and 26 empty locations.
Reconstituted fuel assemblies	Various	Various	14x14	Reconstituted fuel with some fuel rods replaced by stainless steel pins or natural enrichment fuel rods.* Assembly P-26 with one pin removed.
Fuel transfer cart**	≤4.85	≥ 0	14x14	Fuel transfer cart may hold two fuel assemblies at the same time.

*Analysis in Section 4.6 shows that reconstituted fuel with some fuel rods replaced by stainless steel pins or natural enrichment fuel rods is not considered non-standard fuel and may be stored in the SFP as a normal fuel assembly.

** This is not a non-standard fuel configuration but is a unique MPS2 SFP storage geometry.

4.1 Failed fuel storage grid cage G-56

G-56 failed fuel storage grid cage contains 30 fuel rods in a standard assembly cage. The fuel rods in G-56 are from "F" or "G" assemblies which accumulated a minimum of 7428 MWd/MTU assembly average burnup in any cycle of use. The maximum initial fuel pin enrichment in "F" or "G" assemblies is 3.3 weight percent (wt%). Fuel pins were loaded into G-56 in 1984.

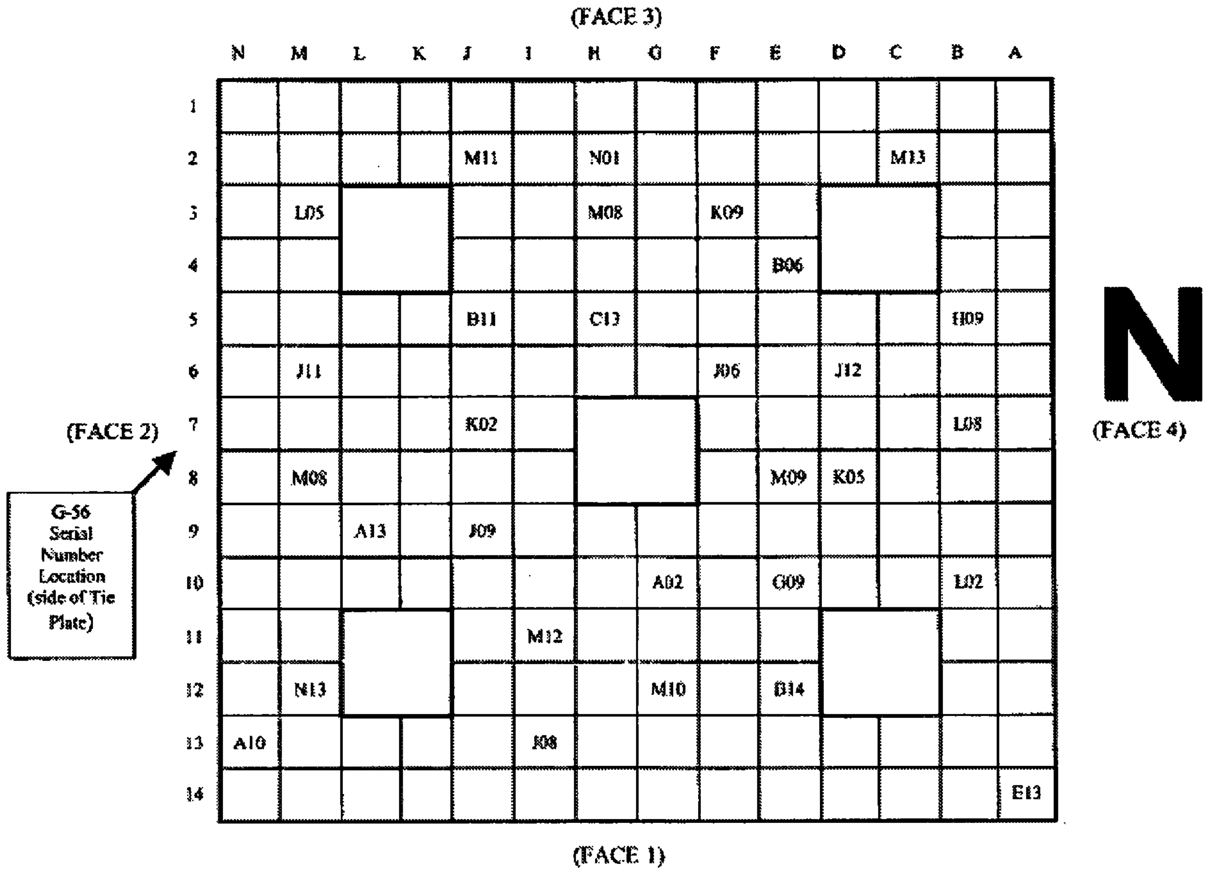
Figure 4.1-1 shows the orientation of fuel pins in G-56. For the KENO model of G-56, the fuel pins are conservatively modeled as 3.3 wt% fresh fuel. Based on burnup worth calculations performed for bias and uncertainty calculations, the fresh fuel conservatism is worth roughly 0.03 dK for G-56. A 2x2 Region 3 (rodlets) KENO rack model is used to demonstrate that the reactivity of G-56 with no rodlets is much lower than a 1.6 wt% fuel assembly with three rodlets installed. The model contains three 1.6 wt% fresh fuel assemblies and G-56. Figure 4.1-2 shows the orientation of the KENO model.

Results in Table 4.1-1 confirm that k_{eff} of the G-56 2x2 model is 0.06 dk lower than the same model with four intact 1.6 wt% fresh fuel assemblies. Several cases were run to demonstrate that irregular lattice effects (resonance treatment and Dancoff factors governed by LATTICELL input) are not significant. Because Region 3 (rodlets) is the most restrictive for fuel reactivity of any of the MPS2 SFP regions, these cases confirm that G-56, without rodlets or a control element assembly (CEA), may be stored anywhere fuel is permitted in the MPS2 SFP.

Fuel rods in G-56 are held in grids, therefore a drop accident for G-56 is similar to the dropping of a fuel assembly. Analysis confirms that G-56 is much less reactive than a fresh 4.85 wt% fuel assembly, therefore the reactivity effect of a G-56 drop or misplacement accident is bounded by the fresh fuel assembly drop or misplacement.

Figure 4.1-1

G-56
FAILED FUEL ROD STORAGE GRID CAGE



Fuel Assembly #	Fuel Rod I.D. #	Cage Storage Location	Fuel Assembly #	Fuel Rod I.D. #	Cage Storage Location
G-32	E-13	A-14	F-42	N-1	H-2
G-24	H-9	B-5	G-62	M-8	H-3
G-60	L-8	B-7	G-24	C-13	H-5
G-32	L-2	B-10	G-41	M-12	I-11
G-41	M-13	C-2	G-26	J-8	I-13
G-35	J-12	D-6 (A-6 at bottom grid)	G-41	M-11	J-2
G-32	K-5	D-8	G-04	B-11	J-5
G-24	B-6	E-4	G-32	K-2	J-7
G-05	M-9	E-8	G-56	J-9	J-9
G-24	G-9	E-10	G-66	A-13	L-9
G-68	B-14	E-12	G-32	L-5	M-3
G-24	K-9	F-3	G-35	J-11	M-6
F-38	J-6	F-6	G-56	M-8	M-8
G-57	A-2 (missing end plug)	G-10	G-41	N-13	M-12
G-60	M-10	G-12	G-10	A-10	N-13

Figure 4.1-2 – KENO3D Representation of G-56 2x2 Model

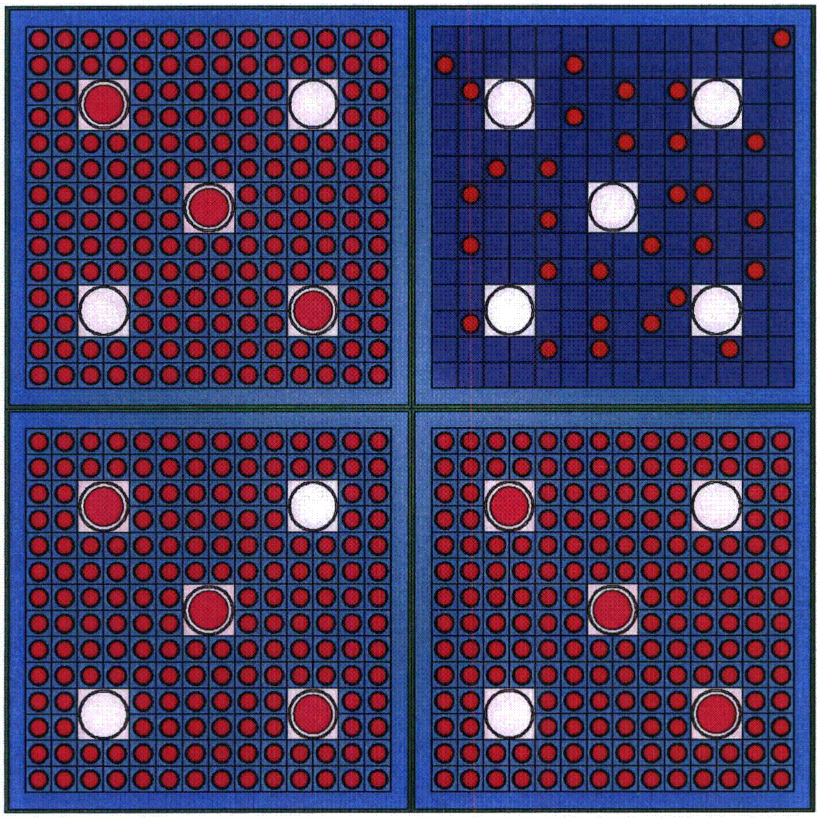


Table 4.1-1 – G-56 Region 3 (Rodlets) 2x2 KENO Model Results

Soluble boron (ppm)	k_{eff}	k_{eff} uncertainty (dK)	Intact Fuel Enrich. (wt%)	Intact Fuel Burnup (GWd/MTU)	Notes
0	0.96211	0.00008	1.6	0	Four intact fuel assemblies (FA) in 2x2 with 3 rodlets each, periodic boundaries
0	0.90112	0.00009	1.6	0	G-56 and 3 intact FA in 2x2, periodic boundaries, normal pin lattice "latticell" G-56 input
0	0.90211	0.00008	1.6	0	G-56 and 3 intact FA in 2x2, periodic boundaries, no "latticell" G-56 input
0	0.90108	0.00008	1.6	0	G-56 and 3 intact FA in 2x2, periodic boundaries, 6x6 pins/assembly "latticell" G-56 input
0	0.90164	0.00008	1.6	0	G-56 and 3 intact FA in 2x2, periodic boundaries, no "latticell" G-56 input, water in gap
0	0.90064	0.00009	1.6	0	G-56 and 3 intact FA in 2x2, periodic boundaries, 6x6 pins/assembly "latticell" G-56 input, water in gap

4.2 B&W failed rod storage container

The B&W failed rod storage container (also known as NUSCO 40 rod basket) contains 16 fuel rods and a tube containing five fuel pellet fragments. The storage container consists of an assembly of grid plates and upper section guide tubes in an array that results in a 7x7 pin lattice with the center nine locations occupied by container structure and a handling fixture. Guide plates, tubes and structural corner brackets are made of Aluminum 6061. Fuel rod pitch is 1.12 inches. The storage canister has forty short guide tubes made of 6061-T6 Aluminum and forty full length fuel rod tubes. Fuel rod tubes have a .625 inch outside diameter (OD) and a .590 inch inside diameter (ID) (0.035 inch wall thickness) and are made of stainless steel. A KENO 3D representation of the container is shown in Figure 4.2-1. The structural components have been modeled as water. The 40 failed fuel storage locations have been modeled as fresh 5.0 wt% U-235 fuel.

The BWSC model is very conservative because the fuel enrichment modeled is higher than any fuel pin in the container, and because all fuel burnup is ignored. Results in Table 4.2-1 confirm that k_{eff} of the BWSC model fully loaded with fresh 5.0 wt% fuel pins is significantly lower (~ 0.02 dk) than the same rack model with four intact 1.6 wt% fresh fuel assemblies. A case with an infinite array of BWSCs has a k_{eff} ~ 0.10 dk lower than the intact fuel case. Because Region 3 (rodlets) is the most restrictive for fuel reactivity of any of the MPS2 SFP regions, these cases confirm that the BWSC, without rodlets or a CEA, may be stored anywhere fuel is permitted in the MPS2 SFP.

Figure 4.2-1
Region 3 2x2 KENO Model with BWSC Fully Loaded

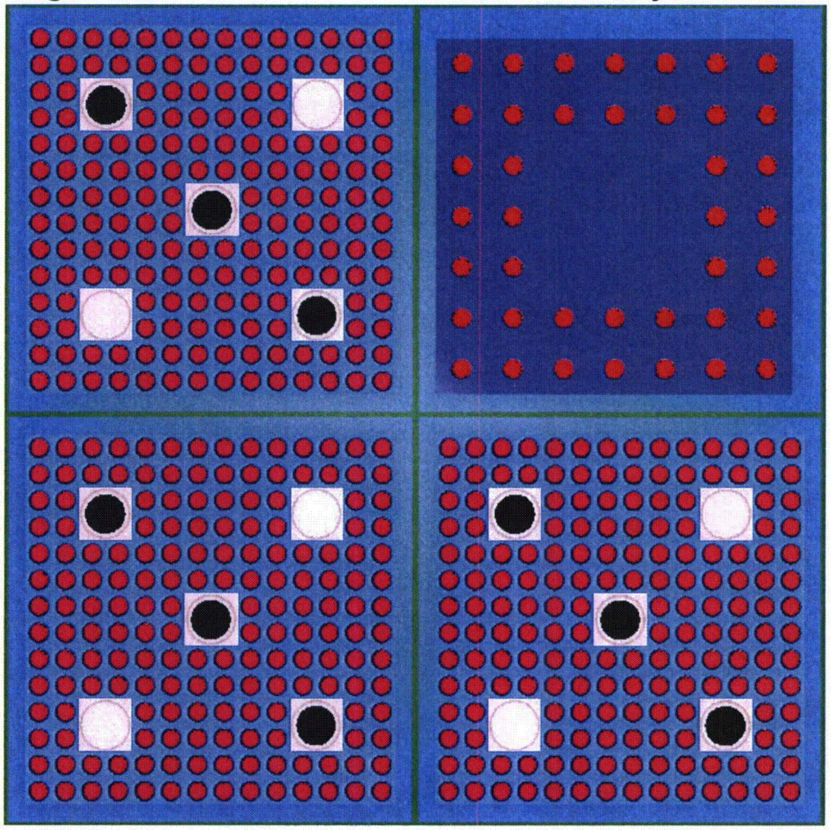


Table 4.2-1
Region 3 2x2 KENO Model Results with BWSC Fully Loaded

Soluble boron (ppm)	k_{eff}	k_{eff} uncertainty (dk)	Intact Fuel Enrich. (wt%)	Intact Fuel Burnup (GWd/MTU)	Notes
0	0.96211	0.00008	1.6	0	Four intact FA in 2x2 with 3 rodlets each, periodic boundaries
0	0.93881	0.00008	1.6	0	BWSC and 3 intact FA in 2x2, periodic boundaries
0	0.93826	0.00008	1.6	0	BWSC and 3 intact FA in 2x2, periodic boundaries, water in failed fuel pin gap
0	0.85834	0.00009	N/A	N/A	BWSC only in 2x2, periodic boundaries, all fuel pins 5.0 wt% fresh

4.3 Consolidated Fuel Storage Boxes

Three consolidated fuel storage boxes (CFSB) contain fuel rods from fuel assemblies A-001, A-002, A-029, A-030, A-063, and A-065. Each storage box has 352 fuel rods that were loaded in 1987. Batch A assemblies were originally 1.93 wt% U-235. The storage canister is a stainless steel box, 8.575 inches outer dimension and 0.120 inch thick.

CFSB BURNUPS

Assembly ID	Burnup (MWD/MTU)
A001	15028
A002	15028
A029	16458
A030	16458
A063	15409
A065	15409

Consolidation of fuel is not anticipated for the future, so analysis of the CFSBs uses the specific fuel in these boxes. Due to the reduced moderator in these boxes, low enrichment, and their burnup, the reactivity of the boxes is low.

Region 3 loading requirements are the most restrictive in the spent fuel pool. Analysis of the CFSB k_{eff} uses a 3x3 rack model with six Region 3 fuel assemblies and three CFSBs. Two arrangements of the CFSBs are modeled, lumped together (cluster) and spread out (diagonal). Since the Region 3 burnup curve determination includes 2.1 wt% U-235 fuel with 10 GWd/MTU burnup (uniform shape), use of this burnup and enrichment combination is convenient to conservatively represent the fuel in the CFSBs. The isotopic content of the CFSB fuel is conservatively represented using 28 major nuclides to shorten the run times of the cases. The enrichment modeled is higher than actual. The burnup modeled is lower than actual.

Although the consolidated fuel pins are loaded into the box as a close packed (hexagonal) array, the CFSB does not have any structure in the box to maintain this geometry. The CFSBs are modeled as a rectangular array of 19x19 pins with 9 pins removed (Figure 4.3-1). This approach preserves the fuel to moderator ratio in the CFSB. The pin pitch is set to match the inner diameter of the CFSB box with 19 pins in a row. There are no guide tubes, so there are no rodlets or CEAs credited in the CFSBs.

Figures 4.3-1 and 4.3-2 show the CFSB models (clustered and diagonal). The models use periodic boundary conditions, which effectively represent the CFSBs as occupying one third of Region 3. Depleted standard fuel (4.85 wt%, 50 GWd/MTU) was conservatively modeled using 28 major nuclides to reduce run time. Table 4.3-1 provides the calculated k_{eff} for the CFSB cases. Even when modeled using a higher enrichment and lower burnup than actual, the CFSBs reduce k_{eff} below the normal Region 3 k_{eff} for the configurations (clustered or diagonal, fresh or depleted intact fuel with rodlets or CEAs). The arrangement of the CFSBs has a small effect on k_{eff}.

The k_{eff} reduction observed between the reference calculation without CFSBs and the calculation with CFSBs is substantial for all cases. It is also clear from the Region 3 (rodlet) cases that the CFSBs exhibit much lower reactivity than a normal fuel assembly with the same enrichment and burnup. The CFSBs lower k_{eff} substantially even without rodlets. These observations support the conclusion that if the CFSBs reduce k_{eff} in Region 3 with rodlets (the most restrictive region of the SFP), the CFSBs will reduce k_{eff} when stored anywhere they replace a normal fuel assembly in the SFP.

Two cases were run to demonstrate that 550 ppm soluble boron is sufficient to ensure $k_{eff} < 0.95$ with CFSBs present. Normal fuel assemblies in the 3x3 array were modeled with the highest enrichment and burnup combination analyzed for Region 3 (4.85 wt%, 50 GWd/MTU). Although the CFSB hardens the neutron spectrum and displaces borated water which reduces boron worth, both 550 ppm cases shown in Table 4.3-1 show that k_{eff} is less than 0.89. Total bias and uncertainty in all regions of the MPS2 SFP is less than 0.046 dk, thus, the keff <0.95 criterion is met with 550 ppm soluble boron.

Since the reactivity of the CFSBs is less than the least reactive fuel required by the burnup curves for any region, the CFSBs do not introduce an interface concern. Further, as shown by comparing the clustered and diagonal results on Table 4.3-1, the positioning of these CFSBs does not introduce a reactivity effect large enough to change these conclusions.

The highest Energy of the Average Lethargy causing Fission (EALF) for the cases shown on Table 4.3-1 is 0.66 eV. EALF of the critical experiments used in the validation ranged between 0.0605 and 0.8485 eV. Code bias increases with EALF. The EALF used to select the bias and uncertainty for the SFP was 0.65 eV. K_{eff} bias as a function of EALF derived from the analysis presented in the LAR Appendix A is:

Bias= 1- 0.998983 + 0.00588*EALF

For 0.66 eV, the bias is 0.00490. The bias used for the spent fuel pool analysis in general is 0.00484. The difference in bias is not significant compared to the margin shown on Table 4.3-1.

This analysis of the CFSB allows these boxes to be placed anywhere in the SFP where normal fuel is allowed. CFSBs do not require rodlets or CEAs.

Due to weight restrictions, a loaded CFSB cannot be moved with the SFP platform crane and would require a special procedure to be moved. The general requirement for movement of objects over the SFP racks is that the height of the object above the fuel rack decreases proportionally by more than the weight increases. Therefore if the CFSBs were to be moved, the potential damage to the fuel racks would be similar to or less than that for a single fuel assembly drop. It would be possible during movement that if the CFSB is dropped, the top could come off and fuel pins could fall out. Analysis in Section 4.9 demonstrates that the reactivity increase from dropping any or all of the

CFSB fuel pins into a restricted storage location is bounded by the fresh fuel assembly misload event analysis.

Figure 4.3-1
3x3 Region 3 Rack Model with 3 CFSBs (Diagonal Orientation)

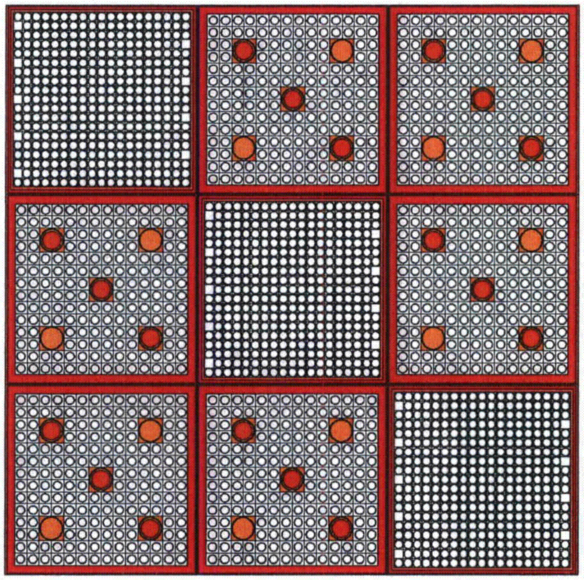


Figure 4.3-2
3x3 Region 3 Rack Model with 3 CFSBs (Cluster Orientation)

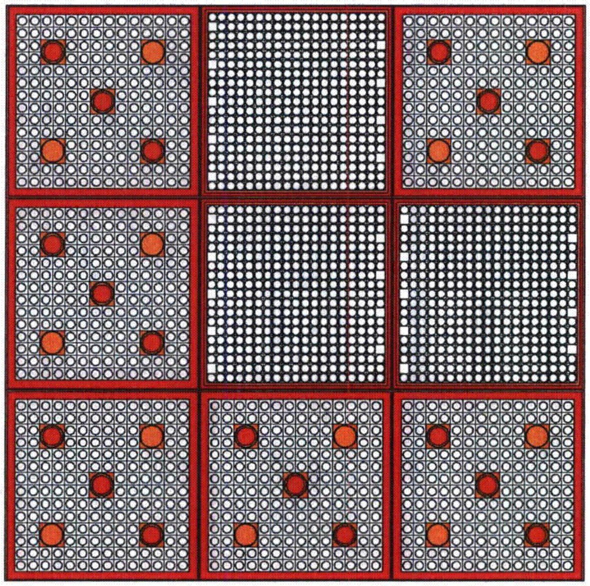


Table 4.3-1
KENO Region 3 3x3 CFSB Model Results

Region	Enrich. (wt%)	Burnup (GWd/MTU)	CFSB orientation	k_{eff}	k_{eff} Uncert.	Soluble boron (ppm)	EALF	Notes
3 (rodlets)	1.6	0	N/A	0.96211	0.00008	0	0.15	Base case
3 (rodlets)	1.6	0	Diagonal	0.94874	0.00008	0	0.29	3 CFSBs with 2.1 wt% 10 GWd/MTU
3 (rodlets)	1.6	0	Cluster	0.94703	0.00008	0	0.28	3 CFSBs with 2.1 wt% 10 GWd/MTU
3 (rodlets)	4.85	50	N/A	0.97785	0.00009	0	0.26	Base case
3 (rodlets)	4.85	50	Diagonal	0.94911	0.00008	0	0.46	3 CFSBs with 2.1 wt% 10 GWd/MTU
3 (rodlets)	4.85	50	Cluster	0.95029	0.00009	0	0.44	3 CFSBs with 2.1 wt% 10 GWd/MTU
3 (rodlets)	4.85	50	Diagonal	0.87976	0.00008	550	0.59	3 CFSBs with 2.1 wt% 10 GWd/MTU
3 (CEA)	2.2	0	N/A	0.96045	0.00009	0	0.18	Base case
3 (CEA)	2.2	0	Diagonal	0.94192	0.00009	0	0.36	3 CFSBs with 2.1 wt% 10 GWd/MTU
3 (CEA)	4.85	33	N/A	0.97599	0.00009	0	0.31	Base case
3 (CEA)	4.85	33	Diagonal	0.94717	0.00009	0	0.53	3 CFSBs with 2.1 wt% 10 GWd/MTU
3 (CEA)	4.85	33	Diagonal	0.88636	0.00008	550	0.66	3 CFSBs with 2.1 wt% 10 GWd/MTU

Note: Depleted fuel conservatively modeled with 28 nuclides. CFSBs have no rodlets or CEAs.

4.4 Individual Rod Storage Containers

The MPS2 SFP contains two individual fuel rod containers (IFRC) that were subsequently inserted in a guide tube of other fuel assemblies. The fuel rods inserted in these containers are broken. One individual fuel rod container contains fuel rod K-5 from fuel assembly F-75 and is stored in fuel assembly G-48. One individual fuel rod container contains fuel rod M-13 from fuel assembly F-42 and is stored in fuel assembly G-46.

- Fuel Rod Container Tube is 304 Stainless Steel.
- Fuel Rod Container Tube has an OD of 0.75 inches.

- Fuel Rod Container Tube has a thickness of .065 inches.

Table 4.4-1 contains enrichment and burnup information for the IFRC.

Table 4.4-1
Individual Storage Rod Container Fuel Enrichment and Burnup

Fuel ID	Initial Enrichment (wt%)	Fuel Burnup (MWd/MTU)
F-75 (RW19)	3.3	20802
F-42 (RW12)	3.3	20131
G-48	3.2	22913
G-46	3.2	22913

The impact of storing a failed fuel rod in an IFRC in a normal fuel assembly is determined using a single assembly Region 3 KENO model and a Region 2 2x2 KENO model. For convenience, the failed fuel rods are modeled as 3.5 wt% fresh fuel pins, which very conservatively bounds the actual pin enrichment and burnup. Figures 4.4-1 through 4.4-3 show IFRC models.

Results in Table 4.4-2 show that the addition of the IFRC reduces k_{eff} by approximately 0.002 dk in Region 3. Region 3 has the most restrictive fuel reactivity requirement of the MPS2 SFP regions. Because the normal fuel reactivity permitted in Region 3 is lower than in any other region, and because the failed fuel is modeled as fresh fuel, the Table 4.4-2 k_{eff} reduction is a conservative estimate of the reduction for any other region in the MPS2 SFP. Confirmation of this is provided via the Region 2 2x2 cases. K_{eff} drops approximately 0.001 dk with one IFRC in the Region 2B assembly, and 0.002 dk with two IFRCs in the Region 2B assembly.

For failed pins of less than or equal to 3.5 wt% enrichment, one or both IFRCs may be stored in any normal fuel assembly or assemblies with available guide thimbles (not fuel requiring CEAs). Because the IFRC reduces fuel reactivity, no changes to the region interface evaluation are required.

An IFRC or a fuel pin being loaded into one of the IFRCs could be dropped during handling. Analyses in Section 4.8 demonstrate that the reactivity increase from dropping a small number of 5.0 wt% fresh fuel pins into a restricted storage location is bounded by the fresh fuel assembly misload.

Figure 4.4-1
KENO Region 3 IFRC Model (1 IFRC)

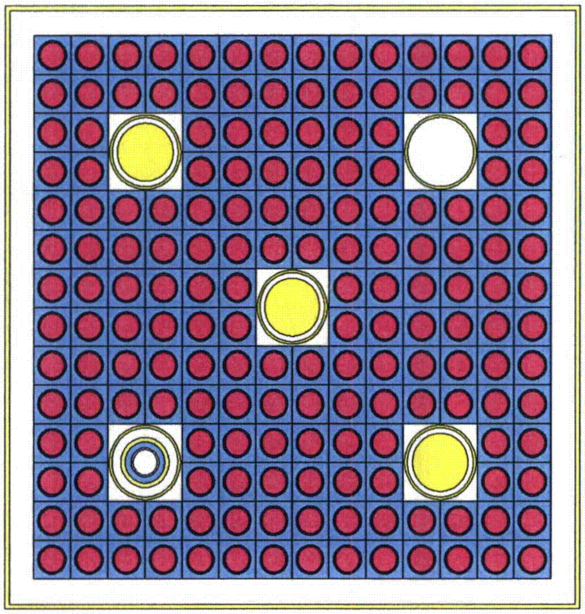


Figure 4.4-2
KENO Region 2 IFRC Model (1 IFRC)

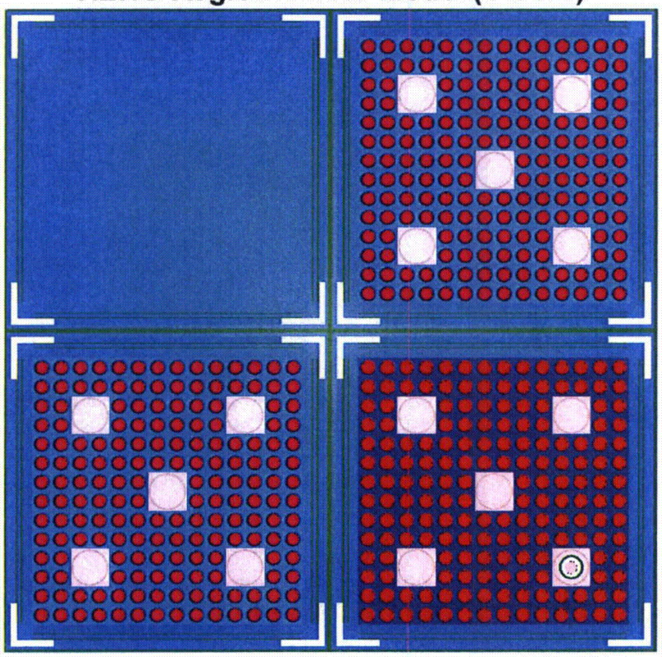


Figure 4.4-3
KENO Region 2 IFRC Model (2 IFRCs)

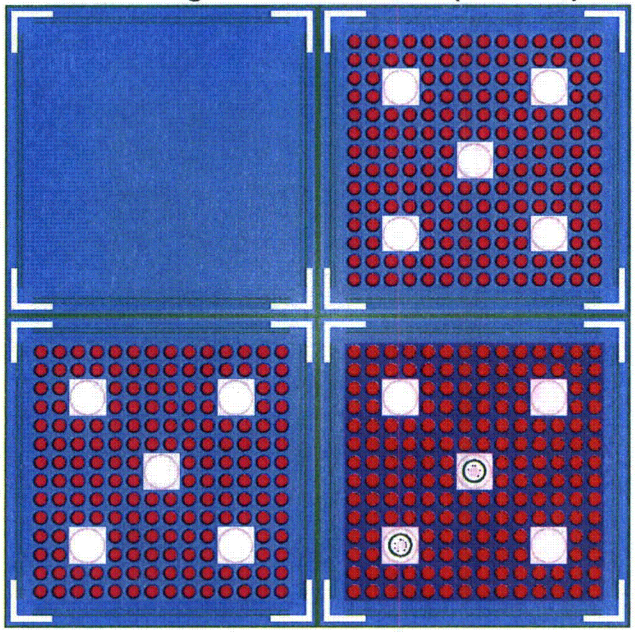


Table 4.4-2
KENO Region 2 and 3 IFRC Model Results

Region	Enrich. wt%	Burnup (GWd/MTU)	k_{eff}	k_{eff} Uncert.	Soluble boron (ppm)	Notes
3 (rodlets)	1.6	0	0.96431	0.00008	0	Base case w/rodlets
3 (rodlets)	1.6	0	0.96249	0.00008	0	Base case plus one 3.5 wt% fresh pin in container
3 (rodlets)	4.85	50	0.95523	0.00009	0	Base case w/rodlets
3 (rodlets)	4.85	50	0.95225	0.00009	0	Base case plus one 3.5 wt% fresh pin in container
2	1.9/2.9	0/0	0.96355	0.00010	0	Base case Region 2
2	1.9/2.9	0/0	0.96258	0.00010	0	1 failed rod stored in Region 2B assembly
2	1.9/2.9	0/0	0.96158	0.00009	0	2 failed rods stored in Region 2B assembly

Note: Each IFRC is modeled containing one fresh 3.5 wt% fuel rod

4.5 Storage Cage 8FR

Storage cage 8FR contains 52 fuel rods, 12 natural enrichment rods, and 86 cage filler rods. Figure 4.5-1 shows the location of the rods in 8FR. Filler rods are comprised of standard fuel cladding with a short internal stainless steel rod. The rod is included to prevent empty clad rods from being buoyant. The stainless steel rods are ignored (modeled as void).

Fuel assemblies T73, T74, T75, and T76 were reconstituted by removing 13 fuel rods, each susceptible to a failure mechanism, and replacing them with natural enrichment fuel rods. Fuel assemblies T73-T76 have initial enrichment of 3.99 wt%. Table 4.5-1 shows fuel assembly burnup at the time of the reconstitution prior to Cycle 19.

Table 4.5-1
Fuel Assembly Burnup after Cycle 17 (before reconstitution)

Fuel ID	Initial Enrichment (wt%)	Burnup (GWd/MTU)
T73	3.99	46.0
T74	3.99	45.9
T75	3.99	46.2
T76	3.99	45.8

Replacement of fuel rods in the T assemblies does not affect their qualification for storage in the MPS2 SFP because natural enrichment fuel rods are much lower enrichment than the lowest enrichment fuel evaluated for the MPS2 SFP (Region 3 with rodlets) and are much lower reactivity than any fuel reactivity limit in the SFP.

T73-T76 occupied core interior locations in Cycles 15 and 16, but resided with one face to the core baffle in Cycle 17. Crediting the average assembly burnup for the removed fuel rods may be non-conservative due to the Cycle 17 fuel assembly burnup gradient. To allow for this possibility for the 8FR evaluation, the assembly average fuel burnup at the end of the previous cycle is credited. Table 4.5-2 shows the assembly average burnup at the end of the previous cycle (Cycle 16).

Table 4.5-2
Fuel Assembly Burnup after Cycle 16

Fuel ID	Initial Enrichment (wt%)	Burnup (GWd/MTU)
T73	3.99	39.2
T74	3.99	39.1
T75	3.99	39.3
T76	3.99	39.1

The most restrictive burnup curve proposed for the MPS2 SFP is Region 3 (rodlets). The burnup requirement by interpolation of the Region 3 (rodlets) loading curve is 39.1 GWd/MTU for 3.99 wt% fuel, which matches the Table 4.5-2 enrichment and burnup. At 4.1 wt%, the interpolated burnup requirement is 40.6 GWd/MTU. The T assembly fuel pins in the 8FR donor cage are modeled as 4.1 wt% with 40 GWd/MTU using a reduced set of isotopes (NUREG/CR-6801 28 major isotope set). This model is conservative because the Cycle 17 burnup addition is ignored, the modeled burnup is slightly less than required, and use of the reduced set of isotopes increases keff.

The KENO model for 8FR consists of three types of pins: Natural enrichment rods, T assembly fuel rods, and filler rods. For this analysis, the filler rods are conservatively modeled without the internal stainless steel rod. A Region 3 single assembly rack model is used without rodlets. Figure 4.5-2 shows KENO 8FR cage model in a Region 3 rack cell. Zircaloy guide thimbles were omitted for convenience to simplify model setup.

Table 4.5-3 shows that k_{eff} for 8FR in Region 3 without rodlets is very low. Therefore, 8FR may be stored anywhere in the SFP where fuel is permitted. 8FR does not require rodlets or a CEA, and no interface effects will be introduced by 8FR.

Fuel rods in 8FR are held in grids, therefore, a drop accident for 8FR is similar to the dropping of a fuel assembly. Analysis confirms that 8FR is much less reactive than a fresh 4.85 wt% fuel assembly. Therefore, the reactivity effect of a drop or misplacement accident is bounded by the fresh fuel assembly drop or misplacement analysis.

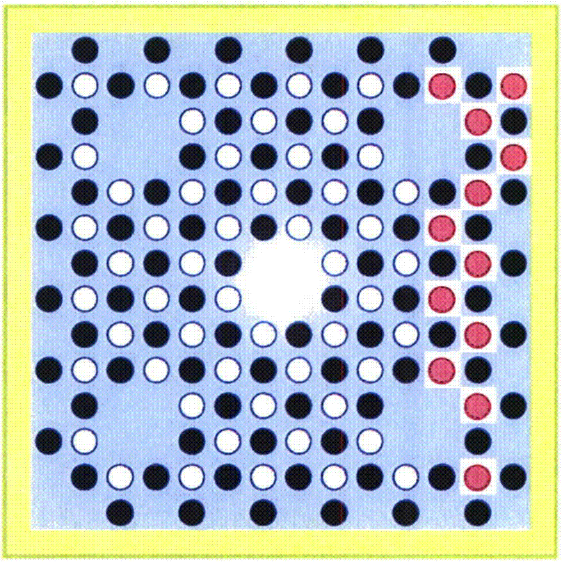
Table 4.5-3
Donor Cage 8FR in Region 3 Results

"T" rods enrich. (wt%)	"T" rods burnup (GWd/MTU)	LATTICELL treatment	k_{eff}	k_{eff} Uncert.	Soluble boron (ppm)	Notes (case name)
4.1	40	Normal fuel lattice	0.77619	0.00008	0	Region 3 single cell, normal latticell input, 86 filler rods, 52 "T" rods, 12 natural enriched rods
4.1	40	None	0.78473	0.00008	0	Region 3 single cell, no latticell input, 86 filler rods, 52 "T" rods, 12 natural enriched rods

Figure 4.5-1
8FR Donor Cage Current Configuration

	A	B	C	D	E	F	G	H	K	L	M	N	P	R
1			FILLER61		FILLER71		FILLER85		FILLER97		FILLER111		FILLER121	
2		FILLER54	T76D13	FILLER66	T75B02	FILLER78	T74C02	FILLER91	T74N02	FILLER104	T73P02	FILLER116	8FRP02	FILLER128
3	FILLER48	T76B03			FILLER72	T75C13	FILLER86	T74P12	FILLER98	T73N13			FILLER122	
4		FILLER55			T75B03	FILLER79	T74B02	FILLER92	T74M02	FILLER105			8FRP04	FILLER129
5	FILLER49	T76B04	FILLER62	T76P12	FILLER73	T75D13	FILLER87	T74P11	FILLER99	T73P13	FILLER112	8FRN05	FILLER123	
6		FILLER56	T76M13	FILLER67	T75B04	FILLER80	T74B03	FILLER93	T73B13	FILLER106	T73N02	FILLER117	8FRP06	FILLER130
7	FILLER50	T76B11	FILLER63	T76P11	FILLER74	T75P02			FILLER100	T73P12	FILLER113	8FRN07	FILLER124	
8		FILLER57	T76N13	FILLER68	T75B11	FILLER81			T73C13	FILLER107	T73M02	FILLER118	8FRP08	FILLER131
9	FILLER51	T76B12	FILLER64	T75D02	FILLER75	T75N02	FILLER88	T74P04	FILLER101	T73P11	FILLER114	8FRN09	FILLER125	
10		FILLER58	T76P13	FILLER69	T75B12	FILLER82	T74B04	FILLER94	T73D13	FILLER108	T76B02	FILLER119	8FRP10	FILLER132
11	FILLER52	T76B13			FILLER76	T75M02	FILLER89	T74P03	FILLER102	T73P04			FILLER126	8FRR11
12		FILLER59			T75B13	FILLER83	T74P13	FILLER95	T73M13	FILLER109			8FRP12	FILLER133
13	FILLER53	T76C13	FILLER65	T75C02	FILLER77	T74D02	FILLER90	T74P02	FILLER103	T73P03	FILLER115	8FRN13	FILLER127	8FRR13
14		FILLER60		FILLER70		FILLER84		FILLER96		FILLER110		FILLER120		

Figure 4.5-2
KENO 8FR Donor Cage Model



4.6 Reconstituted Assemblies

A number of fuel assemblies in the MPS2 SFP have been reconstituted either by replacement of fuel rods (as few as 1 and as many as 13) with natural enrichment fuel rods or with stainless steel rods. Replacement of the removed rods with natural enrichment fuel rods or with stainless steel rods does not impact the storage requirements for these reasons:

1) Natural enrichment fuel reactivity is far below any of the Region 1-4 fuel reactivity limits

2) Stainless steel pins reduce fuel assembly reactivity

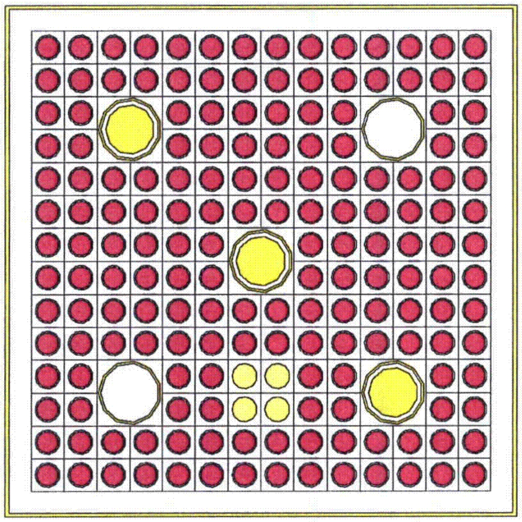
Table 4.6-1 shows the results of a case that demonstrates that stainless steel replacement pins reduce k_{eff}. Figure 4.6-1 shows the position of the replacement pins. No recalculation of fuel burnup is required.

The reactivity of natural enrichment fuel is well below the lowest reactivity fresh fuel considered in the MPS2 SFP criticality analysis (1.6 wt% U-235, Region 3 with rodlets). Reconstitution with natural enrichment fuel pins will either reduce fuel reactivity, or fuel reactivity is already so low as to be well below the lowest reactivity requirement of any region. Therefore, no recalculation of burnup or enrichment is needed.

Table 4.6-1
Stainless Steel Replacement Rod Effect

Enrichment (wt%)	Burnup (GWd/MTU)	Stainless Steel Pins	k_{eff}	k_{eff} Uncert.	Soluble boron (ppm)	Notes (case name)
1.6	0	0	0.96431	0.00008	0	Base case Region 3 with rodlets
1.6	0	4	0.94710	0.00008	0	Base case with 4 fuel pins replaced by SS-304 pins

Figure 4.6-1
Stainless Steel Replacement Rod Model



During reconstitution, the reconstitution assembly is isolated from other fuel assemblies and does not affect SFP k_{eff}. Isolation is ensured by removing fuel from the 8 storage locations that face adjacent or diagonal to the reconstitution assembly and by the restriction that no other fuel assemblies may be within 12 inches of a fuel assembly raised out of the rack cell. Dropping a reconstitution assembly (depleted fuel) into a rack cell is bounded by a single fresh fuel misload. Although reconstitution is infrequently performed (1984, 1987, and 2004), the normal reconstitution process is to replace one fuel pin at a time with a natural enrichment fuel rod or a stainless steel rod. With the reconstitution assembly isolated, the reconstitution process has no effect on SFP keff.

One fuel assembly (P-26) in the MPS2 SFP has a pin removed that has not been replaced. Assembly P-26 is 3.83 wt%, 41.33 GWd/MTU. This enrichment/burnup combination is well above the burnup credit curves for Regions 2-4, but is closest to the

Region 3 (rodlets) burnup curve. Fuel pin B-3 is adjacent to a guide thimble. To evaluate the current configuration of P-26, a Region 3 model with a similar enrichment and burnup (4.1 wt% with 40 GWd/MTU) that was used for development of the burnup curve was modified to remove one fuel pin. The base cases and P-26 models appear to have high k_{eff}, but this is an artifact of using only major actinides to model the fuel content for this pin-removal sensitivity. Results in Table 4.6-2 show that the reactivity of P-26 is reduced by the removal of pin B-3. No special restrictions are required for P-26 as a result of the removal of fuel pin B-3.

Table 4.6-2
Fuel Assembly P-26 Removed Fuel Rod Effect in Region 3 (rodlets)

Enrich (wt%)	Burnup (GWd/MTU)	Soluble Boron (ppm)	K_{eff}	K_{eff} Uncert (dk)	Condition
4.10	40	0	1.06132	0.00010	Normal fuel, major actinides only
4.10	40	0	1.05853	0.00009	Same with missing pin next to rodlet
4.10	40	0	1.05667	0.00009	Same with missing pin next to GT
4.10	40	2000	0.78248	0.00008	Normal fuel, major actinides only
4.10	40	2000	0.77985	0.00008	Same with missing pin next to rodlet

Reconstituted assemblies with removed fuel rods replaced with un-enriched fuel rods or stainless steel rods, and fuel assembly P-26 have been shown to be less reactive than normal fuel assemblies. Therefore, the reactivity effect of a drop or misload accident is bounded by the fresh fuel assembly drop and misload analyses.

4.7 Fuel Transfer Cart

The MPS2 fuel transfer cart is designed to allow simultaneous loading of two fuel assemblies. Fuel assemblies are secured in baskets with 12.2 cm minimum separation. Calculation of separation distance is shown in Table 4.7-1.

Table 4.7-1
Fuel Transfer Cart Fuel Assembly Spacing

Distance between inside basket plate surfaces between storage cells	4.5625 inches
Thickness of two basket plates	0.25 inch
Minimum distance between adjacent fuel assembly faces	4.81 inches (12.2 cm)

Table 4.7-2 shows the results of a KENO model with two fresh 4.85 wt% fuel assemblies in unborated water for several separation distances. Total bias and uncertainty for such a simple configuration is estimated from the Region 1 analysis to be less than 0.02 dk. Table 4.7-2 demonstrates that 10 cm spacing is more than sufficient to ensure $k_{eff} < 1.0$ with no soluble boron. The transfer cart fuel separation of 12.2 cm is sufficient. Figure 4.7-1 depicts the KENO model.

Table 4.7-3 shows the results of a KENO model with three fresh 4.85 wt% fuel assemblies in unborated water for two separation distances. These cases have 2100 ppm soluble boron and are a bounding model for an assembly mishandling or drop accident in the vicinity of the fuel cart loaded with two fresh fuel assemblies. Both spacings in Table 4.7-3 are sufficient to ensure $k_{eff} < 0.95$ with 2100 ppm soluble boron with over 0.1 dk available for bias, uncertainty and margin. Bias and uncertainty is estimated from the Region 1 uncertainty and bias calculations to be less than 0.02 dk. Figure 4.7-2 depicts the KENO model.

Table 4.7-2
Two Fresh 4.85 wt% Fuel Assemblies in Un-borated Water

Assembly separation (cm)	k_{eff}	k_{eff} Uncert.	Notes
7	0.97619	0.00011	Two assemblies in water separated by 7 cm
8	0.96298	0.00012	Two assemblies in water separated by 8 cm
9	0.95195	0.00011	Two assemblies in water separated by 9 cm
10	0.94265	0.00011	Two assemblies in water separated by 10 cm

Table 4.7-3
Three Fresh 4.85 wt% Fuel Assemblies in Water (2100 ppm soluble boron)

Assembly separation (cm)	k_{eff}	k_{eff} Uncert.	Notes
0	0.84154	0.00010	Three assemblies in water separated by 0 cm
2	0.80599	0.00010	Three assemblies in water separated by 2 cm

Figure 4.7-1
Two Fresh Fuel Assemblies in Water

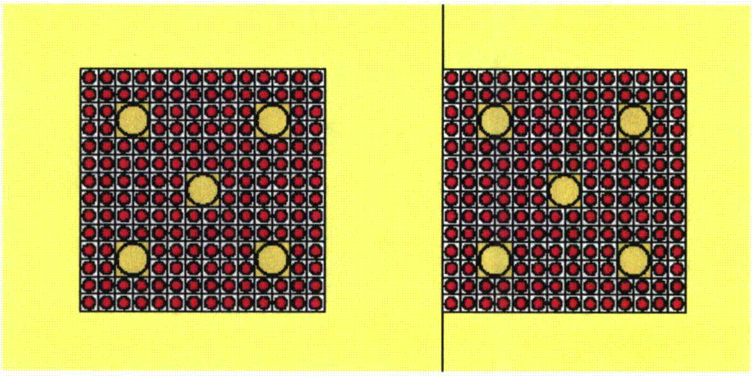
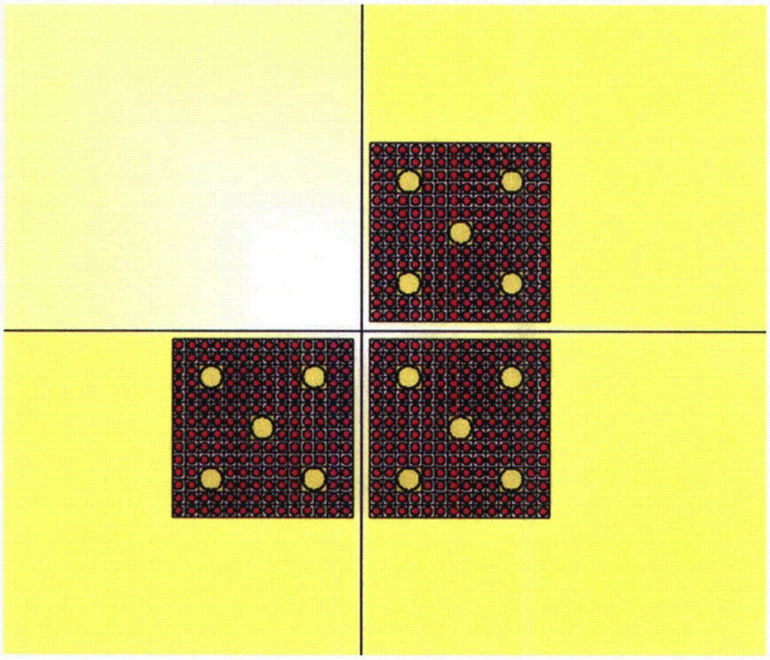


Figure 4.7-2
Three Fresh Fuel Assemblies in Water



4.8 Non-fuel Items

Region 1 and Region 4 infinite lattice cases show that displacement of water by zircaloy can substantially increase k_{eff}. Unrestricted storage of non-fuel materials in normally empty cells is not generically supported. Specific analysis of non-fuel items that are neutron absorbers, particularly adjacent to the SFP wall, may be acceptable if it demonstrates that region k_{eff} does not increase and if no new region boundary effects are created. A Region 4 sensitivity case (Table 5.4-1 in Attachment 5 to this letter) confirms the expectation that storage of full-length full-strength CEAs in Restricted Locations decreases k_{eff} and is acceptable.

Storage of non-fuel items in locations analyzed for fuel storage increases spacing between fuel assemblies and is permitted. Cases in Table 4.8-1 confirm for the MPS2 SFP region with the greatest neutron absorber credit (Region 3 with CEA), introducing an empty cell with no neutron absorber (50% void and 100% void in the empty cell of the 2x2 model) reduces k_{eff} substantially.

Table 4.8-1
Region 3 (CEA) 2x2 Model with One Empty Storage Location

Enrichment (wt%)	Burnup (GWd/MTU)	Empty cell void fraction	k_{eff}	k_{eff} Uncert.	Soluble boron (ppm)	Notes
2.2	0	N/A	0.96045	0.00009	0	Base Case Region 3 with CEA
2.2	0	100	0.94289	0.00009	0	Region 3 CEA 2x2 with 1 empty cell
2.2	0	50	0.91034	0.00010	0	Region 3 CEA 2x2 with 1 empty cell

4.9 Accident Analysis for Non-standard Fuel Configurations

For non-standard fuel configurations in which the fuel pins are not firmly held in place (as they are in standard fuel assemblies by the grids), it is possible to have an accident while moving non-standard fuel because multiple fuel pins may be dropped. For this accident, it is assumed that the non-standard fuel is up to 196 pins of fresh 5.0 wt% U-235 rods or up to 361 rods of fresh 2.0 wt% U-235 and that the optimum number of these rods fall into the location that can increase k_{eff} the most. Further, the arrangement of these pins in the empty cell is optimized. This analysis shows that with the soluble boron level at the minimum concentration allowed by the Technical Specifications (2100 ppm), the k_{eff} will be less than 0.95 including biases and uncertainties.

The most limiting location for a misload of fuel is in a cell that is required to be empty. This occurs in Regions 1, 2, and 4. For each misload case, fuel pins are allowed to fill the empty cell. There is some number of fuel pins that maximizes k_{eff}. For each region this optimum number of fuel pins is determined.

For Regions 2 and 4, the dropped pins analysis assumes high enrichment depleted standard fuel is stored in the racks with the normal storage geometry (3-out-of-4). Boron requirements are higher for higher enrichment depleted fuel than for low enrichment fresh fuel. In general, the optimum pin arrangement is a uniform pitch that matches the available space in the cell. A pin lattice with some vacant locations could occur. With 2100 ppm soluble boron, the worth of removing a fuel pin from a lattice is close to zero and is negative in most of the analysis.

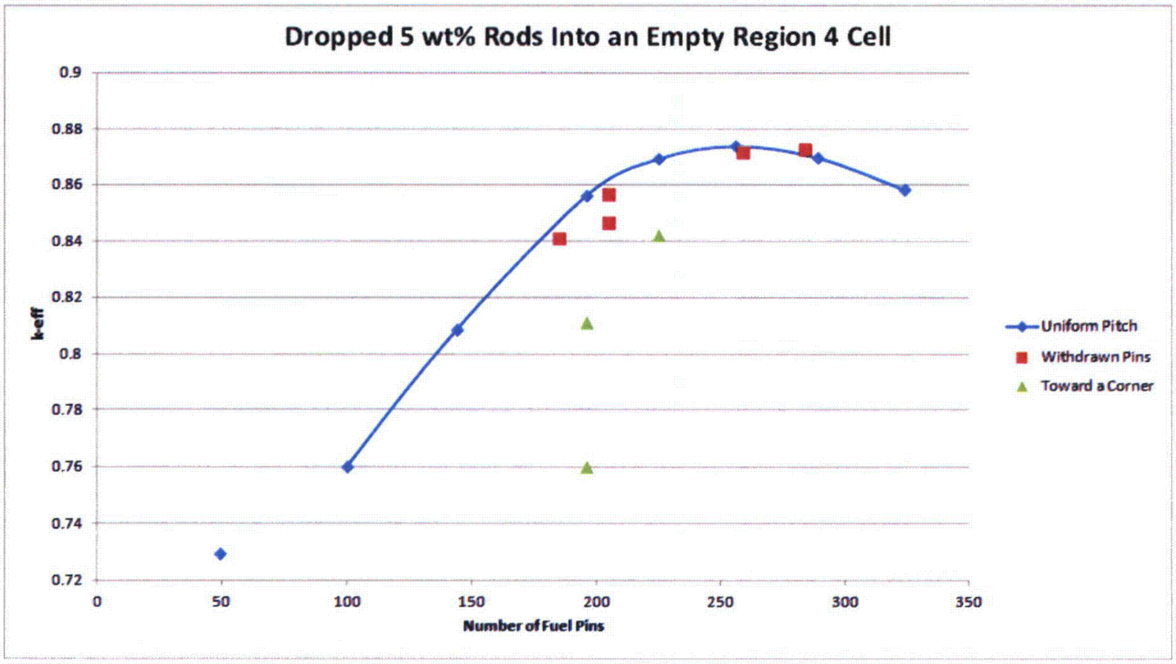
Table 4.9-1 shows the results of the analysis for Region 4 using a 4x4 model with pins dropped into one empty cell. Soluble boron of 2100 ppm is used for all cases. The fuel surrounding the dropped pins is 4.85 wt% U-235 with 40 GWd/MTU burnup. A number of test cases were performed. For the 196 pin case, the fuel pins were expanded as far as possible for the first case (centered). Then the case was rerun with a small pin pitch and a mid pin pitch without changing the origin of the array. This resulted in placing the pins tightly and less tightly in one corner. The placement toward the corner lowered k_{eff}. This was repeated for the 225 pin case and again the highest k_{eff} came from the case with fuel pins uniformly expanded to the edges of the cell. The next test was to check if removing some fuel pins could raise k_{eff}. The first test removed 20 fuel pins as 5 groups of 4 pins. This was followed by removing single pins evenly spaced. The results showed that a higher k_{eff} came from removing isolated single rods.

The results of the Region 4 analysis are shown on Figure 4.9-1. The peak k_{eff} is 0.874 with about 250 fuel pins dropped into the empty cell. The bias and uncertainty for this region is less than 0.04 dk. This means the highest analysis k_{eff} is less than 0.914 with 2100 ppm soluble boron, which is much less than the criterion of $k_{eff} < 0.95$. Further study of this case is not warranted.

Table 4.9-1
Region 4 with Dropped 5.0 wt% Fresh Pins in Empty Cell

4x4 model with one cell used for accident (2100 ppm soluble boron, reduced isotopics)					
Case	**Pins**	**Pitch (cm)**	k_{eff}	**sigma**	**ealf**
Centered 7x7	49	3.22	0.72931	0.000093	4.50E-01
Centered 10x10	100	2.26	0.75980	0.000086	4.00E-01
Centered 12x12	144	1.88	0.80849	0.000091	3.75E-01
Centered 14x14	196	1.61	0.85598	0.00011	4.15E-01
Corner 14x14	196	1.20	0.75976	0.0001	5.83E-01
Mid pitch 14x14	196	1.40	0.81107	0.00011	5.12E-01
Centered 16x16	256	1.41	0.87379	0.00012	5.36E-01
Centered 18x18	324	1.25	0.85811	0.00011	7.33E-01
centered 15x15	225	1.50	0.86915	0.00011	4.65E-01
mid pitch 15x15	225	1.40	0.8422	0.00011	5.20E-01
centered 15x15 20 holes (CE type)	205	1.50	0.84673	0.00011	4.36E-01
centered 15x15 20 holes (scattered)	205	1.50	0.85669	0.00011	4.29E-01
centered 15x15 40 holes (scattered)	185	1.50	0.84124	0.00012	4.04E-01
Centered 17x17 30 holes (scattered)	259	1.33	0.87168	0.00013	5.42E-01
Centered 18x18 40 holes (scattered)	284	1.25	0.87281	0.00011	6.03E-01
centered 17x17	289	1.33	0.86958	0.00011	6.28E-01

Figure 4.9-1
K_{eff} vs Number of 5 wt% Pins Placed in a Region 4 Empty Cell



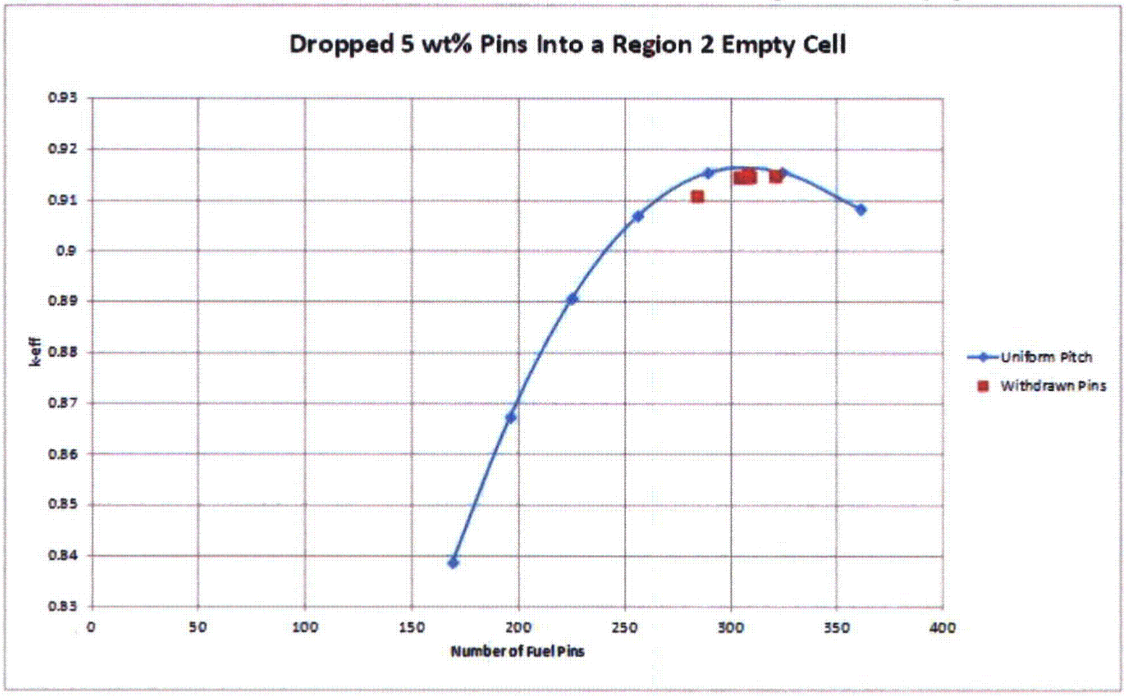
The Region 2 analysis uses 4.85 wt% U-235 fuel and burnups of 16 and 33 GWd/MTU. All cases have 2100 pm soluble boron. This model is a 6x6 model with a 4x4 set of assemblies asymmetrically located in the cell. The Region 2 results are shown on Table 4.9-2 and Figure 4.9-2.

If all the dropped rods are 5 wt% U-235, then the peak k_{eff} is 0.916. Region 2 bias and uncertainty is above 0.03 dk. K_{eff} including bias and uncertainty is close to the regulatory limit, therefore, confirmation of the bias and uncertainty for this case would be needed to generically support any number of 5.0 wt% fresh fuel pins in one empty cell. However, only the consolidated fuel boxes contain more than 196 fuel rods, and those fuel rods are less than 2 wt% U-235. With 196 fuel pins (20 more than in a standard fuel assembly) the maximum k_{eff} is 0.867. There is over 0.08 dk margin to the limit available to accommodate bias and uncertainty, which is approximately 0.03 dk. No further analysis of Region 2 dropped 5 wt% fuel pins is needed.

Table 4.9-2
Region 2 with Dropped 5 wt% Pins

Case	Pins	Pitch (cm)	k_{eff}	sigma	ealf
Centered 13x13	169	1.888	0.83876	0.00013	3.59E-01
Centered 14x14	196	1.754	0.86731	0.00013	3.69E-01
Centered 15x15	225	1.637	0.89066	0.00015	3.95E-01
Centered 16x16	256	1.534	0.90693	0.00014	4.38E-01
Centered 17x17	289	1.444	0.91543	0.00017	4.99E-01
Centered 18x18	324	1.364	0.91551	0.00015	5.81E-01
Centered 19x19	361	1.292	0.90828	0.00014	6.83E-01
Centered 18x18 40 rods withdrawn	284	1.364	0.91092	0.00016	4.84E-01
Centered 18x18 20 rods withdrawn	304	1.364	0.91458	0.00014	5.28E-01
Centered 18x18 16 rods withdrawn	308	1.364	0.9152	0.00015	5.39E-01
Centered 19x19 52 rods withdrawn	309	1.292	0.91463	0.00014	5.34E-01
Centered 19x19 40 rods withdrawn	321	1.292	0.91479	0.00014	5.68E-01

Figure 4.9-2
K_{eff} vs. Number of 5 wt% Pins Placed in a Region 2 Empty Cell

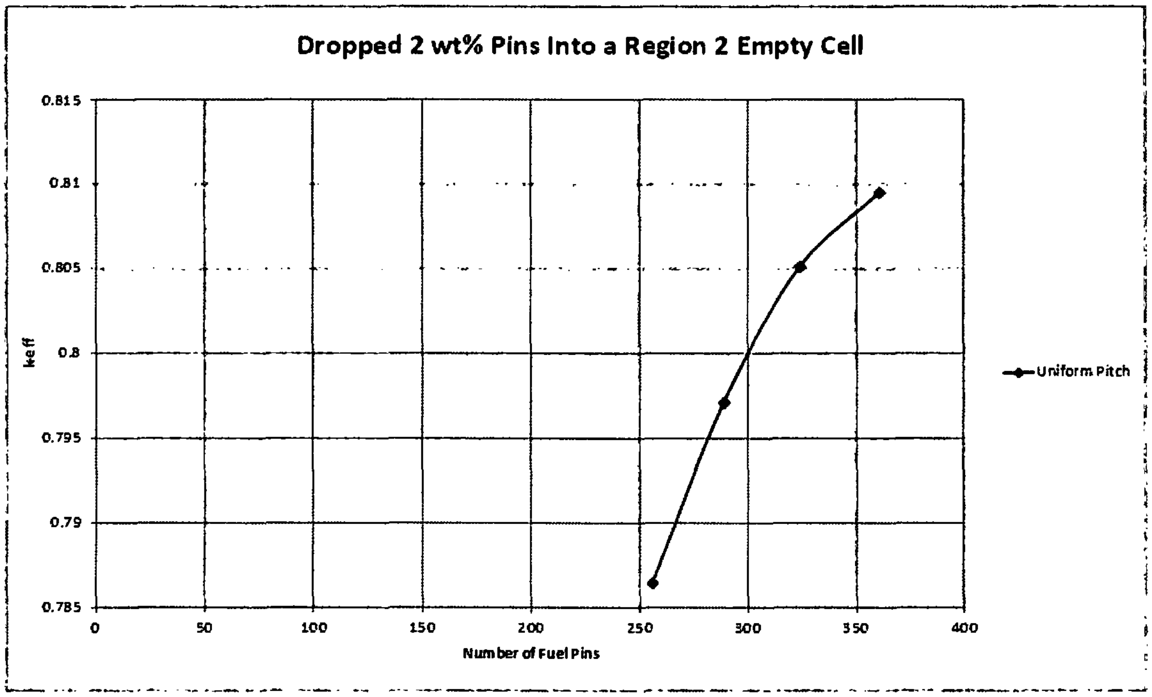


To analyze the CFSBs, the dropped rod enrichment was reduced to 2 wt% U-235 and additional cases were run. Table 4.9-3 and Figure 4.9-3 shows the results. At 2 wt% U-235 the maximum reactivity is not met before 361 (19x19) pins. There are 352 pins in a consolidated fuel box. The maximum k_{eff} for ≤ 361 pins (2 wt% fresh fuel) is 0.809. After allowing for biases and uncertainties k_{eff} is much less than 0.95, so dropping any number of pins from the consolidated fuel boxes is easily covered by the TS minimum soluble boron (2100 ppm).

Table 4.9-3
Region 2 with Dropped 2 wt% Pins

Case	Pins	Pitch (cm)	k_{eff}	sigma	ealf
Centered 16x16	256	1.534	0.78643	0.00011	4.23E-01
Centered 17x17	289	1.444	0.79711	0.00012	4.37E-01
Centered 18x18	324	1.364	0.80509	0.00012	4.62E-01
Centered 19x19	361	1.292	0.80949	0.00014	4.97E-01

Figure 4.9-3
K_{eff} vs. Number of 2 wt% Pins Placed in a Region 2 Empty Cell



The analysis was repeated for Region 1. For the Region 1 case, the Region 2 model used for this accident was modified to replace the burned fuel with 5 wt% fresh U-235 fuel. To be consistent with Region 1 requirements, the checkerboard of empty cells were put into the model. This model still contains the asymmetric features, but due to the checkerboard there are only 8 asymmetric Region 1 assemblies. This is less asymmetry than assumed for the normal Region 1 models but the asymmetry must occur collocated with the dropped pins. This specific location requirement makes the asymmetry modeling reasonable.

Table 4.9-4 and Figure 4.9-4 show the results of the Region 1 analysis. The peak k_{eff} is 0.925. The bias and uncertainty for Region 1 is less than 0.02 dk but adding this bias and uncertainty results in less margin than desired. Similar to the Region 2 analysis, margin is established by limiting the number of fresh 5 wt% fuel to 196 fuel pins. With up to 196 dropped pins, k_{eff} is $\leq$ 0.873. Adding 0.02 for the bias and uncertainty makes the maximum k_{eff} 0.89, which is much less than 0.95. Dropping up to 196 fuel pins of 5 wt% U-235 is generously covered by the minimum TS soluble boron of 2100 ppm.

For the analysis for consolidated fuel boxes, 2 wt% U-235 fuel pins were dropped. Table 4.9-5 and Figure 4.9-5 shows the results of the Region 1 analysis with the 2 wt% dropped pins. The maximum k_{eff} is 0.811. After allowing for bias and uncertainty, the maximum k_{eff} is much less than 0.95. Dropping up to 361 2 wt% U-235 fuel pins (more than in a consolidated fuel box) is generously covered by the minimum TS soluble boron (2100 ppm).

Table 4.9-4
Region 1 with Dropped 5 wt% Pins

Case	Pins	Pitch (cm)	k_{eff}	sigma	ealf
Centered 13x13	169	1.89	0.84322	0.00013	3.41E-01
Centered 14x14	196	1.75	0.87343	0.00012	3.56E-01
Centered 15x15	225	1.64	0.89787	0.00013	3.87E-01
Centered 16x16	256	1.53	0.91461	0.00014	4.36E-01
Centered 17x17	289	1.44	0.92346	0.00014	5.05E-01
Centered 18x18	324	1.36	0.92413	0.00014	5.99E-01
Centered 19x19	361	1.29	0.91658	0.00013	7.21E-01
Centered 18x18 40 rods withdrawn	284	1.36	0.9191	0.00014	4.88E-01
Centered 18x18 20 rods withdrawn	304	1.36	0.92323	0.00014	5.38E-01
Centered 18x18 16 rods withdrawn	308	1.36	0.92351	0.00014	5.51E-01
Centered 19x19 52 rods withdrawn	309	1.29	0.9231	0.00015	5.46E-01
Centered 19x19 40 rods withdrawn	321	1.29	0.92337	0.00015	5.85E-01

Figure 4.9-4
K_{eff} vs Number of 5 wt% Pins Placed in a Region 1 Empty Cell

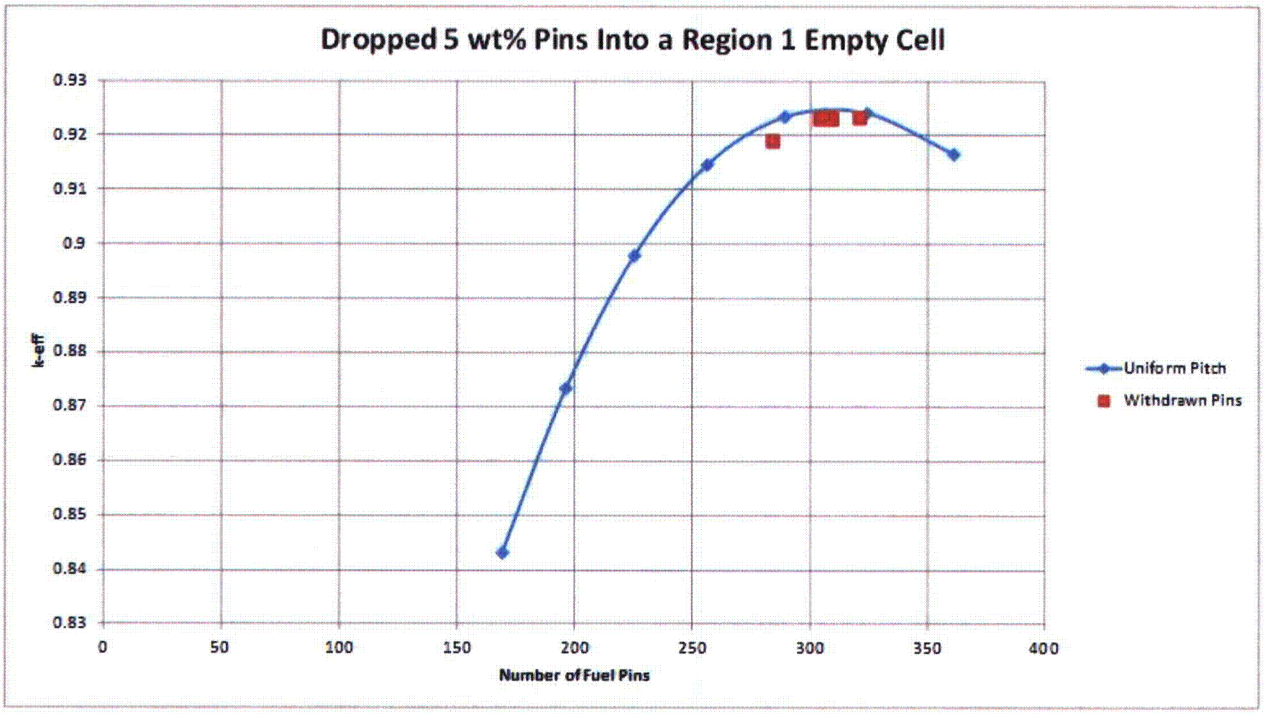
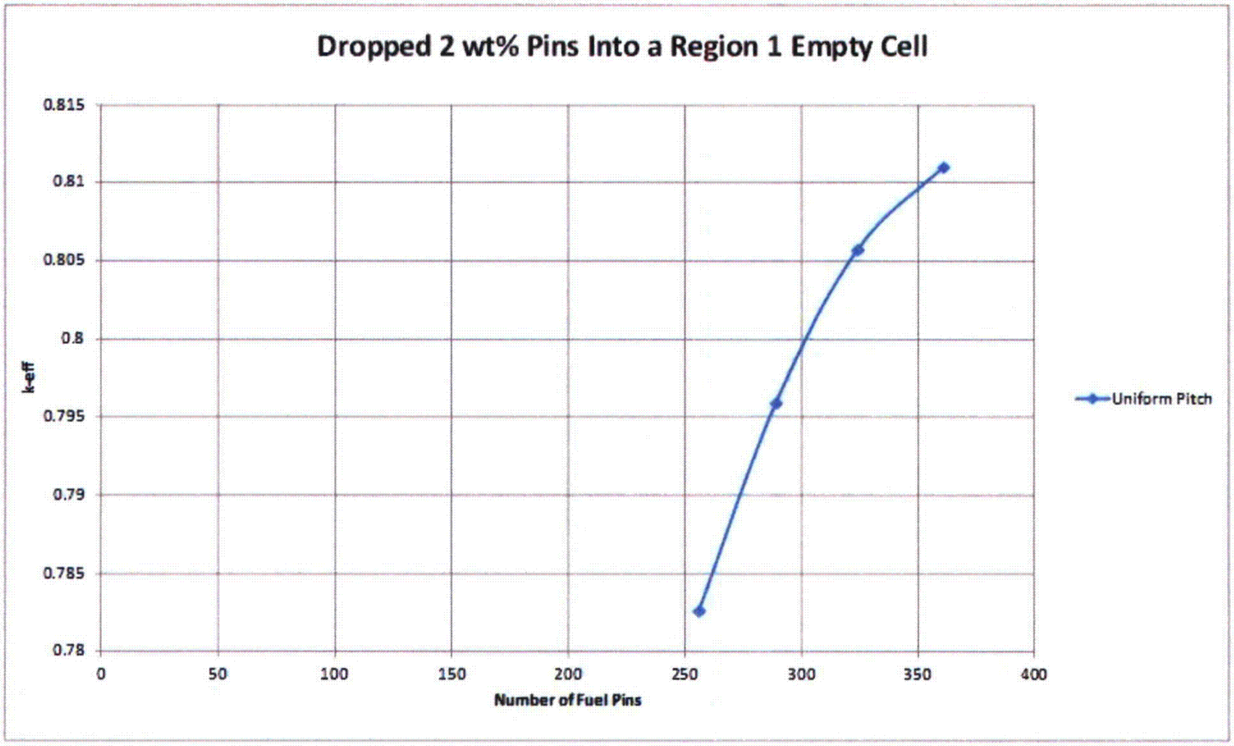


Table 4.9-5
Region 1 results with Dropped 2 wt% Pins

Case	Pins	Pitch (cm)	k_{eff}	sigma	ealf
Centered 16x16	256	1.534	0.78264	0.00012	4.12E-01
Centered 17x17	289	1.444	0.79591	0.00012	4.33E-01
Centered 18x18	324	1.364	0.80574	0.00011	4.67E-01
Centered 19x19	361	1.292	0.81102	0.00013	5.15E-01

Figure 4.9-5
K_{eff} vs. Number of 2 wt% Pins Placed in a Region 1 Empty Cell



Non-standard Fuel Accident Analysis Summary

The analysis has shown that dropping up to 196 fuel pins of 5 wt% fresh U-235 anywhere (single location) in the SFP does not increase k_{eff} including bias and uncertainty above 0.95 when the pool is at the minimum soluble boron allowed by the TS (2100 ppm). Further, dropping up to 361 fuel pins of 2 wt% fresh U-235 anywhere (single location) in the SFP does not increase k_{eff} including bias and uncertainty above 0.95 when the pool is at the minimum soluble boron allowed by the TS (2100 ppm). This analysis addresses any concern about a failed consolidated rod box or losing fuel pins from any of the non-standard arrangements of fuel.

ATTACHMENT 5

REVISED SFP REGIONS 1-4 BIAS, UNCERTAINTY, MARGIN AND BURNUP CURVES

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

Revised SFP Regions 1-4 Bias, Uncertainty, Margin and Burnup Curves

5.0 Discussion of Revisions

Regions 1-4 bias, uncertainty, margin, and burnup curve calculations have been revised as a result of resolution of RAI issues. Revised analysis results for each region are provided in Sections 5.1-5.5. RAI responses incorporated into the revised uncertainty, margin, and burnup curve analyses are listed below.

RAI 6: Regions 1 and 2 analyses accommodate restricted cell poison box removal.
RAI 11: Burnup worth uncertainty is increased to 5%.
RAI 13: Regions 2-4 analyses include uniform burnup shape cases.
RAI 15: Partial removal of volatile fission products is included in Regions 2-4 analyses.
RAI 21: Poison box uncertainty cases are included in Regions 1 and 2 analyses.
RAI 22b: Fuel rod creep modeled in Regions 2-4.
RAI 23: Eccentric fuel placement is treated as a bias in region analyses.
RAI 24: Revised definition of significance employed in region analyses.
RAI 25a.2, 30: Control element assembly (CEA) uncertainties calculated for Region 3.
RAI 25a.4: Additional bias included for elevated temperature calculations.
RAI 27, 28: Bias and uncertainty calculated for each region analysis.
RAI 29: Mixed rodlet / CEA cases included in Region 3 analysis.
RAI 31: Non-centered rodlet and CEA included in Region 3 analyses.

Incorporation of the RAI responses resulted in two other changes in the calculation method for simplicity and to limit the number of cases required. Regions 2-4 burnup credit curves were determined in the December 2012 LAR using interpolation of data provided at 0.5 weight percent (wt%) increments and 10 GWd/MTU increments (Ref. 5.1, Section 6.1, Key Analysis Assumption 2). For the revised curves, each analyzed point on each burnup curve is calculated directly with no use of interpolation or interpolation uncertainty. Dominion administrative margin is calculated at each point on the burnup curve for the 0 ppm boron condition as 1 – total bias – total uncertainty – KENO k_{eff}.

This direct burnup credit curve calculation method also results in a change to the enrichment uncertainty sensitivity method used in Regions 2-4. Enrichment uncertainty of 0.05 wt% U-235 is included in the set of uncertainties calculated for each region. This is a simple calculation requiring one KENO sensitivity case if the fuel is fresh. For depleted fuel, this calculation uses a second enrichment at the same burnup, which requires 18 TRITON depletions and a KENO case for Regions 3 and 4 and 36 TRITON depletions and a KENO case for Region 2. To avoid the need for TRITON depletions, a simple conservative approximation is used for the depleted fuel enrichment uncertainty:

Sensitivity(EN) = Base Enrichment / EN x Sensitivity(Base Enrichment)

Where EN is the initial enrichment of the desired sensitivity, Base Enrichment is the fresh fuel endpoint enrichment of the burnup curve, and Sensitivity (Base Enrichment) is the KENO calculated enrichment sensitivity at the fresh fuel base enrichment. This model has been verified to produce conservatively large enrichment sensitivity values for depleted fuel in Regions 2-4. The approximation was verified using sensitivity values from the December

2012 LAR as well as sensitivity values derived from data available in the revised burnup credit analyses.

Direct calculation of points on the burnup curves requires use of a 16 GWd/MTU case in Region 2. The 16 GWd/MTU burnup shape in NUREG/CR-6801 (Group 9) is unnecessarily conservative for use in a MPS2 analysis. In NUREG/CR-6801 Section 4.2.3 (Ref 5.2), these observations are made regarding groups 8-10:

> ***For example, inspection of the bounding profiles for burnup groups 8–10 (see Figures 14–16) suggests that these profiles have experienced significant exposure to control rods and/or APSRs. It is worth noting that these particular profiles are from assemblies with very low enrichment (~2 wt % ^{235}U); indicating they correspond to early operations in which control rods were used to a greater extent than they currently are used.***

Neither of these features (control rod exposure and very low enrichment) are consistent with MPS2 fuel depletion. Operation with control rods inserted at MPS2 was previously documented in Section 3.1.3.5 of the MPS2 SFP December 2012 LAR to be minimal over the entire history of MPS2. For MPS2 analysis, a heavily rodded burnup shape is not necessary.

NUREG/CR-6801 Group 8 shape (18-22 GWd/MTU) will be used for MPS2 16 GWd/MTU depletion analysis. To further support use of the NUREG Group 8 shape, 562 measured burnup shapes from MPS2 Cycles 14-22 in the burnup range 15.5-22 GWd/MTU were examined. Figure 5.0-1 compares the average MPS2 shape in two burnup ranges (15.5-18 and 18-22 GWd/MTU) to NUREG /CR-6801 Group 8 and Group 9 shapes. The Group 9 shape is much different than the other shapes.

The "end effect" (the effect of non-uniform burnup shape on k_{eff}) is dependent on the relative burnup near the ends of the fuel (Ref. 5.2, Section 2.3). Figure 5.0-2 is a plot of the relative burnup for the top 1/6th assembly for the 562 MPS2 shapes and for NUREG/CR-6801 burnup groups 5-11. The NUREG values are plotted at the midpoint of the group burnup interval. Group 9 is an outlier. Group 8 (18-22 GWd/MTU) conservatively bounds the MPS2 shapes and is therefore acceptable to use for the Region 2 4.85 wt% 16 GWd/MTU model.

Due to the number of KENO cases required for RAI resolution and the amount of computer time required for cases with a full set of nuclides, a reduced set of nuclides is used for depleted fuel sensitivity and uncertainty cases. The 29 nuclides (28 plus oxygen) from "Set 2" of Table 4 in NUREG/CR-6801 will be used (Table 5.0-1). This set was used in the NUREG in the assessment of limiting burnup shapes and the end effect. A test case included with the Region 2 minor actinides and fission product worth cases at the maximum burnup credit (two 4.85 wt% assemblies with 16 GWd/MTU and one 4.85 wt% assembly with 33 GWd/MTU) produced a burnup worth approximately 92% of the burnup worth using a full set of nuclides. The reduced isotope cases are appropriate for calculation of uncertainty and sensitivity.

For depleted fuel sensitivity calculations, no clad inner diameter (ID) or outer diameter (OD) cases were run because clad creep geometry (reduced clad OD and ID) is included in the depleted fuel KENO models. Verification cases are included to ensure conservatism of the creep geometry in each region analysis. A bias is included if the verification case indicates depleted fuel creep geometry is non-conservative.

No fuel pellet OD cases were run for depleted fuel due to the complication with creep down geometry. In addition, the fuel mass change represented by the pellet OD uncertainty is about 16% of the fuel mass change of the pellet density uncertainty. In Region 1 (0 ppm), the best estimate fuel density sensitivity is 0.0018 and the fuel OD sensitivity is 0.00017 (~10%). In Region 2, the fuel OD sensitivity is nearly zero, and in Region 3 (rodlets) the ratio is ~17%. It is apparent that the fuel OD case is dominated by the fuel mass change and the effect of fuel geometry is very small. The fuel OD sensitivity for depleted fuel is not important because fuel mass uncertainty is well represented in the fuel density uncertainty case and because the magnitude of the OD sensitivity is too small to influence the total uncertainty.

Sufficient density change cases were run for depleted fuel to demonstrate that the density effect is essentially the same as for fresh fuel.

References:

5.1 Letter Serial No. 12-678, Dominion Nuclear Connecticut, Inc. to U.S. Nuclear Regulatory Commission, "Dominion Nuclear Connecticut, Inc, Millstone Power Station Unit 2 License Amendment Request Regarding Proposed Technical Specifications Changes for Spent Fuel Storage," December 17, 2012.

5.2 NUREG/CR-6801 , "Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses," March, 2003.

Table 5.0-1
NUREG/CR-6801 29 Nuclides for Burnup Credit

Set 2: Actinide and fission-product nuclides (29 total)									
U-234	U-235	U-236	U-238	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Am-241
Am-243	Np-237	Mo-95	Tc-99	Ru-101	Rh-103	Ag-109	Cs-133	Sm-147	Sm-149
Sm-150	Sm-151	Sm-152	Nd-143	Nd-145	Eu-151	Eu-153	Gd-155	O[†]	

[†]Oxygen is neither an actinide nor a fission product, but is included in this list because it is an integral part of fuel, and hence included in the calculations.

Figure 5.0-1

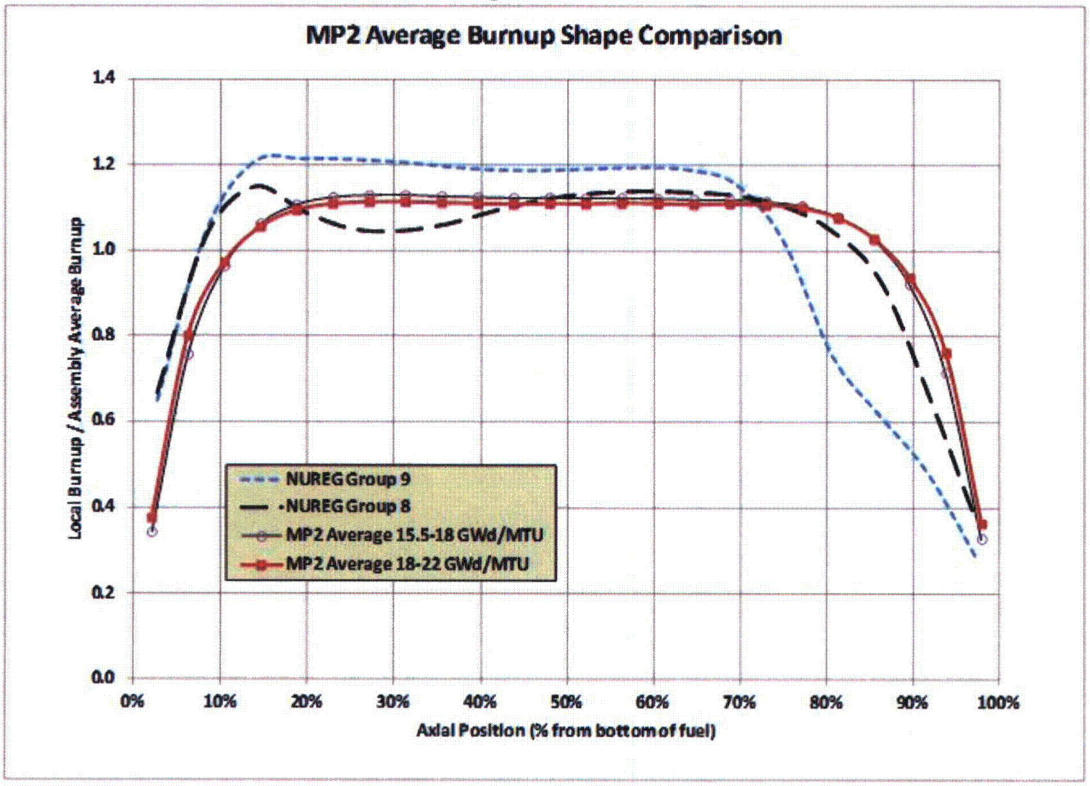
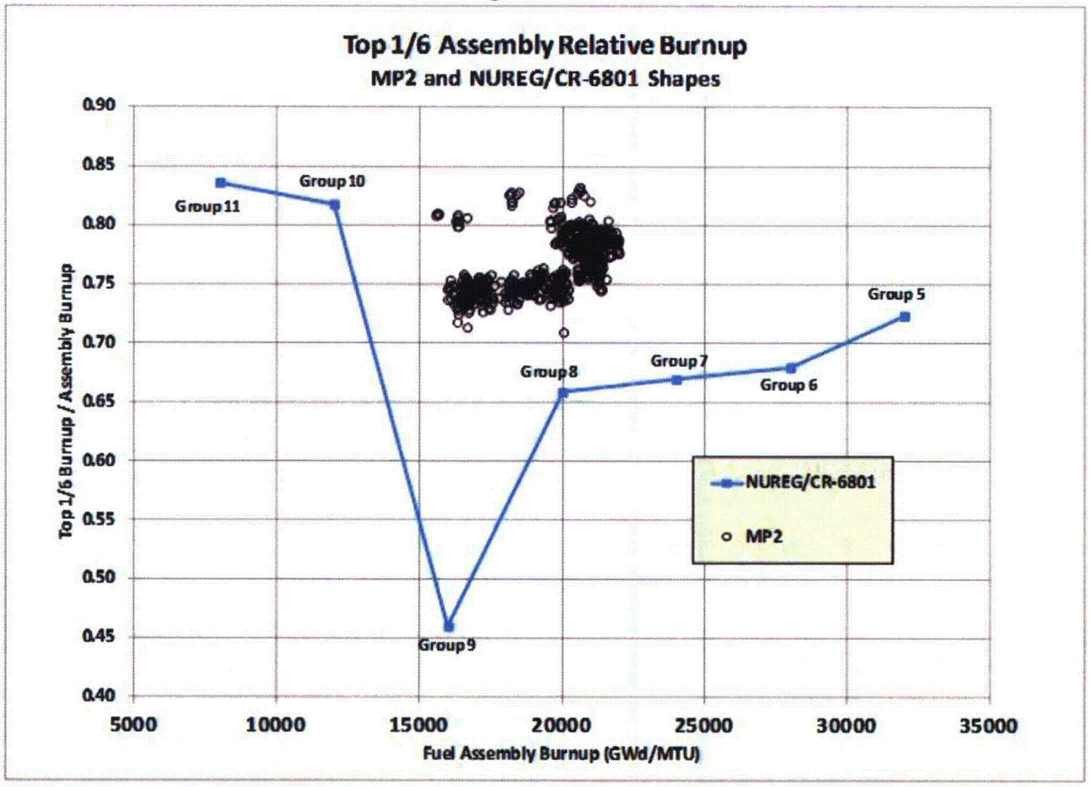


Figure 5.0-2



5.1 Region 1

Region 1 does not require burnup credit and allows storage of 4.85 wt% U-235 fresh fuel in a 2-out-of-4 checkerboard orientation (two fuel storage locations and two Restricted Locations). Tables 5.1-1 through 5.1-4 contain the revised bias, uncertainty and margin calculations for Region 1. Sufficient margin is demonstrated to permit removal of poison boxes in Restricted Locations. Poison box removal, storage of non-fuel items in restricted locations, and storage of non-fuel items in locations intended for fuel but missing a poison box is examined in Tables 5.1-3. Region 1 storage cells intended to contain fuel shall have a poison box present or be unavailable for fuel storage. Storage of non-fuel items in a cell normally intended for fuel reduces k_{eff}, even if the poison box is removed. Therefore, non-fuel items may be stored in a location intended for fuel storage with or without a poison box present.

Table 5.1-1
Region 1 Uncertainty and Bias Cases (0 ppm soluble boron)

Initial Enrichment (w/o U235)	Poison Box	Burnup (GWd/MTU)	KENO K-effective	KENO K-effective Uncertainty	Sensitivity (dk)	Case
5.0	YES	0	0.90873	0.00011	N/A	Base case
5.0	YES	0	0.90697	0.00011	-0.0014	Reduce fuel density
5.0	**YES**	**0**	**0.91055**	**0.00011**	**0.0021**	**Increase fuel density**
5.05	**YES**	**0**	**0.91034**	**0.00012**	**0.0019**	**Increase enrichment**
5.0	YES	0	0.90533	0.00011	-0.0018	Water temp 210 F (bias +0.0013)
5.0	**YES**	**0**	**0.90935**	**0.00011**	**0.0013**	**Water temp 110 F (bias + 0.0004)**
5.0	YES	0	0.90925	0.00011	0.0008	Water temp 32 F
5.0	**YES**	**0**	**0.90894**	**0.00012**	**0.0005**	**Increase pellet OD**
5.0	YES	0	0.90855	0.00011	0.0001	Reduce pellet OD
5.0	**YES**	**0**	**0.91125**	**0.00011**	**0.0028**	**Reduce cell pitch**
5.0	**YES**	**0**	**0.90938**	**0.00012**	**0.0010**	**Reduce cell wall thickness**
5.0	YES	0	0.90835	0.00011	-0.0001	Offcenter monodirectional
5.0	**YES**	**0**	**0.90947**	**0.00004**	**0.0010**	**Offcenter bias 6x6 in 8x8**
5.0	YES	0	0.90442	0.00011	-0.0040	Maximum Zr grids
5.0	**YES**	**0**	**0.91068**	**0.00012**	**0.0023**	**Reduce clad OD**
5.0	YES	0	0.90701	0.00011	-0.0014	Increase clad OD
5.0	**YES**	**0**	**0.90872**	**0.00011**	**0.0003**	**Reduce clad ID**
5.0	**YES**	**0**	**0.90956**	**0.00011**	**0.0011**	**Increase pin pitch**
5.0	YES	0	0.90725	0.00011	-0.0012	Reduce pin pitch
5.0	**YES**	**0**	**0.90931**	**0.00011**	**0.0009**	**Reduce GT OD**
5.0	**YES**	**0**	**0.90909**	**0.00011**	**0.0007**	**Increase GT ID**
5.0	YES	0	0.90868	0.00012	0.0003	Reduce GT ID
5.0	YES	0	0.90873	0.00011	0.0003	Stack height increase (0.2 cm)
5.0	**YES**	**0**	**0.91025**	**0.00011**	**0.0018**	**Reduce wrapper thickness**

Table 5.1-2
Region 1 Uncertainty and Bias Cases (2000 ppm soluble boron)

Initial Enrichment (w/o U235)	Poison Box	Burnup (GWd/MTU)	KENO K-effective	KENO K-effective Uncertainty	Sensitivity (dk)	Case
5.0	YES	0	0.68994	0.00010	N/A	Base case
5.0	YES	0	0.68678	0.00010	-0.0029	Reduce fuel density
5.0	**YES**	**0**	**0.69319**	**0.00010**	**0.0035**	**Increase fuel density**
5.05	**YES**	**0**	**0.69192**	**0.00010**	**0.0023**	**Increase enrichment**
5.0	YES	0	0.68946	0.00010	0.0009	Water temp 210 F (bias +0.0013)
5.0	**YES**	**0**	**0.69045**	**0.00010**	**0.0011**	**Water temp 110 F (bias + 0.0004)**
5.0	YES	0	0.69026	0.00010	0.0006	Water temp 32 F
5.0	**YES**	**0**	**0.69047**	**0.00010**	**0.0008**	**Increase pellet OD**
5.0	YES	0	0.68953	0.00010	-0.0001	Reduce pellet OD
5.0	**YES**	**0**	**0.69220**	**0.00010**	**0.0025**	**Reduce cell pitch**
5.0	YES	0	0.68945	0.00010	-0.0002	Reduce cell wall thickness
5.0	**YES**	**0**	**0.69072**	**0.00010**	**0.0011**	**Increase cell wall thickness**
5.0	YES	0	0.68811	0.00010	-0.0015	Offcenter monodirectional
5.0	YES	0	0.68941	0.00004	-0.0002	Offcenter bias 6x6 in 8x8
5.0	YES	0	0.68774	0.00010	-0.0019	Maximum Zr grids
5.0	**YES**	**0**	**0.69090**	**0.00010**	**0.0012**	**Reduce clad OD**
5.0	YES	0	0.68898	0.00010	-0.0007	Increase clad OD
5.0	**YES**	**0**	**0.69004**	**0.00010**	**0.0004**	**Reduce clad ID**
5.0	**YES**	**0**	**0.69041**	**0.00010**	**0.0008**	**Increase pin pitch**
5.0	YES	0	0.68951	0.00010	-0.0002	Reduce pin pitch
5.0	**YES**	**0**	**0.68994**	**0.00011**	**0.0003**	**Reduce GT OD**
5.0	YES	0	0.68984	0.00010	0.0002	Increase GT ID
5.0	**YES**	**0**	**0.69003**	**0.00010**	**0.0004**	**Reduce GT ID**
5.0	**YES**	**0**	**0.69028**	**0.00010**	**0.0006**	**Reduce wrapper thickness**

Table 5.1-3
Region 1 Empty Cell Storage and Poison Box Removal

Initial Enrichment (w/o U235)	Poison Box	Boron (ppm)	KENO K-effective	KENO K-effective Uncertainty	Sensitivity (dk)	Case
5.00	ALL	0	0.90873	0.00011	N/A	Base case
5.00	ALL	0	0.94016	0.00011	0.0317	50% Zr in empty cells
5.00	HALF	0	0.96357	0.00011	0.0552	50% Zr in empty cells w/o poison box
5.00	HALF	0	1.01984	0.00011	0.1114	75% Zr in empty cells
5.00	**HALF**	**0**	**0.91212**	**0.00011**	**0.0037**	**No poison boxes in empty cells**
5.00	HALF	0	0.90580	0.00012	-0.0026	No poison boxes in empty cells, 4x4, missing 1 FA, water in missing fuel location
5.00	HALF	0	0.90625	0.00012	-0.0022	No poison boxes in empty cells, 4x4, missing 1 FA, 75% zr in missing fuel location
5.00	NONE	0	0.93439	0.00011	0.0260	No poison boxes at all, centered fuel
4.85	HALF	0	0.90767	0.00011	N/A	No poison boxes in empty cells
5.00	ALL	2000	0.68994	0.0001	N/A	Base case with 2000 ppm
5.00	HALF	2000	0.68613	0.00010	-0.0035	No poison boxes in empty cells 2K ppm

Table 5.1-4
Region 1 Total Bias and Uncertainty

Case Type	Case	0 ppm boron (dK)	2000 ppm boron (dK)
Uncertainty	Increase fuel density	0.0021	0.0035
Uncertainty	Increase enrichment	0.0019	0.0023
Uncertainty	Increase pellet OD	0.0005	0.0008
Uncertainty	Reduce cell pitch	0.0028	0.0025
Uncertainty	Reduce cell wall thickness	0.0010	0.0000
Uncertainty	Increase cell wall thickness	0.0000	0.0011
Uncertainty	Reduce clad OD	0.0023	0.0012
Uncertainty	Reduce clad ID	0.0003	0.0004
Uncertainty	Increase pin pitch	0.0011	0.0008
Uncertainty	Reduce GT OD	0.0009	0.0003
Uncertainty	Increase GT ID	0.0007	0.0000
Uncertainty	Reduce GT ID	0.0000	0.0004
Uncertainty	Reduce wrapper thickness	0.0018	0.0006
Uncertainty	Code uncertainty	0.0052	0.0052
Uncertainty	2 x KENO std. dev.	0.0002	0.0002
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008
TOTAL UNCERT		**0.0075**	**0.0075**
Bias	Water temp 110 F (bias + 0.0004)	0.0013	0.0011
Bias	Maximum Zr grids	0.0000	0.0000
Bias	Asymmetric fuel bias	0.0010	0.0000
Bias	No poison boxes in empty cells	0.0037	0.0000
Bias	Code bias	0.0048	0.0048
Bias	NRC administrative margin	0.0050	0.0050
TOTAL BIAS		**0.0158**	**0.0109**
Total bias and uncertainty (dK)		**0.0234**	**0.0185**
KENO K-effective		**0.9087**	**N/A**
Dominion administrative margin (dK)		**0.0679**	**N/A**

5.2 Region 2

Region 2 analysis allows fuel storage in a 3-out-of 4 checkerboard configuration with two Region 2A fuel assemblies, one Region 2B fuel assembly, and one Restricted Location. Tables 5.2-1 through 5.2-10 contain the revised bias, uncertainty and margin calculation for Region 2. Burnup worth for 2000 ppm calculations use the 0 ppm burnup worth values, which is conservative. Sensitivity cases in Table 5.2-8 verify that burnup worth is substantially lower with 2000 ppm.

Sufficient margin is demonstrated to permit removal of poison boxes in Restricted Locations. Region 2 storage cells intended to contain fuel shall have a poison box present or be unavailable for fuel storage. Region 1 cases confirm that storage of non-fuel items in a cell normally intended for fuel reduces k_{eff}, even if the poison box is removed. Therefore, non-fuel items may be stored in a location intended for fuel storage with or without a poison box present.

Burnup credit curves for Region 2 are shown on Figure 5.2-1. The fit lines shown bound the curve data points.

Figure 5.2-1

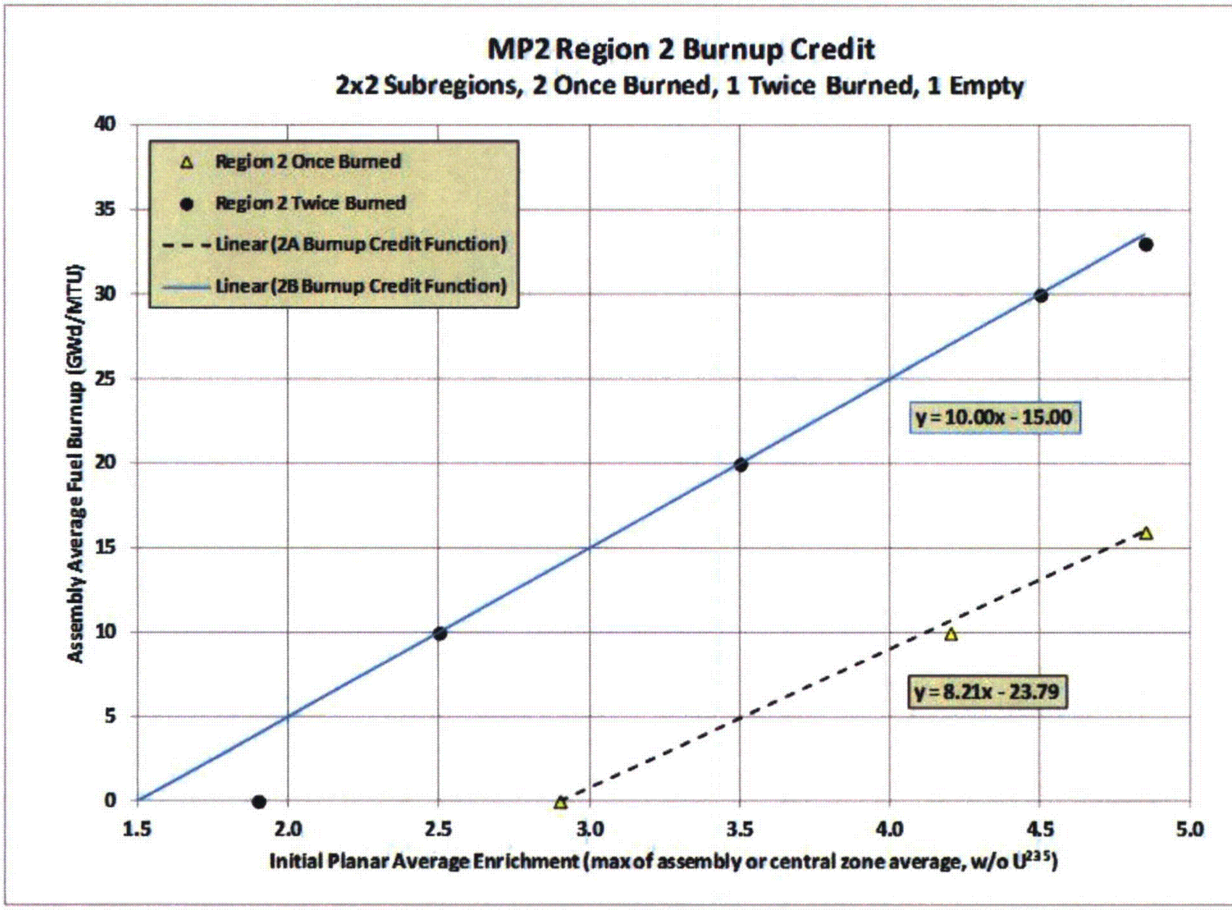


Table 5.2-1
Region 2 Burnup Worth (0 ppm soluble boron)

2A Enrich. (w/o U235)	2A Burnup (GWd/MTU)	2B Enrich. (w/o U235)	2B Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Burnup Worth or Sensitivity (dk)	Value
2.90	0	1.90	0	0.96355	0.00010		
2.90	0	2.50	10	0.95626	0.00019		
2.90	**0**	**2.50**	**10U**	**0.95747**	**0.00019**	**0.0356**	Burnup worth
2.90	0	3.50	20	0.95839	0.00020		
2.90	**0**	**3.50**	**20U**	**0.96133**	**0.00020**	**0.0678**	Burnup worth
2.90	0	4.50	30	0.95914	0.00019		
2.90	**0**	**4.50**	**30U**	**0.96244**	**0.00019**	**0.0923**	Burnup worth
2.90	0	4.85	33	0.95913	0.00021		
2.90	**0**	**4.85**	**33U**	**0.96264**	**0.00018**	**0.0996**	Burnup worth
4.20	10	1.90	0	0.96188	0.00019		
4.20	**10U**	**1.90**	**0**	**0.96424**	**0.00020**	**0.0512**	Burnup worth
4.20	10	2.50	10	0.95460	0.00018		
4.20	10U	2.50	10	0.95667	0.00019		
4.20	10	2.50	10U	0.95586	0.00020		
4.20	**10U**	**2.50**	**10U**	**0.95788**	**0.00018**	**0.0829**	Burnup worth
4.20	10	3.50	20	0.95798	0.00018		
4.20	10U	3.50	20	0.95911	0.00018		
4.20	10	3.50	20U	0.95950	0.00018		
4.20	**10U**	**3.50**	**20U**	**0.96204**	**0.00019**	**0.1109**	Burnup worth
4.20	10	4.50	30	0.96039	0.00020		
4.20	10U	4.50	30	0.96013	0.00019		
4.20	**10U**	**4.50**	**30U**	**0.96197**	**0.00019**	**0.1339**	Burnup worth
4.20	10	4.85	33	0.95959	0.00019		
4.20	10U	4.85	33	0.96037	0.00019		
4.20	**10U**	**4.85**	**33U**	**0.96317**	**0.00020**	**0.1392**	Burnup worth
4.85	16	1.90	0	0.95619	0.00018		
4.85	**16U**	**1.90**	**0**	**0.95962**	**0.00010**	**0.0737**	Burnup worth
4.85	16	2.50	10	0.95068	0.00019		
4.85	16U	2.50	10	0.95214	0.00018		
4.85	16	2.50	10U	0.95116	0.00018		
4.85	**16U**	**2.50**	**10U**	**0.95340**	**0.00010**	**0.1045**	Burnup worth
4.85	**16**	**3.50**	**20**	**0.96225**	**0.00019**	**0.1267**	Burnup worth
4.85	16U	3.50	20	0.95506	0.00018		
4.85	16	3.50	20U	0.95486	0.00018		
4.85	16U	3.50	20U	0.95755	0.00019		
4.85	**16**	**4.50**	**30**	**0.96580**	**0.00020**	**0.1452**	Burnup worth
4.85	16U	4.50	30	0.95641	0.00019		
4.85	**16**	**4.85**	**33**	**0.96501**	**0.00019**	**0.1522**	Burnup worth
4.85	16U	4.85	33	0.95678	0.00019		
2.90	0	2.50	0	0.99264	0.00010		BU worth, fresh fuel case
2.90	0	3.00	0	1.01238	0.00010		BU worth, fresh fuel case
2.90	0	3.50	0	1.02868	0.00010		BU worth, fresh fuel case
2.90	0	4.50	0	1.05431	0.00010		BU worth, fresh fuel case
2.90	0	4.85	0	1.06179	0.00010		BU worth, fresh fuel case
4.20	0	1.90	0	1.01498	0.00010		BU worth, fresh fuel case
4.20	0	2.50	0	1.04035	0.00010		BU worth, fresh fuel case
4.20	0	3.50	0	1.07250	0.00010		BU worth, fresh fuel case
4.20	0	4.50	0	1.09546	0.00010		BU worth, fresh fuel case
4.20	0	4.85	0	1.10190	0.00010		BU worth, fresh fuel case
4.85	0	1.90	0	1.03301	0.00010		BU worth, fresh fuel case
4.85	0	2.50	0	1.05760	0.00010		BU worth, fresh fuel case
4.85	0	3.50	0	1.08850	0.00010		BU worth, fresh fuel case
4.85	0	4.50	0	1.11054	0.00010		BU worth, fresh fuel case
4.85	0	4.85	0	1.11675	0.00010		BU worth, fresh fuel case

Tables 5.2-2
Region 2 Minor Actinides and Fission Product and Poison Box Worth (0 ppm soluble boron)

Enrichment (w/o U235)	2A Burnup (GWd/MTU)	Enrichment (w/o U235)	2B Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Burnup Worth or Sensitivity (dk)	Value
2.90	0	2.50	10U	0.97561	0.00019	**0.0187**	Minor actinides and FP
2.90	0	3.50	20U	0.98989	0.00019	0.0291	Minor actinides and FP
2.90	**0**	**4.50**	**30U**	**0.99905**	**0.00020**	**0.0372**	Minor actinides and FP
2.90	0	4.85	33U	1.00322	0.00019	0.0411	Minor actinides and FP
4.20	**10U**	**1.90**	**0**	**0.99205**	**0.00019**	**0.0284**	Minor actinides and FP
4.20	10U	2.50	10U	1.00294	0.00019	0.0456	Minor actinides and FP
4.20	**10U**	**3.50**	**20U**	**1.01645**	**0.00019**	**0.0549**	Minor actinides and FP
4.20	10U	4.50	30U	1.02560	0.00019	0.0642	Minor actinides and FP
4.20	**10U**	**4.85**	**33U**	**1.02853**	**0.00019**	**0.0659**	Minor actinides and FP
4.85	16U	1.90	0	0.99661	0.00019	**0.0374**	Minor actinides and FP
4.85	**16U**	**1.90**	**0**	**0.99676**	**0.00010**	**0.0374**	Minor actinides and FP
4.85	16U	2.50	10U	1.00738	0.00020	**0.0544**	Minor actinides and FP
4.85	16	3.50	20	1.01875	0.00019	**0.0570**	Minor actinides and FP
4.85	16	4.50	30	1.02810	0.00020	**0.0629**	Minor actinides and FP
4.85	**16**	**4.85**	**33**	**1.03063**	**0.00020**	**0.0662**	Minor actinides and FP
4.85	16	4.85	33	0.97767	0.00013	**0.1394**	28 Major isotopes worth
2.90	0	1.90	0	0.96403	0.00009	**0.0007**	No poison box in empty cell
2.90	0	1.90	0	0.98297	0.00009	**0.0271**	No poison box in empty cell with 50% zirc/water mix
4.85	**16**	**4.85**	**33**	**0.97796**	**0.00013**	**0.0007**	No poison box in empty cell
4.20	10	4.50	30	0.96039	0.00020		

Table 5.2-3
Region 2 Bias and Uncertainty (Fresh fuel, 0 ppm soluble boron)

Enrichment (w/o U235)	2A Burnup (GWd/MTU)	Enrichment (w/o U235)	2B Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
2.90	0	1.90	0	0.96355	0.00010		Base
2.90	0	1.90	0	0.96204	0.00009	-0.0012	1% longer fuel 1% less dense
2.95	**0**	**1.90**	**0**	**0.96572**	**0.00009**	**0.0024**	2A enrich +0.05 w/o
2.90	0	1.95	0	0.96619	0.00009	0.0029	2B enrich +0.05 w/o
2.95	**0**	**1.95**	**0**	**0.96865**	**0.00019**	**0.0055**	Enrich both + 0.05 w/o
2.90	0	1.90	0	0.96459	0.00019	0.0015	Increase 2A density
2.90	**0**	**1.90**	**0**	**0.96421**	**0.00019**	**0.0011**	Increase 2B density
2.90	0	1.90	0	0.96404	0.00010	0.0008	Increase 2B density rerun
2.90	**0**	**1.90**	**0**	**0.96563**	**0.00020**	**0.0025**	Increase fuel density
2.90	0	1.90	0	0.96450	0.00019	**0.0028**	Water temp 210 F (bias +0.0014)
2.90	**0**	**1.90**	**0**	**0.96416**	**0.00019**	**0.0014**	Water temp 110 F (bias +0.0004)
2.90	0	1.90	0	0.96355	0.00019	**0.0004**	Water temp 32 F
2.90	0	1.90	0	0.96357	0.00019	**0.0004**	Increase pellet OD
2.90	0	1.90	0	0.96320	0.00019	**0.0001**	Reduce pellet OD
2.90	**0**	**1.90**	**0**	**0.96466**	**0.00019**	**0.0015**	Reduce clad OR
2.90	0	1.90	0	0.96326	0.00019	**0.0001**	Increase clad IR
2.90	0	1.90	0	0.96325	0.00019	**0.0001**	Decrease clad IR
2.90	0	1.90	0	0.96377	0.00019	**0.0006**	Increase GT IR
2.90	**0**	**1.90**	**0**	**0.96356**	**0.00019**	**0.0004**	Reduce GT OR
2.90	0	1.90	0	0.96324	0.00018	0.0001	Increase GT OR
2.90	0	1.90	0	0.96447	0.00019	0.0013	Increase pin pitch
2.90	**0**	**1.90**	**0**	**0.97220**	**0.00019**	**0.0091**	Reduce rack pitch
2.90	0	1.90	0	0.96447	0.00019	**0.0013**	Reduce cell wall thickness
2.90	0	1.90	0	0.96229	0.00012	-0.0010	Asym placement monodirection
2.90	**0**	**1.90**	**0**	**0.96541**	**0.00012**	**0.0022**	Asym placement 4x4 in 6x6
2.90	0	1.90	0	0.96563	0.00012	**0.0024**	Thin poison wrapper

Table 5.2-4
Region 2 Bias and Uncertainty (Depleted fuel, 0 ppm soluble boron)

Enrichment (w/o U235)	2A Burnup (GWd/MTU)	Enrichment (w/o U235)	2B Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
4.85	16	4.85	33	0.97767	0.00013	N/A	28 Nuclide Base case
4.85	16	4.85	33	0.97409	0.00013	-0.0036	NO creep (dK)
N/A	N/A	N/A	N/A	N/A	N/A	N/A	2A Enrich + 0.05
N/A	N/A	N/A	N/A	N/A	N/A	N/A	2B Enrich + 0.05
4.85	**16**	**4.85**	**33**	**0.97845**	**0.00013**	**0.0011**	**Increase 2A density**
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Increase 2B density
4.85	**16**	**4.85**	**33**	**0.97917**	**0.00013**	**0.0033**	**Water temp 210 F (bias +0.0014)**
4.85	16	4.85	33	0.97849	0.00013	0.0016	Water temp 110 F (bias +0.0004)
4.85	16	4.85	33	0.97764	0.00013	0.0003	Water temp 32 F
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Increase pellet OD
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Reduce pellet OD
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Reduce clad OR
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Increase clad IR
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Decrease clad IR
4.85	**16**	**4.85**	**33**	**0.97780**	**0.00012**	**0.0005**	**Increase GT IR**
4.85	**16**	**4.85**	**33**	**0.97776**	**0.00013**	**0.0005**	**Reduce GT OR**
4.85	16	4.85	33	0.97742	0.00014	0.0001	Increase GT OR
4.85	**16**	**4.85**	**33**	**0.97883**	**0.00012**	**0.0015**	**Increase pin pitch**
4.85	**16**	**4.85**	**33**	**0.98596**	**0.00012**	**0.0086**	**Reduce rack pitch**
4.85	**16**	**4.85**	**33**	**0.97844**	**0.00013**	**0.0011**	**Reduce cell wall thickness**
4.85	**16**	**4.85**	**33**	**0.97973**	**0.00013**	**0.0024**	**Asym placement 4x4 in 6x6**
4.85	**16**	**4.85**	**33**	**0.97973**	**0.00013**	**0.0024**	**Thin poison wrapper**

Table 5.2-5
Part 1 – Region 2 Bias, Uncertainty, and Margin (0 ppm soluble boron)

	2A Burnup (GWd/MTU)	0	0	0	0	0	10	10	10	10	10
	2A Enrichment (w/o)	2.90	2.90	2.90	2.90	2.90	4.20	4.20	4.20	4.20	4.20
	2A BU worth (dK)	0.000	0.000	0.000	0.000	0.000	0.051	0.051	0.051	0.051	0.051
	2B Burnup (GWd/MTU)	0	10	20	30	33	0	10	20	30	33
	2B Enrichment (w/o)	1.90	2.50	3.50	4.50	4.85	1.90	2.50	3.50	4.50	4.85
	2B BU worth (dK)	0.000	0.036	0.068	0.092	0.100	0.000	0.032	0.060	0.083	0.088
	Total BU worth (dK)	0.000	0.036	0.068	0.092	0.100	0.051	0.083	0.111	0.134	0.139
	Minor actinide and FP worth (dK)	0.000	0.019	0.029	0.037	0.041	0.028	0.046	0.055	0.064	0.066
Case Type	**Case**										
Uncertainty	Rack wall thickness	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
Uncertainty	Pitch	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091
Uncertainty	2A Density	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Uncertainty	2B Density	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	2A Enrichment +0.05%	0.0024	0.0024	0.0024	0.0024	0.0024	0.0017	0.0017	0.0017	0.0017	0.0017
Uncertainty	2B Enrichment +0.05%	0.0029	0.0022	0.0016	0.0012	0.0011	0.0029	0.0022	0.0016	0.0012	0.0011
Uncertainty	2A Burnup worth (5%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0026	0.0026	0.0026	0.0026	0.0026
Uncertainty	2B Burnup worth (5%)	0.0000	0.0018	0.0034	0.0046	0.0050	0.0000	0.0016	0.0030	0.0041	0.0044
Uncertainty	2A Burnup (3.5%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0018	0.0018	0.0018	0.0018
Uncertainty	2B Burnup (3.5%)	0.0000	0.0012	0.0024	0.0032	0.0035	0.0000	0.0011	0.0021	0.0029	0.0031
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OD	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad ID	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
Uncertainty	Pin pitch	0.0013	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015
Uncertainty	GT ID	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Uncertainty	GT OD	0.0004	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Uncertainty	Poison wrapper thickness	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
Uncertainty	2 x KENO std. dev.	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
TOTAL UNCERT		**0.0118**	**0.0119**	**0.0123**	**0.0129**	**0.0130**	**0.0121**	**0.0120**	**0.0123**	**0.0128**	**0.0129**
Bias	1.5% total minor actnides and FP	0.0000	0.0003	0.0004	0.0006	0.0006	0.0004	0.0007	0.0008	0.0010	0.0010
Bias	Temperature	0.0028	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033
Bias	Off-center placement	0.0022	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
Bias	Empty cell poison box removal	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0156**	**0.0165**	**0.0167**	**0.0168**	**0.0168**	**0.0167**	**0.0169**	**0.0171**	**0.0172**	**0.0172**
Total bias and uncertainty (dK)		**0.0274**	**0.0284**	**0.0290**	**0.0296**	**0.0299**	**0.0288**	**0.0289**	**0.0294**	**0.0300**	**0.0301**
KENO K-effective		0.9636	0.9575	0.9613	0.9624	0.9626	0.9642	0.9579	0.9620	0.9620	0.9632
Dominion Margin (dK)		0.0091	0.0141	0.0097	0.0079	0.0075	0.0070	0.0132	0.0086	0.0081	0.0067

Table 5.2-6
Part 2 – Region 2 Bias, Uncertainty, and Margin (0 ppm soluble boron)

	2A Burnup (GWd/MTU)	16	16	16	16	16
	2A Enrichment (w/o)	4.85	4.85	4.85	4.85	4.85
	2A BU worth (dK)	0.074	0.074	0.074	0.074	0.074
	2B Burnup (GWd/MTU)	0	10	20	30	33
	2B Enrichment (w/o)	1.90	2.50	3.50	4.50	4.85
	2B BU worth (dK)	0.000	0.031	0.053	0.072	0.078
	Total BU worth (dK)	0.074	0.104	0.127	0.145	0.152
	Minor actinide and FP worth (dK)	0.037	0.054	0.057	0.063	0.066
Case Type	**Case**					
Uncertainty	Rack wall thickness	0.0013	0.0013	0.0013	0.0013	0.0011
Uncertainty	Pitch	0.0091	0.0091	0.0091	0.0091	0.0086
Uncertainty	2A Density	0.0015	0.0015	0.0015	0.0015	0.0011
Uncertainty	2B Density	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	2A Enrichment +0.05%	0.0015	0.0015	0.0015	0.0015	0.0015
Uncertainty	2B Enrichment +0.05%	0.0029	0.0022	0.0016	0.0012	0.0011
Uncertainty	2A Burnup worth (5%)	0.0037	0.0037	0.0037	0.0037	0.0037
Uncertainty	2B Burnup worth (5%)	0.0000	0.0015	0.0027	0.0036	0.0039
Uncertainty	2A Burnup (3.5%)	0.0026	0.0026	0.0026	0.0026	0.0026
Uncertainty	2B Burnup (3.5%)	0.0000	0.0011	0.0019	0.0025	0.0027
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0004	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OD	0.0015	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad ID	0.0001	0.0000	0.0000	0.0000	0.0000
Uncertainty	Pin pitch	0.0015	0.0015	0.0015	0.0015	0.0015
Uncertainty	GT ID	0.0006	0.0006	0.0006	0.0006	0.0005
Uncertainty	GT OD	0.0005	0.0005	0.0005	0.0005	0.0005
Uncertainty	Poison wrapper thinner	0.0024	0.0024	0.0024	0.0024	0.0024
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052
Uncertainty	2 x KENO std. dev.	0.0004	0.0004	0.0004	0.0004	0.0004
TOTAL UNCERT		**0.0125**	**0.0124**	**0.0126**	**0.0129**	**0.0127**
Bias	1.5% total minor actnides and FP	0.0006	0.0008	0.0009	0.0009	0.0010
Bias	Temperature	0.0033	0.0033	0.0033	0.0033	0.0033
Bias	Off-center placement	0.0024	0.0024	0.0024	0.0024	0.0024
Bias	Empty cell poison box removal	0.0007	0.0007	0.0007	0.0007	0.0007
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0168**	**0.0170**	**0.0171**	**0.0172**	**0.0172**
Total bias and uncertainty (dK)		**0.0293**	**0.0295**	**0.0297**	**0.0301**	**0.0299**
KENO K-effective		0.9596	0.9534	0.9623	0.9658	0.9650
Dominion Margin (dK)		0.0111	0.0171	0.0081	**0.0041**	0.0051

Table 5.2-7
Region 2 Bias and Uncertainty (Fresh fuel, 2000 ppm soluble boron)

Enrichment (w/o U235)	2A Burnup (GWd/MTU)	Enrichment (w/o U235)	2B Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
2.90	0	1.90	0	0.65755	0.00010	N/A	Base
2.90	**0**	**1.95**	**0**	**0.6599**	**0.00015**	**0.0027**	**2A enrich +0.05 w/o**
2.95	**0**	**1.90**	**0**	**0.6607**	**0.00016**	**0.0035**	**2B enrich +0.05 w/o**
2.90	**0**	**1.90**	**0**	**0.65998**	**0.00015**	**0.0028**	**Increase 2A density**
2.90	**0**	**1.90**	**0**	**0.65885**	**0.0001**	**0.0016**	**Increase 2B density**
2.90	**0**	**1.90**	**0**	**0.66619**	**0.00016**	**0.0105**	**Water temp 210 F (bias +0.0014)**
2.90	0	1.90	0	0.65805	0.00015	0.0009	Increase pellet OD
2.90	**0**	**1.90**	**0**	**N/A**	**N/A**	**N/A**	**Reduce pellet OD**
2.90	0	1.90	0	0.65795	0.0001	0.0007	Reduce clad OR
2.90	**0**	**1.90**	**0**	**0.65749**	**0.00015**	**0.0003**	**Increase clad IR**
2.90	0	1.90	0	0.65784	0.00016	0.0007	Reduce clad IR
2.90	**0**	**1.90**	**0**	**0.65741**	**0.00015**	**0.0002**	**Increase GT IR**
2.90	**0**	**1.90**	**0**	**0.65786**	**0.00016**	**0.0007**	**Reduce GT IR**
2.90	0	1.90	0	0.65744	0.00016	0.0003	Reduce GT OR
2.90	**0**	**1.90**	**0**	**0.65747**	**0.0001**	**0.0002**	**Increase GT OR**
2.90	**0**	**1.90**	**0**	**0.65812**	**0.0001**	**0.0009**	**Increase pin pitch**
2.90	0	1.90	0	0.66528	0.00015	0.0081	Reduce rack pitch
2.90	**0**	**1.90**	**0**	**0.65696**	**0.00015**	**-0.0002**	**Reduce cell wall thickness**
2.90	0	1.90	0	0.65794	0.00015	0.0008	Increase cell wall thickness
2.90	**0**	**1.90**	**0**	**0.65494**	**0.0001**	**-0.0023**	**Asym placement**
2.90	**0**	**1.90**	**0**	**0.66082**	**0.00011**	**0.0036**	**Asym placement 4x4 in 6x6**
2.90	0	1.90	0	0.65779	0.00010	0.0005	Thick poison wrapper
2.90	**0**	**1.90**	**0**	**0.65599**	**0.00010**	**-0.0013**	Remove poison box in empty cell

Table 5.2-8
Region 2 Bias and Uncertainty (Depleted fuel, 2000 ppm soluble boron)

2A Initial Enrichment (w/o U235)	2A Burnup (GWd/MTU)	2B Initial Enrichment (w/o U235)	2B Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
4.85	16	4.85	33	0.72020	0.00016	N/A	All nuclides
4.85	16	4.85	33	0.72803	0.00012	N/A	28 Nuclide Base case
4.85	16	4.85	33	0.72673	0.00011	-0.0013	No creep (dK only)
4.85	0	4.85	0	0.83405	0.00011	**0.1142**	Burnup worth (all nuclides)
4.85	16	4.85	33	0.75898	0.00017	**0.0392**	Minor actinides and FP worth
N/A	N/A	N/A	N/A	N/A	N/A	N/A	2A Enrich + 0.05
N/A	N/A	N/A	N/A	N/A	N/A	N/A	2B Enrich + 0.05
4.85	**16**	**4.85**	**33**	**0.73002**	**0.00011**	**0.0023**	**Increase 2A density**
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Increase 2B density
4.85	**16**	**4.85**	**33**	**0.73639**	**0.00011**	**0.0101**	**Water temp 210 F (bias +0.0014)**
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Water temp 110 F (bias +0.0004)
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Water temp 32 F
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Increase pellet OD
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Reduce pellet OD
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Reduce clad OR
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Increase clad IR
N/A	N/A	N/A	N/A	N/A	N/A	N/A	Decrease clad IR
4.85	**16**	**4.85**	**33**	**0.72779**	**0.00011**	**0.0001**	**Increase GT IR**
4.85	**16**	**4.85**	**33**	**0.72792**	**0.00011**	**0.0002**	**Reduce GT OR**
4.85	16	4.85	33	0.72793	0.00012	0.0002	Increase GT OR
4.85	**16**	**4.85**	**33**	**0.72878**	**0.00011**	**0.0011**	**Increase pin pitch**
4.85	**16**	**4.85**	**33**	**0.73652**	**0.00011**	**0.0088**	**Reduce rack pitch**
4.85	**16**	**4.85**	**33**	**0.72865**	**0.00011**	**0.0009**	**Reduce cell wall thickness**
4.85	**16**	**4.85**	**33**	**0.73197**	**0.00011**	**0.0043**	**Asym placement 4x4 in 6x6**
4.85	**16**	**4.85**	**33**	**0.72826**	**0.0001**	**0.0005**	**Thick poison wrapper**
4.85	16	4.85	33	0.72604	0.00012	-0.0017	Remove poison box in empty cell

Table 5.2-9
Part 1 – Region 2 Total Bias and Uncertainty (2000 ppm soluble boron)

	2A Burnup (GWd/MTU)	0	0	0	0	0	10	10	10	10	10
	2A Enrichment (w/o)	2.90	2.90	2.90	2.90	2.90	4.20	4.20	4.20	4.20	4.20
	2A BU worth (dK)	0.000	0.000	0.000	0.000	0.000	0.051	0.051	0.051	0.051	0.051
	2B Burnup (GWd/MTU)	0	10	20	30	33	0	10	20	30	33
	2B Enrichment (w/o)	1.90	2.50	3.50	4.50	4.85	1.90	2.50	3.50	4.50	4.85
	2B BU worth (dK)	0.000	0.036	0.068	0.092	0.100	0.000	0.032	0.060	0.083	0.088
	Total BU worth (dK)	0.000	0.036	0.068	0.092	0.100	0.051	0.083	0.111	0.134	0.139
	Minor actinide and FP worth (dK)	0.000	0.019	0.029	0.037	0.041	0.028	0.046	0.055	0.064	0.066
Case Type	**Case**										
Uncertainty	Rack wall thickness	0.0008	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009
Uncertainty	Pitch	0.0081	0.0088	0.0088	0.0088	0.0088	0.0088	0.0088	0.0088	0.0088	0.0088
Uncertainty	2A Density	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028
Uncertainty	2B Density	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
Uncertainty	2A Enrichment +0.05%	0.0027	0.0027	0.0027	0.0027	0.0027	0.0019	0.0019	0.0019	0.0019	0.0019
Uncertainty	2B Enrichment +0.05%	0.0035	0.0027	0.0019	0.0015	0.0014	0.0035	0.0027	0.0019	0.0015	0.0014
Uncertainty	2A Burnup worth (5%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0026	0.0026	0.0026	0.0026	0.0026
Uncertainty	2B Burnup worth (5%)	0.0000	0.0018	0.0034	0.0046	0.0050	0.0000	0.0016	0.0030	0.0041	0.0044
Uncertainty	2A Burnup (3.5%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0018	0.0018	0.0018	0.0018	0.0018
Uncertainty	2B Burnup (3.5%)	0.0000	0.0012	0.0024	0.0032	0.0035	0.0000	0.0011	0.0021	0.0029	0.0031
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OD	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad ID	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
Uncertainty	Pin pitch	0.0009	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011
Uncertainty	GT ID	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
Uncertainty	GT OD	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Uncertainty	Poison wrapper thickness	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
Uncertainty	2 x KENO std. dev.	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
TOTAL UNCERT		**0.0113**	**0.0118**	**0.0122**	**0.0127**	**0.0129**	**0.0121**	**0.0120**	**0.0122**	**0.0126**	**0.0128**
Bias	1.5% total minor actnides and FP	0.0000	0.0003	0.0004	0.0006	0.0006	0.0004	0.0007	0.0008	0.0010	0.0010
Bias	Temperature	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105
Bias	Off-center placement	0.0036	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0239**	**0.0248**	**0.0250**	**0.0251**	**0.0252**	**0.0250**	**0.0252**	**0.0254**	**0.0255**	**0.0256**
Total bias and uncertainty (dK)		**0.0351**	**0.0367**	**0.0372**	**0.0378**	**0.0381**	**0.0371**	**0.0372**	**0.0376**	**0.0382**	**0.0383**

Table 5.2-10
Part 2 – Region 2 Total Bias and Uncertainty (2000 ppm soluble boron)

	2A Burnup (GWd/MTU)	16	16	16	16	16
	2A Enrichment (w/o)	4.85	4.85	4.85	4.85	4.85
	2A BU worth (dK)	0.074	0.074	0.074	0.074	0.074
	2B Burnup (GWd/MTU)	0	10	20	30	33
	2B Enrichment (w/o)	1.90	2.50	3.50	4.50	4.85
	2B BU worth (dK)	0.000	0.031	0.053	0.072	0.078
	Total BU worth (dK)	0.074	0.104	0.127	0.145	0.152
	Minor actinide and FP worth (dK)	0.037	0.054	0.057	0.063	0.066
Case Type	**Case**					
Uncertainty	Rack wall thickness	0.0009	0.0009	0.0009	0.0009	0.0009
Uncertainty	Pitch	0.0088	0.0088	0.0088	0.0088	0.0088
Uncertainty	2A Density	0.0028	0.0028	0.0028	0.0028	0.0023
Uncertainty	2B Density	0.0016	0.0016	0.0016	0.0016	0.0016
Uncertainty	2A Enrichment +0.05%	0.0016	0.0016	0.0016	0.0016	0.0016
Uncertainty	2B Enrichment +0.05%	0.0035	0.0027	0.0019	0.0015	0.0014
Uncertainty	2A Burnup worth (5%)	0.0037	0.0037	0.0037	0.0037	0.0037
Uncertainty	2B Burnup worth (5%)	0.0000	0.0015	0.0027	0.0036	0.0039
Uncertainty	2A Burnup (3.5%)	0.0026	0.0026	0.0026	0.0026	0.0026
Uncertainty	2B Burnup (3.5%)	0.0000	0.0011	0.0019	0.0025	0.0027
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0009	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OD	0.0007	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad ID	0.0007	0.0000	0.0000	0.0000	0.0000
Uncertainty	Pin pitch	0.0011	0.0011	0.0011	0.0011	0.0011
Uncertainty	GT ID	0.0007	0.0007	0.0007	0.0007	0.0001
Uncertainty	GT OD	0.0003	0.0003	0.0003	0.0003	0.0002
Uncertainty	Poison wrapper thickness	0.0005	0.0005	0.0005	0.0005	0.0005
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052
Uncertainty	2 x KENO std. dev.	0.0003	0.0003	0.0003	0.0003	0.0003
TOTAL UNCERT		**0.0125**	**0.0123**	**0.0125**	**0.0128**	**0.0128**
Bias	1.5% total minor actnides and FP	0.0006	0.0008	0.0009	0.0009	0.0010
Bias	Temperature	0.0105	0.0105	0.0105	0.0105	0.0101
Bias	Off-center placement	0.0043	0.0043	0.0043	0.0043	0.0043
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0251**	**0.0254**	**0.0254**	**0.0255**	**0.0252**
Total bias and uncertainty (dK)		**0.0376**	**0.0377**	**0.0379**	**0.0383**	**0.0380**

5.3 Region 3

Region 3 features two different burnup credit curves, one for fuel containing three borated stainless steel rodlets (Section 5.3.1), and one for fuel containing a control element assembly (CEA, Section 5.3.2).

5.3.1 Region 3 (rodlets)

Tables 5.3.1-1 through 5.3.1-8 contain the revised bias, uncertainty and margin calculation for Region 3 (rodlets). Region 3 (rodlets) analysis allows 4-out-of-4 fuel storage. The burnup credit curve for Region 3 (rodlets) is shown on Figure 5.3.1-1. The fit line shown bounds the curve data points.

Figure 5.3.1-1

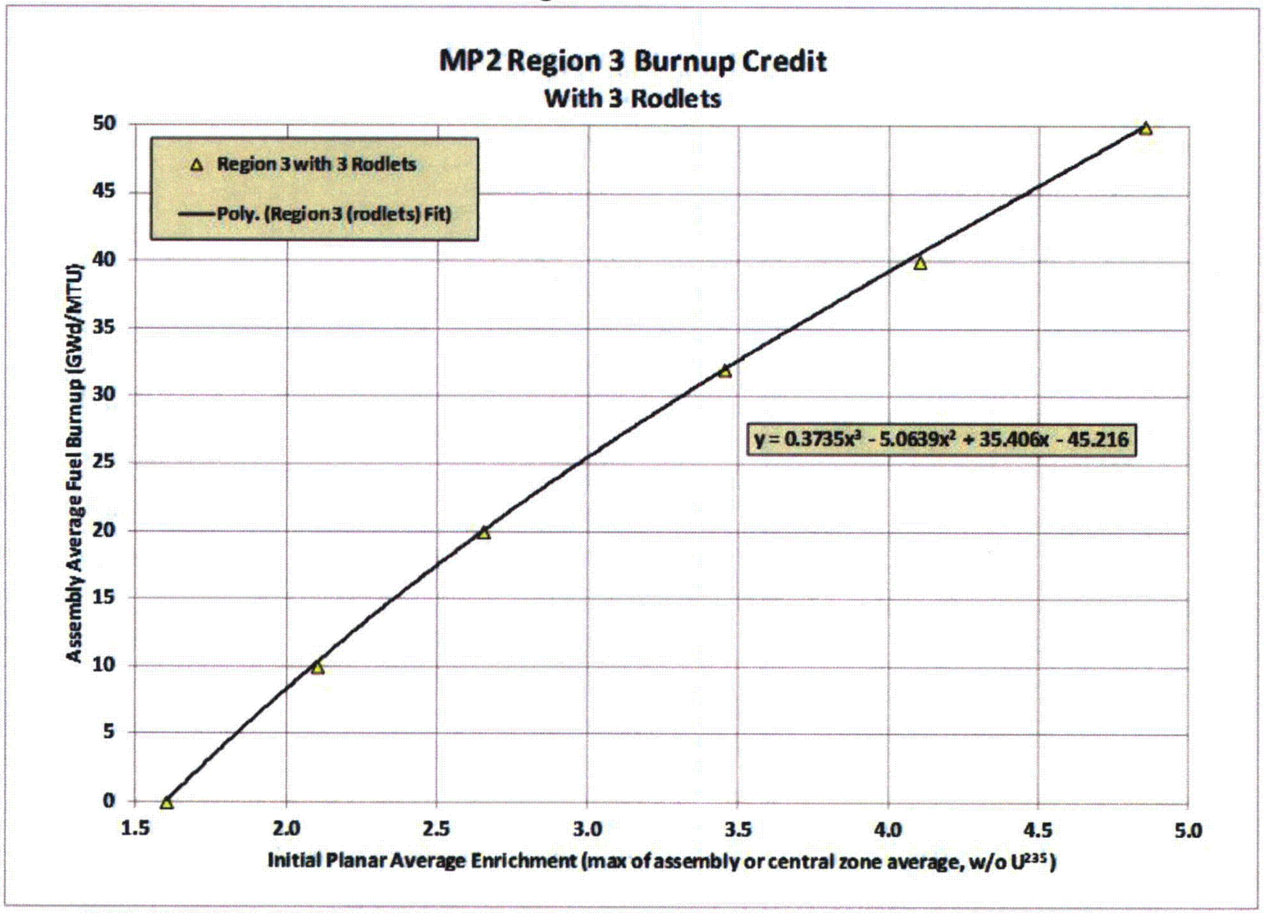


Table 5.3.1-1
Region 3 (rodlets) Burnup Worth (0 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Burnup Worth or Sensitivity (dk)	Value
1.60	0	0.96431	0.00008		Base
2.10	**10U**	**0.96123**	**0.00008**	**0.0942**	**Burnup worth**
2.10	10	0.95670	0.00008		Burnup worth
2.60	20U	0.93900	0.000081	0.1828	Burnup worth
2.65	20U	0.94429	0.000082		Burnup worth
2.65	**20**	**0.96254**	**0.000082**	**0.1650**	**Burnup worth**
2.70	20	0.96754	0.000082		Burnup worth
				0.0052	**Enrichment +0.05 w/o verif**
3.45	**32**	**0.96067**	**0.000087**	**0.2414**	**Burnup worth**
3.45*	32	0.96064	0.00009	0.2414	Burnup worth
3.5*	32	0.96473	0.00009	0.2409	Burnup worth
				0.0043	**Enrichment +0.05 w/o verif**
4.10	**40**	**0.95461**	**0.000093**	**0.2915**	**Burnup worth**
4.85	**50**	**0.95523**	**0.00009**	**0.3306**	**Burnup worth**
2.10	0	1.05521	0.00009		Fresh fuel geom
2.60	0	1.12154	0.00009		Fresh fuel geom
2.65	0	1.12728	0.00009		Fresh fuel geom
2.70	0	1.13290	0.00009		Fresh fuel geom
3.45	0	1.20179	0.00009		Fresh fuel geom
3.50	0	1.20539	0.00010		Fresh fuel geom
4.10	0	1.24586	0.00009		Fresh fuel geom
4.85	0	1.28553	0.00010		Fresh fuel geom
2.10	10	1.01003	0.00009	0.0536	Minor actinides and FP
2.10	**10U**	**1.01274**	**0.00008**	**0.0517**	**Minor actinides and FP**
2.60	20U	1.02027	0.00008	0.0815	Minor actinides and FP
2.65	**20**	**1.02862**	**0.00009**	**0.0663**	**Minor actinides and FP**
2.65	20U	1.02540	0.00009	0.0813	Minor actinides and FP
2.70	20	1.03344	0.00009	0.0661	Minor actinides and FP
3.45	**32**	**1.05007**	**0.00009**	**0.0896**	**Minor actinides and FP corr.**
3.45*	32	1.04961	0.00009	0.0892	Minor actinides and FP
3.5*	32	1.05393	0.00009	0.0894	Minor actinides and FP
				0.0046	**Enrichment +0.05 w/o verif**
4.10	**40**	**1.06132**	**0.00010**	**0.1070**	**Minor actinides and FP**
4.85	**50**	**1.07296**	**0.00009**	**0.1180**	**Minor actinides and FP**
4.85	**50**	**0.97945**	**0.00009**	**0.3064**	**28 Major isotopes worth**
4.85	50	0.95142	0.00009	0.0024	Creep worth (dK)
4.85	50	0.95384	0.00009	0.0014	Gap isotope reduction worth (dK)

Table 5.3.1-2
Region 3 (rodlets) Bias and Uncertainty (Fresh fuel, 0 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
1.60	0	0.96431	0.00008		Base
1.60	**0**	**0.96447**	**0.00008**	**0.0004**	**Offcenter rodlets 1**
1.60	0	0.96380	0.00008	-0.0003	Offcenter rodlets 2
1.60	0	0.96396	0.00008	-0.0001	Offcenter rodlets 3
1.65	**0**	**0.97492**	**0.00008**	**0.0108**	**Enrich +0.05 w/o**
1.60	**0**	**0.96695**	**0.00008**	**0.0029**	**Increase fuel density**
1.60	0	0.95775	0.00009	-0.0049	Water temp 210 F (bias +0.0014)
1.60	0	0.96274	0.00008	-0.0009	Water temp 110 F (bias +0.0004)
1.60	**0**	**0.96429**	**0.00008**	**0.0002**	**Water temp 32 F**
1.60	**0**	**0.96477**	**0.00008**	**0.0007**	**Increase pellet OD**
1.60	0	0.96391	0.00008	-0.0002	Reduce pellet OD
1.60	0	0.96369	0.00008	-0.0004	Increase clad OR
1.60	**0**	**0.96499**	**0.00008**	**0.0009**	**Reduce clad OR**
1.60	**0**	**0.96466**	**0.00008**	**0.0006**	**Increase clad IR**
1.60	0	0.96412	0.00008	0.0000	Reduce clad IR
1.60	**0**	**0.96419**	**0.00008**	**0.0001**	**Increase GT IR**
1.60	0	0.96422	0.00008	0.0002	Reduce GT OR
1.60	**0**	**0.96430**	**0.00009**	**0.0002**	**Increase GT OR**
1.60	0	0.96281	0.00008	-0.0013	Max Zr grids
1.60	**0**	**0.96618**	**0.00008**	**0.0021**	**Reduce rodlet dia**
1.60	**0**	**0.96491**	**0.00008**	**0.0008**	**Reduce rodlet boron**
1.60	**0**	**0.96526**	**0.00008**	**0.0012**	**Increase pin pitch**
1.60	**0**	**0.96681**	**0.00008**	**0.0027**	**Reduce rack cell pitch**
1.60	**0**	**0.96851**	**0.00008**	**0.0044**	**Reduce cell wall thickness**
1.60	0	0.96298	0.00008	-0.0011	Offcenter fuel 6x6 one direction*
1.60	0	0.96090	0.00008	-0.0032	Offcenter fuel max 4x4 in 6x6*
1.60	**0**	**0.96445**	**0.00008**	**0.0004**	**Offcenter fuel 6x6 one direction**
1.60	0	0.96223	0.00008	-0.0018	Offcenter fuel max 4x4 in 6x6

*Uniform rodlet orientation

Table 5.3.1-3
Region 3 (rodlets) Bias and Uncertainty (Depleted fuel, 0 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
4.85	50	0.97945	0.00009	N/A	28 Nuclide Base case reflected
4.85	50	0.97785	0.00009	-0.0016	28 nuclide base periodic
4.85	50	0.97698		-0.0025	NO creep (dK only)
4.85	50	0.97914	0.00009	-0.0001	Offcenter rodlets 1
4.85	50	0.97921	0.00009	0.0000	Offcenter rodlets 2
4.85	**50**	**0.97926**	**0.00009**	**0.0001**	**Offcenter rodlets 3**
4.85	50	N/A	N/A	N/A	Enrich +0.05 w/o
4.85	50	N/A	N/A	N/A	Increase fuel density
4.85	50	0.97772	0.00009	0.0000	Water temp 210 F (bias +0.0014)
4.85	50	N/A	N/A	N/A	Water temp 110 F (bias +0.0004)
4.85	**50**	**0.97942**	**0.00009**	**0.0002**	**Water temp 32 F**
4.85	50	N/A	N/A	N/A	Increase pellet OD
4.85	50	N/A	N/A	N/A	Reduce pellet OD
4.85	50	N/A	N/A	N/A	Reduce clad OR
4.85	50	N/A	N/A	N/A	Increase clad IR
4.85	50	N/A	N/A	N/A	Reduce clad IR
4.85	**50**	**0.97927**	**0.00010**	**0.0001**	**Increase GT IR**
4.85	**50**	**0.97935**	**0.00009**	**0.0002**	**Reduce GT OR**
4.85	50	0.97919	0.00009	0.0000	Increase GT OR
4.85	50	N/A	N/A	N/A	Max Zr grids
4.85	**50**	**0.98072**	**0.00009**	**0.0015**	**Reduce rodlet dia**
4.85	**50**	**0.97999**	**0.00009**	**0.0008**	**Reduce rodlet boron**
4.85	**50**	**0.98020**	**0.00010**	**0.0010**	**Increase fuel pin pitch**
4.85	**50**	**0.98127**	**0.00009**	**0.0021**	**Reduce rack cell pitch**
4.85	**50**	**0.98285**	**0.00009**	**0.0037**	**Reduce cell wall thickness**

Table 5.3.1-4
Region 3 (rodlets) Total Bias, Uncertainty, and Margin (0 ppm soluble boron)

	Burnup (GWd/MTU)	0	10	20	32	40	50
	Enrichment (w/o)	1.60	2.10	2.65	3.45	4.10	4.85
	Minor Actinides and FP	0.000	0.052	0.066	0.090	0.107	0.118
	BU worth (dK)	0.000	0.094	0.165	0.241	0.292	0.331
Case Type	**Case**						
Uncertainty	Rack wall thickness	0.0044	0.0044	0.0044	0.0044	0.0044	0.0037
Uncertainty	Rack cell pitch	0.0027	0.0027	0.0027	0.0027	0.0027	0.0021
Uncertainty	Fuel density	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
Uncertainty	Fuel enrichment	0.0108	0.0083	0.0065	0.0050	0.0042	0.0036
Uncertainty	Reduced rodlet diameter	0.0021	0.0021	0.0021	0.0021	0.0021	0.0015
Uncertainty	Off center rodlets	0.0004	0.0004	0.0004	0.0004	0.0004	0.0001
Uncertainty	Reduced Rodlet Boron	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Burnup worth (5%)	0.0000	0.0047	0.0082	0.0121	0.0146	0.0165
Uncertainty	Burnup (3.5%)	0.0000	0.0033	0.0058	0.0084	0.0102	0.0116
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OR	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad IR	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Increase fuel pin pitch	0.0012	0.0012	0.0012	0.0012	0.0012	0.0010
Uncertainty	GT OD	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Uncertainty	GT ID	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Uncertainty	2 x KENO std. dev.	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
TOTAL UNCERT		**0.0138**	**0.0131**	**0.0146**	**0.0177**	**0.0201**	**0.0218**
Bias	1.5% minor actnides and FP	0.0000	0.0008	0.0010	0.0013	0.0016	0.0018
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	Temperature	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Bias	Asymmetric fuel placement	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Bias	Maximum Zr grids	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bias	Use of assembly average enrich	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0114**	**0.0122**	**0.0124**	**0.0128**	**0.0130**	**0.0132**
Total bias and uncertainty (dK)		**0.0252**	**0.0253**	**0.0271**	**0.0305**	**0.0332**	**0.0351**
K-effective		**0.9643**	**0.9612**	**0.9625**	**0.9607**	**0.9546**	**0.9552**
Dominion margin (dK)		**0.0105**	**0.0135**	**0.0104**	**0.0089**	**0.0122**	**0.0097**

Table 5.3.1-5
Region 3 (rodlets) Burnup Worth (2000 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Burnup Worth or Sensitivity (dk)	Value
1.60	0	0.63745	0.00006	0.00000	Base
2.10	**10U**	**0.67968**	**0.00007**	**0.0461**	**Burnup worth**
2.10	10	0.67679	0.00007		Burnup worth
2.65	**20**	**0.69741**	**0.00008**	**0.1045**	**Burnup worth**
3.45	**32**	**0.71356**	**0.00008**	**0.1731**	**Burnup worth**
4.10	**40**	**0.71870**	**0.00008**	**0.2215**	**Burnup worth**
4.85	**50**	**0.72768**	**0.00008**	**0.2631**	**Burnup worth**
2.10	0	0.72561	0.00007		Fresh fuel geom base case
2.65	0	0.80165	0.00008		Fresh fuel geom base case
3.45	0	0.88639	0.00009		Fresh fuel geom base case
4.10	0	0.94000	0.00008		Fresh fuel geom base case
4.85	0	0.99051	0.00008		Fresh fuel geom base case
2.10	10	0.70570	0.00007	0.0291	Minor actinides and FP
2.10	**10U**	**0.70769**	**0.00007**	**0.0282**	**Minor actinides and FP**
2.65	**20**	**0.73497**	**0.00007**	**0.0378**	**Minor actinides and FP**
3.45	**32**	**0.76580**	**0.00008**	**0.0525**	**Minor actinides and FP**
4.10	**40**	**0.78248**	**0.00008**	**0.0640**	**Minor actinides and FP**
4.85	**50**	**0.79947**	**0.00008**	**0.0720**	**Minor actinides and FP**

Table 5.3.1-6
Region 3 (rodlets) Bias and Uncertainty (Fresh fuel, 2000 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
1.60	0	0.63745	0.00006		Base
1.60	**0**	**0.63763**	**0.00007**	**0.0004**	**Offcenter rodlets 1**
1.60	0	0.63678	0.00007	-0.0005	Offcenter rodlets 2
1.60	0	0.63710	0.00006	-0.0002	Offcenter rodlets 3
1.65	**0**	**0.64736**	**0.00007**	**0.0101**	**Enrich +0.05 w/o**
1.60	**0**	**0.64119**	**0.00007**	**0.0039**	**Increase fuel density**
1.60	**0**	**0.64303**	**0.00007**	**0.0072**	**Water temp 210 F (bias +0.00144)**
1.60	0	0.63712	0.00006	-0.0001	Water temp 32 F
1.60	**0**	**0.63812**	**0.00006**	**0.0008**	**Increase pellet OD**
1.60	0	0.63679	0.00006	-0.0005	Reduce pellet OD
1.60	0	0.63695	0.00006	-0.0003	Reduce clad OR
1.60	**0**	**0.63784**	**0.00006**	**0.0006**	**Increase clad OR**
1.60	**0**	**0.63737**	**0.00007**	**0.0001**	**Increase clad IR**
1.60	0	0.63724	0.00006	0.0000	Reduce clad IR
1.60	**0**	**0.63755**	**0.00007**	**0.0003**	**Increase GT IR**
1.60	0	0.63731	0.00006	0.0000	Reduce GT OR
1.60	**0**	**0.63752**	**0.00006**	**0.0003**	**Increase GT OR**
1.60	**0**	**0.63794**	**0.00006**	**0.0007**	**Max Zr grids**
1.60	**0**	**0.63836**	**0.00007**	**0.0011**	**Reduce rodlet dia**
1.60	**0**	**0.63806**	**0.00006**	**0.0008**	**Reduce rodlet boron**
1.60	**0**	**0.63815**	**0.00006**	**0.0009**	**Increase fuel pin pitch**
1.60	**0**	**0.64136**	**0.00007**	**0.0041**	**Reduce rack cell pitch**
1.60	**0**	**0.63746**	**0.00006**	**0.0002**	**Reduce cell wall thickness**
1.60	0	0.63431	0.00007	-0.0030	Offcenter fuel 6x6 one direction
1.60	**0**	**0.64013**	**0.00007**	**0.0029**	**Offcenter fuel max 4x4 in 6x6**

Table 5.3.1-7
Region 3 (rodlets) Bias and Uncertainty (Depleted fuel, 2000 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
4.85	50	0.74321	0.00008	N/A	28 Nuclide Base case reflected
4.85	50	0.74298	0.00008	-0.0002	28 nuclide base periodic (dK)
4.85	**50**	**0.74350**	**0.00008**	**0.0005**	**No creep (incl uncert)**
4.85	**50**	**0.74356**	**0.00008**	**0.0006**	**Offcenter rodlets 1**
4.85	50	0.74314	0.00008	0.0002	Offcenter rodlets 2
4.85	50	0.74306	0.00008	0.0001	Offcenter rodlets 3
4.85	50	N/A	N/A	N/A	Enrich +0.05 w/o
4.85	50	N/A	N/A	N/A	Increase fuel density
4.85	**50**	**0.75257**	**0.00008**	**0.0110**	**Water temp 210 F (bias +0.00144)**
4.85	**50**	N/A	N/A	N/A	Water temp 32 F
4.85	50	N/A	N/A	N/A	Water temp 32 F
4.85	50	N/A	N/A	N/A	Increase pellet OD
4.85	50	N/A	N/A	N/A	Increase clad OR
4.85	50	N/A	N/A	N/A	Increase clad IR
4.85	50	N/A	N/A	N/A	Reduce clad IR
4.85	**50**	**0.74333**	**0.00008**	**0.0004**	**Increase GT IR**
4.85	50	0.74320	0.00008	0.0002	Reduce GT OR
4.85	**50**	**0.74333**	**0.00009**	**0.0004**	**Increase GT OR**
4.85	50	N/A	N/A	N/A	Max Zr grids
4.85	**50**	**0.74426**	**0.00008**	**0.0013**	**Reduce rodlet dia**
4.85	**50**	**0.74393**	**0.00008**	**0.0010**	**Reduce rodlet boron**
4.85	**50**	**0.74438**	**0.00008**	**0.0014**	**Increase fuel pin pitch**
4.85	**50**	**0.74740**	**0.00008**	**0.0044**	**Reduce rack cell pitch**
4.85	**50**	**0.74357**	**0.00008**	**0.0006**	**Reduce cell wall thickness**

Table 5.3.1-8
Region 3 (rodlets) Total Bias and Uncertainty (2000 ppm soluble boron)

	Burnup (GWd/MTU)	0	10	20	32	40	50
	Enrichment (w/o)	1.60	2.10	2.65	3.45	4.10	4.85
	Minor Actinides and FP	0.000	0.028	0.038	0.052	0.064	0.072
	BU worth (dK)	0.000	0.046	0.104	0.173	0.222	0.263
Case Type	**Case**						
Uncertainty	Rack wall thickness	0.0002	0.0006	0.0006	0.0006	0.0006	0.0006
Uncertainty	Rack Pitch	0.0041	0.0044	0.0044	0.0044	0.0044	0.0044
Uncertainty	Density	0.0039	0.0039	0.0039	0.0039	0.0039	0.0039
Uncertainty	Enrichment	0.0101	0.0077	0.0061	0.0047	0.0039	0.0033
Uncertainty	Reduced rodlet diameter	0.0011	0.0013	0.0013	0.0013	0.0013	0.0013
Uncertainty	Off center rodlets	0.0004	0.0006	0.0006	0.0006	0.0006	0.0006
Uncertainty	Reduced Rodlet Boron	0.0008	0.0010	0.0010	0.0010	0.0010	0.0010
Uncertainty	Burnup worth (5%)	0.0000	0.0023	0.0052	0.0087	0.0111	0.0132
Uncertainty	Burnup (3.5%)	0.0000	0.0016	0.0037	0.0061	0.0078	0.0092
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OR	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad IR	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Increase fuel pin pitch	0.0009	0.0014	0.0014	0.0014	0.0014	0.0014
Uncertainty	GT OD	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004
Uncertainty	GT ID	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004
Uncertainty	2 x KENO std. dev.	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
TOTAL UNCERT		**0.0129**	**0.0116**	**0.0121**	**0.0142**	**0.0163**	**0.0184**
Bias	1.5% minor actnides and FP	0.0000	0.0004	0.0006	0.0008	0.0010	0.0011
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	Temperature	0.0072	0.0110	0.0110	0.0110	0.0110	0.0110
Bias	Maximum Zr grids	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
Bias	Asymmetric fuel placement	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
Bias	Creep dimension assumption	0.0000	0.0005	0.0005	0.0005	0.0005	0.0005
Bias	Use of assembly average enrich	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0216**	**0.0264**	**0.0265**	**0.0267**	**0.0269**	**0.0270**
Total bias and uncertainty (dK)		**0.0344**	**0.0380**	**0.0386**	**0.0409**	**0.0432**	**0.0454**

5.3.2 Region 3 (CEA)

Tables 5.3.2-1 through 5.3.2-8 contain the revised bias, uncertainty and margin calculation for Region 3 (CEA). Region 3 (CEA) analysis allows 4-out-of-4 fuel storage. The burnup credit curve for Region 3 (CEA) is shown on Figure 5.3.2-1. The fit line shown bounds the curve data points.

Figure 5.3.2-1

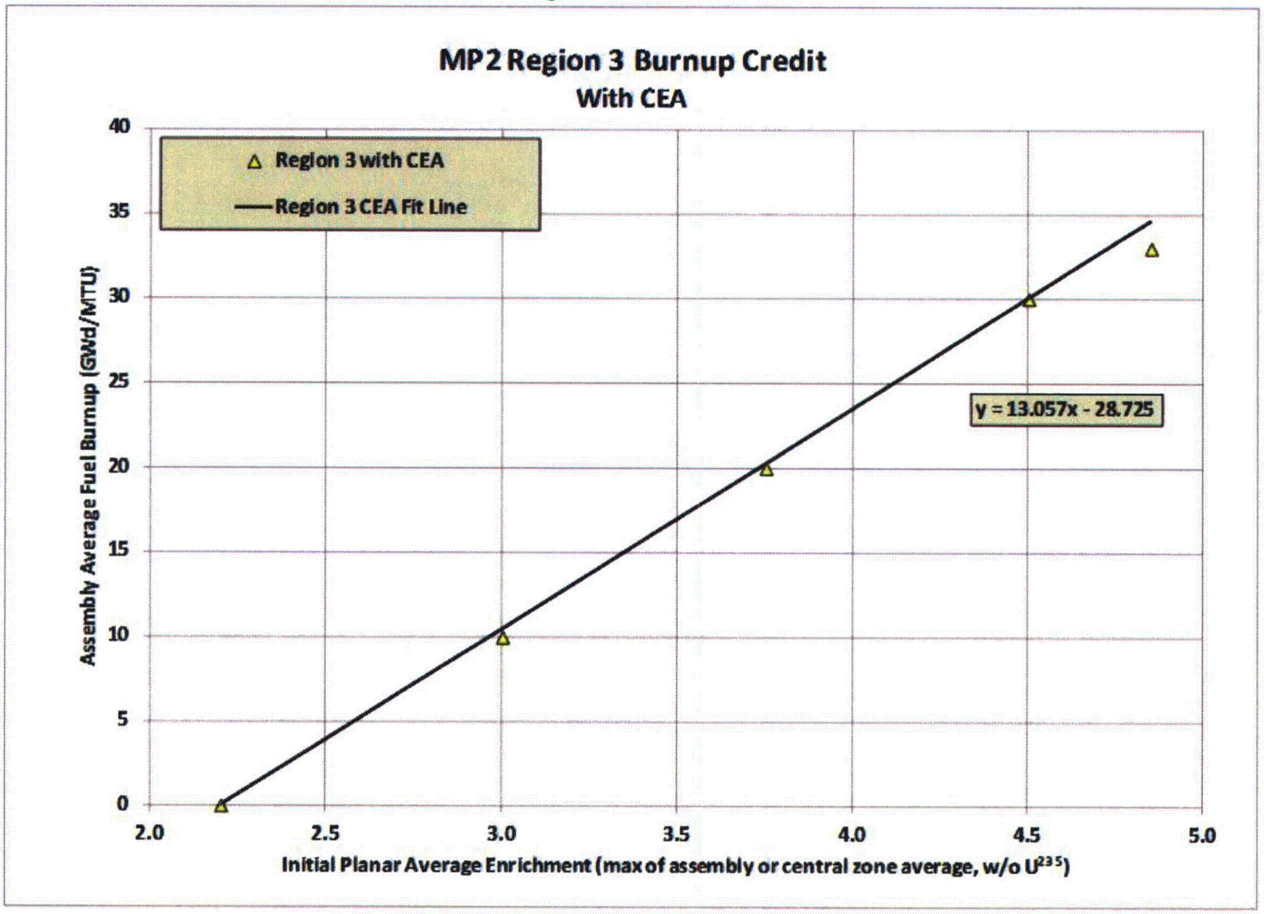


Table 5.3.2-1
Region 3 (CEA) Burnup Worth (0 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Burnup Worth or Sensitivity (dk)	Value
2.20	0	0.96045	0.00009		Base
2.50	10U	0.91233	0.00009		Shape check
2.50	10	0.91351	0.00009		Shape check
3.00	**10**	**0.96410**	**0.00009**	**0.0878**	**Burnup worth**
				0.0051	Enrich. sens check +0.05 w/o
3.50	20U	0.93083	0.00009		Shape check
3.50	20	0.94283	0.00009		Shape check
3.75	**20**	**0.96144**	**0.00009**	**0.1504**	**Burnup worth**
				0.0038	Enrich. sens check +0.05 w/o
4.50	**30**	**0.95983**	**0.00009**	**0.1971**	**Burnup worth**
4.85	**33**	**0.95961**	**0.00009**	**0.2151**	**Burnup worth**
3.00	0	1.05161	0.00009		Fresh fuel geom
3.75	0	1.11159	0.00010		Fresh fuel geom
4.50	0	1.15663	0.00010		Fresh fuel geom
4.85	0	1.17439	0.00010		Fresh fuel geom
4.90	0	1.17672	0.00010	0.0026	Enrich. sens check +0.05 w/o
3.00	10	1.00546	0.00010	0.0416	Minor actinides and FP
3.75	20	1.02064	0.00010	0.0595	Minor actinides and FP
4.50	30	1.03433	0.00010	0.0748	Minor actinides and FP
4.85	33	1.04088	0.00010	0.0815	Minor actinides and FP
4.85	33	0.97599	0.00009	0.1987	28 Major isotopes worth
4.85	33	0.95655	0.00010	0.0031	Creep worth (dK)
4.85	33	0.95561	0.00010	0.0009	Gap isotopes worth (dK)

Table 5.3.2-2
Region 3 (CEA) Bias and Uncertainty (Fresh fuel, 0 ppm soluble boron)

Initial Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
2.20	0	0.96045	0.00009		Base
2.20	0	0.95997	0.00009	-0.0002	Offcenter CEA 1
2.20	**0**	**0.96040**	**0.00009**	**0.0002**	**Offcenter CEA 2**
2.25	**0**	**0.96719**	**0.00009**	**0.0070**	**Enrich +0.05 w/o**
2.20	**0**	**0.96293**	**0.00009**	**0.0027**	**Increase density**
2.20	0	0.94977	0.00009	-0.0090	Water temp 210 F (bias +0.0014)
2.20	0	0.95800	0.00009	-0.0018	Water temp 110 F (bias +0.0004)
2.20	**0**	**0.96056**	**0.00009**	**0.0004**	**Water temp 32 F**
2.20	**0**	**0.96088**	**0.00009**	**0.0007**	**Increase pellet OD**
2.20	0	0.96009	0.00009	-0.0001	Reduce pellet OD
2.20	**0**	**0.96149**	**0.00009**	**0.0013**	**Reduce clad OR**
2.20	**0**	**0.96045**	**0.00009**	**0.0002**	**Increase clad IR**
2.20	0	0.96018	0.00009	0.0000	Reduce clad IR
2.20	**0**	**0.96046**	**0.00009**	**0.0003**	**Increase GT IR**
2.20	0	0.96044	0.00009	0.0002	Reduce GT OR
2.20	**0**	**0.96049**	**0.00009**	**0.0003**	**Increase GT OR**
2.20	**0**	0.95794	0.00009	-0.0023	Max Zr grids
2.20	**0**	**0.96035**	**0.00009**	**0.0002**	**Reduce CEA clad OD**
2.20	**0**	**0.96029**	**0.00009**	**0.0001**	**Increase CEA clad ID**
2.20	**0**	**0.96050**	**0.00009**	**0.0003**	**Reduce CEA B4C OD**
2.20	**0**	**0.96056**	**0.00009**	**0.0004**	**Reduce CEA AIC OD**
2.20	**0**	**0.96055**	**0.00009**	**0.0004**	**Increase CEA AIC annulus ID**
2.20	**0**	**0.96188**	**0.00009**	**0.0017**	**CEA shifted up 1 cm**
2.20	**0**	**0.96131**	**0.00009**	**0.0011**	**Increase fuel pin pitch**
2.20	**0**	**0.96243**	**0.00009**	**0.0022**	**Reduce rack pitch**
2.20	**0**	**0.96501**	**0.00009**	**0.0048**	**Reduce rack cell wall thickness**
2.20	**0**	**0.96207**	**0.00009**	**0.0019**	**Offcenter fuel monodirectional**
2.20	0	0.95787	0.00009	-0.0023	Offcenter fuel max 4x4 in 6x6

Table 5.3.2-3
Region 3 (CEA) Bias and Uncertainty (Depleted fuel, 0 ppm soluble boron)

Initial Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
4.85	33	0.95961	0.00009		Base
4.85	33	0.97599	0.00009		28 nuclides for uncert. Cases
4.85	33	0.97592	0.00010	0.0002	Offcenter CEA 1
4.85	**33**	**0.97603**	**0.00001**	**0.0002**	**Offcenter CEA 2**
N/A	N/A	N/A	N/A	N/A	Enrich +0.05 w/o
N/A	N/A	N/A	N/A	N/A	Increase density
4.85	33	0.96984	0.00009	-0.0044	Water temp 210 F (bias +0.0014)
N/A	N/A	N/A	N/A	N/A	Water temp 110 F (bias +0.0004)
4.85	**33**	**0.97615**	**0.00009**	**0.0004**	**Water temp 32 F**
N/A	N/A	N/A	N/A	N/A	Increase pellet OD
N/A	N/A	N/A	N/A	N/A	Reduce pellet OD
N/A	N/A	N/A	N/A	N/A	Increase clad OR
N/A	N/A	N/A	N/A	N/A	Increase clad IR
4.85	**33**	**0.97605**	**0.00009**	**0.0003**	**Increase GT IR**
4.85	**33**	**0.97605**	**0.00009**	**0.0003**	**Reduce GT OR**
4.85	**33**	**0.97602**	**0.00010**	**0.0003**	**Increase GT OR**
N/A	N/A	N/A	N/A	N/A	Max Zr grids
4.85	**33**	**0.97597**	**0.00009**	**0.0002**	**Reduce CEA clad OD**
4.85	33	0.97576	0.00010	0.0000	Increase CEA clad ID
4.85	**33**	**0.97597**	**0.00010**	**0.0003**	**Reduce CEA B4C OD**
4.85	**33**	**0.97629**	**0.00001**	**0.0005**	**Reduce CEA AIC OD**
4.85	**33**	**0.97674**	**0.00010**	**0.0010**	**Increase fuel pin pitch**
4.85	**33**	**0.97736**	**0.00009**	**0.0016**	**Reduce rack pitch**
4.85	**33**	**0.97986**	**0.00009**	**0.0041**	**Reduce rack cell wall thickness**

Table 5.3.2-4
Region 3 (CEA) Total Bias, Uncertainty, and Margin (0 ppm soluble boron)

	Burnup (GWd/MTU)	0	10	20	30	33
	Enrichment (w/o)	2.20	3.00	3.75	4.50	4.85
	Minor Actinides and FP	0.000	0.042	0.059	0.075	0.082
	BU worth (dK)	0.000	0.088	0.150	0.197	0.215
Case Type	**Case**					
Uncertainty	Rack wall thickness	0.0048	0.0048	0.0048	0.0048	0.0041
Uncertainty	Rack Pitch	0.0022	0.0022	0.0022	0.0022	0.0016
Uncertainty	Density	0.0027	0.0027	0.0027	0.0027	0.0027
Uncertainty	Enrichment	0.0070	0.0051	0.0041	0.0034	0.0032
Uncertainty	Burnup worth (5%)	0.0000	0.0044	0.0075	0.0099	0.0108
Uncertainty	Burnup (3.5%)	0.0000	0.0031	0.0053	0.0069	0.0075
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0007	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OR	0.0013	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad IR	0.0002	0.0000	0.0000	0.0000	0.0000
Uncertainty	Pin pitch	0.0011	0.0011	0.0011	0.0011	0.0010
Uncertainty	GT OD	0.0003	0.0003	0.0003	0.0003	0.0003
Uncertainty	GT ID	0.0003	0.0003	0.0003	0.0003	0.0003
Uncertainty	2 x KENO std. dev.	0.0002	0.0002	0.0002	0.0002	0.0002
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052
TOTAL UNCERT		**0.0108**	**0.0109**	**0.0129**	**0.0149**	**0.0154**
Bias	1.5% minor actnides and FP	0.0000	0.0006	0.0009	0.0011	0.0012
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	Temperature	0.0004	0.0004	0.0004	0.0004	0.0004
Bias	Asymetric fuel placement	0.0019	0.0019	0.0019	0.0019	0.0019
Bias	Use of assembly average enrich	0.0010	0.0010	0.0010	0.0010	0.0010
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0131**	**0.0137**	**0.0140**	**0.0142**	**0.0144**
Total bias and uncertainty (dK)		**0.0238**	**0.0246**	**0.0268**	**0.0291**	**0.0298**
K-effective		**0.9605**	**0.9641**	**0.9614**	**0.9598**	**0.9596**
Dominion margin (dK)		**0.0157**	**0.0113**	**0.0117**	**0.0111**	**0.0106**

Table 5.3.2-5
Region 3 (CEA) Burnup Worth (2000 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Burnup Worth or Sensitivity (dk)	Value
2.20	0	0.68507	0.00008		Base
3.00	**10**	**0.72080**	**0.00008**	**0.0598**	**Burnup worth**
3.75	**20**	**0.73754**	**0.00008**	**0.1105**	**Burnup worth**
4.50	**30**	**0.74765**	**0.00008**	**0.1538**	**Burnup worth**
4.85	**33**	**0.75136**	**0.00008**	**0.1718**	**Burnup worth**
3.00	0	0.78036	0.00009		Fresh fuel geom
3.75	0	0.84776	0.00009		Fresh fuel geom
4.50	0	0.90125	0.00009		Fresh fuel geom
4.85	0	0.92293	0.00009		Fresh fuel geom
3.00	**10**	**0.74830**	**0.00008**	**0.0277**	**Minor actinides and FP**
3.75	**20**	**0.77517**	**0.00008**	**0.0378**	**Minor actinides and FP**
4.50	**30**	**0.79637**	**0.00008**	**0.0489**	**Minor actinides and FP**
4.85	**33**	**0.80472**	**0.00009**	**0.0536**	**Minor actinides and FP**
4.85	33	0.76298	0.00009	0.1602	28 Major isotopes worth
4.85	33	0.75101	0.00008	0.0003	Creep worth (dK)
4.85	33	0.75017	0.00008	0.0008	Gap isotopes worth (dK)

Table 5.3.2-6
Region 3 (CEA) Bias and Uncertainty (Fresh fuel, 2000 ppm soluble boron)

Initial Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
2.20	0	0.68507	0.00008		Base
2.20	0	0.68444	0.00007	-0.0004	Offcenter CEA 1
2.20	**0**	**0.68536**	**0.00008**	**0.0005**	**Offcenter CEA 2**
2.25	**0**	**0.69187**	**0.00008**	**0.0070**	**Enrich +0.05 w/o**
2.20	**0**	**0.68867**	**0.00008**	**0.0038**	**Increase density**
2.20	**0**	**0.68741**	**0.00007**	**0.0040**	**Water temp 210 F (bias +0.0014)**
2.20	**0**	**0.68561**	**0.00007**	**0.0008**	**Increase pellet OD**
2.20	0	0.68428	0.00007	-0.0006	Reduce pellet OD
2.20	0	0.68477	0.00008	-0.0001	Reduce clad OR
2.20	**0**	**0.68508**	**0.00007**	**0.0002**	**Increase clad OR**
2.20	**0**	**0.68505**	**0.00007**	**0.0002**	**Increase clad IR**
2.20	0	0.68478	0.00007	-0.0001	Reduce clad IR
2.20	0	0.68481	0.00007	-0.0001	Increase GT IR
2.20	**0**	**0.68494**	**0.00007**	**0.0001**	**Reduce GT IR**
2.20	**0**	**0.68499**	**0.00007**	**0.0001**	**Reduce GT OR**
2.20	0	0.68484	0.00007	0.0000	Increase GT OR
2.20	0	0.68470	0.00007	-0.0002	Max Zr grids
2.20	**0**	**0.68492**	**0.00008**	**0.0001**	**Reduce CEA clad OD**
2.20	0	0.68473	0.00007	-0.0001	Increase CEA clad ID
2.20	**0**	**0.68502**	**0.00007**	**0.0002**	**Reduce CEA B4C OD**
2.20	**0**	**0.68501**	**0.00007**	**0.0001**	**Reduce CEA AIC OD**
2.20	**0**	**0.68512**	**0.00007**	**0.0003**	**CEA shifted up 1 cm**
2.20	**0**	**0.68569**	**0.00007**	**0.0008**	**Increase fuel pin pitch**
2.20	**0**	**0.68877**	**0.00007**	**0.0039**	**Reduce rack pitch**
2.20	**0**	**0.68513**	**0.00008**	**0.0003**	**Reduce rack cell wall thickness**
2.20	0	0.68183	0.00008	-0.0030	Offcenter fuel monodirectional
2.20	**0**	**0.68558**	**0.00008**	**0.0007**	**Offcenter fuel max 4x4 in 6x6**

Table 5.3.2-7
Region 3 (CEA) Bias and Uncertainty (Depleted fuel, 2000 ppm soluble boron)

Initial Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
4.85	33	0.75136	0.00008		Base
4.85	33	0.76298	0.00009		28 nuclides for uncert. Cases
4.85	33	0.76253	0.00008	-0.0002	Offcenter CEA 1
4.85	**33**	**0.76327**	**0.00008**	**0.0005**	**Offcenter CEA 2**
N/A	N/A	N/A	N/A	N/A	Enrich +0.05 w/o
N/A	N/A	N/A	N/A	N/A	Density +1.6%
4.85	**33**	**0.76822**	**0.00008**	**0.0069**	**Water temp 210 F (bias+0.0014)**
N/A	N/A	N/A	N/A	N/A	Water temp 32 F
N/A	N/A	N/A	N/A	N/A	Increase pellet OD
N/A	N/A	N/A	N/A	N/A	Reduce pellet OD
N/A	N/A	N/A	N/A	N/A	Increase clad OR
N/A	N/A	N/A	N/A	N/A	Increase clad IR
N/A	N/A	N/A	N/A	N/A	Reduce clad IR
4.85	**33**	**0.76294**	**0.00008**	**0.0002**	**Increase GT IR**
4.85	**33**	**0.76293**	**0.00008**	**0.0002**	**Reduce GT OR**
4.85	**33**	**0.76292**	**0.00009**	**0.0002**	**Increase GT OR**
N/A	N/A	N/A	N/A	N/A	Max Zr grids
4.85	**33**	**0.76290**	**0.00008**	**0.0002**	**Reduce CEA clad OD**
4.85	33	0.76269	0.00009	0.0000	Increase CEA clad ID
4.85	**33**	**0.76281**	**0.00008**	**0.0001**	**Reduce CEA B4C OD**
4.85	33	0.76270	0.00008	0.0000	Reduce CEA AIC OD
4.85	**33**	**0.76402**	**0.00008**	**0.0013**	**Increase fuel pin pitch**
4.85	**33**	**0.76679**	**0.00008**	**0.0041**	**Reduce rack pitch**
4.85	**33**	**0.76311**	**0.00008**	**0.0004**	**Reduce rack cell wall thickness**

Table 5.3.2-8
Region 3 (CEA) Total Bias and Uncertainty (2000 ppm soluble boron)

	Burnup (GWd/MTU)	0	10	20	30	33
	Enrichment (w/o)	2.20	3.00	3.75	4.50	4.85
	Minor Actinides and FP	0.000	0.028	0.038	0.049	0.054
	BU worth (dK)	0.000	0.060	0.110	0.154	0.172
Case Type	**Case**					
Uncertainty	Rack wall thickness	0.0003	0.0004	0.0004	0.0004	0.0004
Uncertainty	Rack Pitch	0.0039	0.0041	0.0041	0.0041	0.0041
Uncertainty	Density	0.0038	0.0038	0.0038	0.0038	0.0038
Uncertainty	Enrichment	0.0070	0.0051	0.0041	0.0034	0.0032
Uncertainty	Burnup worth (5%)	0.0000	0.0030	0.0055	0.0077	0.0086
Uncertainty	Burnup (3.5%)	0.0000	0.0021	0.0039	0.0054	0.0060
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0008	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OR	0.0002	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad IR	0.0002	0.0000	0.0000	0.0000	0.0000
Uncertainty	Pin pitch	0.0008	0.0013	0.0013	0.0013	0.0013
Uncertainty	GT OD	0.0001	0.0002	0.0002	0.0002	0.0002
Uncertainty	GT ID	0.0001	0.0002	0.0002	0.0002	0.0002
Uncertainty	2 x KENO std. dev.	0.0002	0.0002	0.0002	0.0002	0.0002
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052
TOTAL UNCERT		**0.0104**	**0.0100**	**0.0111**	**0.0127**	**0.0134**
Bias	1.5% minor actnides and FP	0.0000	0.0004	0.0006	0.0007	0.0008
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	Temperature	0.0040	0.0069	0.0069	0.0069	0.0069
Bias	Asymmetric fuel placement	0.0007	0.0007	0.0007	0.0007	0.0007
Bias	Creep dimension assumption	0.0000	0.0000	0.0000	0.0000	0.0000
Bias	Use of assembly average enrich	0.0010	0.0010	0.0010	0.0010	0.0010
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0155**	**0.0189**	**0.0190**	**0.0192**	**0.0193**
Total bias and uncertainty (dK)		**0.0259**	**0.0289**	**0.0301**	**0.0319**	**0.0327**

5.4 Region 4

Region 4 features 3-out-of-4 storage with one burnup curve and no neutron poisons. Tables 5.4-1 through 5.4-8 contain the revised bias, uncertainty and margin calculation for Region 4. The burnup credit curve for Region 4 is shown on Figure 5.4-1. The fit line shown bounds the curve data points.

Figure 5.4-1

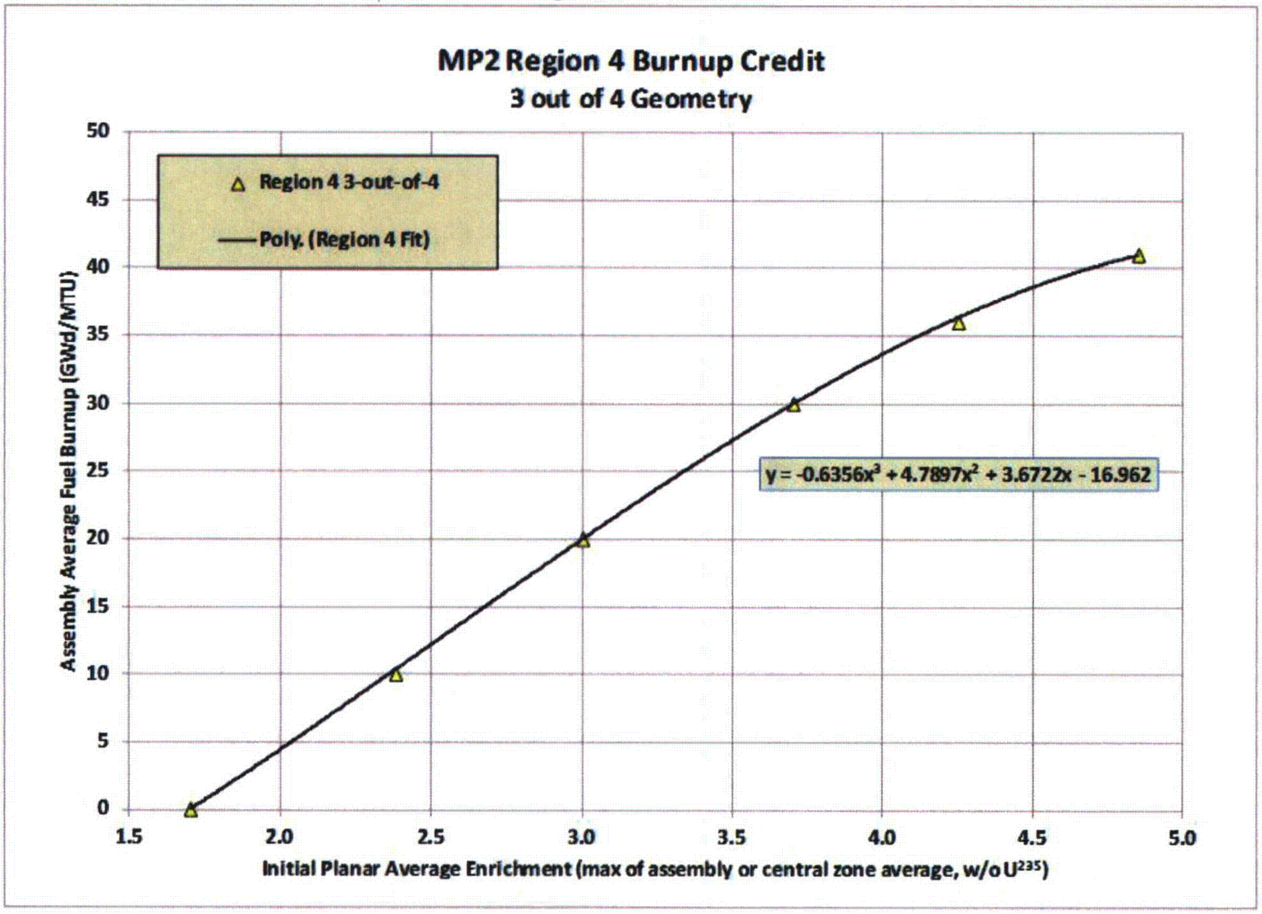


Table 5.4-1
Region 4 Burnup Worth (0 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Burnup Worth or Sensitivity (dk)	Value
1.70	0	0.96318	0.00010		Base
1.70	0	0.95886	0.00009		CEA in empty cell
2.38	**10U**	**0.96317**	**0.00010**	**0.0983**	Burnup worth
2.40	10U	0.96555	0.00009		
2.50	10U	0.97589	0.00017		
				0.0054	Enrich. Worth check 0.05 w/o
2.50	10	0.97179	0.00016		
3.00	20U	0.94373	0.00009		
3.00	**20**	**0.96102**	**0.00019**	**0.1609**	Burnup worth
3.70	**30**	**0.95954**	**0.00010**	**0.2114**	Burnup worth
3.80	30	0.96630	0.00009		
				0.0035	Enrich. Worth check 0.05 w/o
3.85	32	0.95303	0.00010		
4.25	**36**	**0.96007**	**0.00010**	**0.2406**	**Burnup worth**
4.85	**40**	**0.96145**	**0.00009**	**0.2651**	**Burnup worth**
4.85	**41**	**0.95694**	**0.00010**	**0.2696**	**Burnup worth**
				-0.0045	Bu worth (dK) / GWd/MTU
2.38	0	1.06122	0.00010		Fresh fuel geom
3.00	0	1.12151	0.00010		Fresh fuel geom
3.70	0	1.17064	0.00010		Fresh fuel geom
4.25	0	1.20039	0.00010		Fresh fuel geom
4.85	0	1.22625	0.00010		Fresh fuel geom
2.38	**10U**	**1.01478**	**0.00010**	**0.0519**	**Minor actinides and FP**
3.00	**20**	**1.02603**	**0.00010**	**0.0654**	**Minor actinides and FP**
3.70	**30**	**1.04162**	**0.00010**	**0.0824**	**Minor actinides and FP**
4.25	**36**	**1.05167**	**0.00010**	**0.0919**	**Minor actinides and FP**
4.85	40	1.06676	0.00010		
4.85	**41**	**1.06308**	**0.00010**	**0.1064**	**Minor actinides and FP**
4.85	**40**	**0.98268**	**0.00010**	**0.2439**	**28 Major isotopes worth**
4.85	41	0.95395	0.00010	0.0030	Creep worth (dK)
4.85	41	0.95262	0.00010	0.0013	Gap isotopes worth (dK)

Table 5.4-2
Region 4 Bias and Uncertainty (Fresh fuel, 0 ppm soluble boron)

Initial Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
1.70	0	0.96318	0.00010		Base
1.70	0	0.98694	0.00009		50% zirc in empty cell
1.75	**0**	**0.97205**	**0.00009**	**0.0091**	**Enrich +0.05 w/o**
1.70	**0**	**0.96528**	**0.00009**	**0.0024**	**Increase density**
1.70	**0**	**0.96327**	**0.00009**	**0.0018**	**Water temp 210 F (bias +0.0014)**
1.70	0	0.96343	0.00009	0.0009	Water temp 110 F (bias +0.0004)
1.70	**0**	**0.96332**	**0.00010**	**0.0004**	**Increase pellet OD**
1.70	**0**	**0.96390**	**0.00009**	**0.0010**	**Reduce clad OR**
1.70	**0**	**0.96310**	**0.00009**	**0.0002**	**Increase clad IR**
1.70	0	0.96303	0.00009	0.0001	Reduce clad IR
1.70	0	0.96275	0.00009	-0.0002	Increase GT IR
1.70	**0**	**0.96308**	**0.00009**	**0.0002**	**Reduce GT IR**
1.70	**0**	**0.96308**	**0.00009**	**0.0002**	**Reduce GT OR**
1.70	0	0.96289	0.00009	0.0000	Increase GT OR
1.70	0	0.96094	0.00009	-0.0020	Max Zr grids
1.70	**0**	**0.96378**	**0.00009**	**0.0009**	**Increase fuel pin pitch**
1.70	**0**	**0.96519**	**0.00009**	**0.0023**	**Reduce rack pitch**
1.70	**0**	**0.96668**	**0.00009**	**0.0038**	**Reduce cell wall thickness**
1.70	**0**	**0.96361**	**0.00009**	**0.0007**	**Offcenter fuel 6x6 monodirectional**
1.70	0	0.96293	0.00009	0.0000	Offcenter fuel max 4x4 in 6x6

Table 5.4-3
Region 4 Bias and Uncertainty (Depleted fuel, 0 ppm soluble boron)

Initial Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
4.85	40	0.98268	0.00010		Base
4.85	40	N/A	N/A	N/A	Enrich +0.05 w/o
4.85	40	N/A	N/A	N/A	Increase density
4.85	**40**	**0.98490**	**0.00010**	**0.0039**	**Water temp 210 F (bias +0.0014)**
4.85	40	0.98401	0.00010	0.0020	Water temp 110 F (bias +0.0004)
4.85	40	N/A	N/A	N/A	Increase pellet OD
4.85	40	N/A	N/A	N/A	Increase clad OR
4.85	40	N/A	N/A	N/A	Increase clad IR
4.85	40	N/A	N/A	N/A	Reduce clad IR
4.85	**40**	**0.98247**	**0.00010**	**0.0001**	**Increase GT IR**
4.85	**40**	**0.98286**	**0.00010**	**0.0005**	**Reduce GT OR**
4.85	40	0.98246	0.00010	0.0001	Increase GT OR
4.85	40	N/A	N/A	N/A	Max Zr grids
4.85	**40**	**0.98356**	**0.00010**	**0.0012**	**Increase fuel pin pitch**
4.85	**40**	**0.98455**	**0.00010**	**0.0022**	**Reduce rack pitch**
4.85	**40**	**0.98609**	**0.00010**	**0.0037**	**Reduce cell wall thickness**

Table 5.4-4
Region 4 Total Bias, Uncertainty, and Margin (0 ppm soluble boron)

	Burnup (GWd/MTU)	0	10	20	30	36	41
	Enrichment (w/o)	1.70	2.38	3.00	3.70	4.25	4.85
	Minor Actinides and FP	0.000	0.052	0.065	0.082	0.092	0.106
	BU worth (dK)	0.000	0.098	0.161	0.211	0.241	0.270
Case Type	**Case**						
Uncertainty	Rack wall thickness	0.0038	0.0038	0.0038	0.0038	0.0038	0.0037
Uncertainty	Rack Pitch	0.0023	0.0023	0.0023	0.0023	0.0023	0.0022
Uncertainty	Density	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024
Uncertainty	Enrichment	0.0091	0.0065	0.0052	0.0042	0.0037	0.0032
Uncertainty	Burnup worth (5%)	0.0000	0.0049	0.0080	0.0106	0.0120	0.0135
Uncertainty	Burnup (3.5%)	0.0000	0.0034	0.0056	0.0074	0.0084	0.0094
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OR	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad IR	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Pin pitch	0.0009	0.0012	0.0012	0.0012	0.0012	0.0012
Uncertainty	GT OD	0.0002	0.0005	0.0005	0.0005	0.0005	0.0005
Uncertainty	GT ID	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001
Uncertainty	2 x KENO std. dev.	0.0002	0.0004	0.0004	0.0004	0.0004	0.0004
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
TOTAL UNCERT		**0.0117**	**0.0115**	**0.0133**	**0.0154**	**0.0168**	**0.0183**
Bias	1.5% minor actnides and FP	0.0000	0.0008	0.0010	0.0012	0.0014	0.0016
Bias	Code bias	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	Temperature	0.0018	0.0039	0.0039	0.0039	0.0039	0.0039
Bias	Asymmetric fuel placement	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
Bias	Maximum Zr grids	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bias	Use of assembly average enrich	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0133**	**0.0162**	**0.0164**	**0.0167**	**0.0168**	**0.0171**
Total bias and uncertainty (dK)		**0.0251**	**0.0278**	**0.0298**	**0.0321**	**0.0337**	**0.0353**
K-effective		**0.9632**	**0.9632**	**0.9610**	**0.9595**	**0.9601**	**0.9569**
Dominion margin (dK)		**0.0118**	**0.0091**	**0.0092**	**0.0083**	**0.0063**	**0.0077**

Table 5.4-5
Region 4 Burnup Worth (2000 ppm soluble boron)

Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Burnup Worth or Sensitivity (dk)	Value
1.70	0	0.61710	0.00007		Base
2.38	**10U**	**0.66522**	**0.00008**	**0.0521**	Burnup worth
2.50	10U	0.67767	0.00008		
				0.0053	Enrich. Worth check 0.05 w/o
2.50	10	0.67459	0.00007		
3.00	20U	0.66902	0.00007		
3.00	**20**	**0.68168**	**0.00008**	**0.1038**	Burnup worth
3.70	**30**	**0.69591**	**0.00008**	**0.1492**	Burnup worth
3.80	30	0.70254	0.00008		
				0.0034	Enrich. Worth check 0.05 w/o
4.25	**36**	**0.70460**	**0.00008**	**0.1787**	**Burnup worth**
4.85	**40**	**0.71393**	**0.00008**	**0.2045**	**Burnup worth**
4.85	**41**	**0.71013**	**0.00008**	**0.2083**	**Burnup worth**
				-0.0038	**Bu worth (dK) / GWd/MTU**
2.38	0	0.71706	0.00008		Fresh fuel geom
3.00	0	0.78520	0.00009		Fresh fuel geom
3.70	0	0.84491	0.00009		Fresh fuel geom
4.25	0	0.88305	0.00010		Fresh fuel geom
4.85	0	0.91813	0.00010		Fresh fuel geom
2.38	**10U**	**0.69258**	**0.00008**	**0.0276**	**Minor actinides and FP**
3.00	**20**	**0.71787**	**0.00008**	**0.0364**	**Minor actinides and FP**
3.70	**30**	**0.74277**	**0.00009**	**0.0471**	**Minor actinides and FP**
4.25	**36**	**0.75792**	**0.00009**	**0.0536**	**Minor actinides and FP**
4.85	**41**	**0.77277**	**0.00009**	**0.0629**	**Minor actinides and FP**
4.85	**40**	**0.72711**	**0.00009**	**0.1913**	**28 Major isotopes worth**
4.85	41	0.70942	0.00008	0.0007	Creep worth (dK)
4.85	41	0.70847	0.00009	0.0009	Gap isotopes worth (dK)

Table 5.4-6
Region 4 Bias and Uncertainty (Fresh fuel, 2000 ppm soluble boron)

Initial Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
1.70	0	0.61710	0.00007		Base
1.75	**0**	**0.62550**	**0.00007**	**0.0086**	**Enrich +0.05 w/o**
1.70	**0**	**0.62050**	**0.00007**	**0.0036**	**Increase density**
1.70	**0**	**0.62340**	**0.00007**	**0.0079**	**Water temp 210 F (bias +0.0014)**
1.70	**0**	**0.61771**	**0.00007**	**0.0008**	**Increase pellet OD**
1.70	0	0.61671	0.00007	-0.0002	Reduce clad OR
1.70	**0**	**0.61728**	**0.00007**	**0.0004**	**Increase clad OR**
1.70	**0**	**0.61708**	**0.00007**	**0.0002**	**Increase clad IR**
1.70	0	0.61681	0.00007	-0.0001	Reduce clad IR
1.70	**0**	**0.61719**	**0.00007**	**0.0003**	**Increase GT IR**
1.70	0	0.61677	0.00007	-0.0001	Reduce GT OR
1.70	**0**	**0.61700**	**0.00007**	**0.0001**	**Increase GT OR**
1.70	**0**	**0.61743**	**0.00007**	**0.0005**	**Max Zr grids**
1.70	**0**	**0.61734**	**0.00007**	**0.0004**	**Increase fuel pin pitch**
1.70	**0**	**0.61971**	**0.00007**	**0.0028**	**Reduce rack pitch**
1.70	0	0.61688	0.00007	0.0000	Reduce cell wall thickness
1.70	0	0.61439	0.00007	-0.0025	Offcenter fuel 6x6 monodirectional
1.70	**0**	**0.61888**	**0.00007**	**0.0020**	**Offcenter fuel max 4x4 in 6x6**

Table 5.4-7
Region 4 Bias and Uncertainty (Depleted fuel, 2000 ppm soluble boron)

Initial Enrichment (w/o U235)	Burnup (GWd/MTU)	KENO K-effective	KENO K-eff Uncert.	Sensitivity (dK)	Case Type
4.85	40	0.72711	0.00009		Base
4.85	**40**	N/A	N/A	N/A	Enrich +0.05 w/o
4.85	**40**	N/A	N/A	N/A	Increase density
4.85	**40**	**0.73562**	**0.00008**	**0.0102**	**Water temp 210 F (bias +0.0014)**
4.85	**40**	N/A	N/A	N/A	Increase pellet OD
4.85	**40**	N/A	N/A	N/A	Increase clad OR
4.85	40	N/A	N/A	N/A	Increase clad IR
4.85	40	N/A	N/A	N/A	Reduce clad IR
4.85	**40**	**0.72719**	**0.00008**	**0.0003**	**Increase GT IR**
4.85	**40**	**0.72715**	**0.00009**	**0.0003**	**Reduce GT OR**
4.85	**40**	**0.72723**	**0.00009**	**0.0004**	**Increase GT OR**
4.85	**40**	**0.72792**	**0.00008**	**0.0010**	**Increase fuel pin pitch**
4.85	**40**	**0.73007**	**0.00009**	**0.0032**	**Reduce rack pitch**
4.85	**40**	**0.72720**	**0.00009**	**0.0003**	**Cell wall thickness**

Table 5.4-8
Region 4 Total Bias and Uncertainty (2000 ppm soluble boron)

	Burnup (GWd/MTU)	0	10	20	30	36	41
	Enrichment (w/o)	1.70	2.38	3.00	3.70	4.25	4.85
	Minor Actinides and FP	0.000	0.028	0.036	0.047	0.054	0.063
	BU worth (dK)	0.000	0.052	0.104	0.149	0.179	0.208
Case Type	**Case**						
Uncertainty	Rack wall thickness	0.0000	0.0003	0.0003	0.0003	0.0003	0.0003
Uncertainty	Rack Pitch	0.0028	0.0032	0.0032	0.0032	0.0032	0.0032
Uncertainty	Density	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036
Uncertainty	Enrichment	0.0086	0.0061	0.0049	0.0040	0.0034	0.0030
Uncertainty	Burnup worth (5%)	0.0000	0.0026	0.0052	0.0075	0.0089	0.0104
Uncertainty	Burnup (3.5%)	0.0000	0.0018	0.0036	0.0052	0.0063	0.0073
Uncertainty	NUREG 7109 Structural Materials	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008
Uncertainty	Fuel OD	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad OR	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Clad IR	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
Uncertainty	Pin pitch	0.0004	0.0010	0.0010	0.0010	0.0010	0.0010
Uncertainty	GT OD	0.0001	0.0004	0.0004	0.0004	0.0004	0.0004
Uncertainty	GT ID	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Uncertainty	2 x KENO std. dev.	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002
Uncertainty	Code uncertainty	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
TOTAL UNCERT		**0.0111**	**0.0100**	**0.0108**	**0.0123**	**0.0135**	**0.0149**
Bias	1.5% minor actnides and FP	0.0000	0.0004	0.0005	0.0007	0.0008	0.0009
Bias	*Code bias*	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048
Bias	Temperature	0.0079	0.0102	0.0102	0.0102	0.0102	0.0102
Bias	Maximum Zr grids	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Bias	Asymmetric fuel placement	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
Bias	Creep dimension assumption	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bias	Use of assembly average enrich	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Bias	NRC administrative margin	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
TOTAL BIAS		**0.0213**	**0.0240**	**0.0241**	**0.0243**	**0.0244**	**0.0245**
Total bias and uncertainty (dK)		**0.0324**	**0.0340**	**0.0349**	**0.0365**	**0.0379**	**0.0394**

ATTACHMENT 6

MARKED-UP TECHNICAL SPECIFICATIONS PAGES

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

VENTING

1.35 VENTING is the controlled process of discharging air or gas from a confinement to maintain temperature, pressure, humidity, concentration or other operating condition, in such a manner that replacement air or gas is not provided or required during VENTING. Vent, used in system names, does not imply a VENTING process.

MEMBER(S) OF THE PUBLIC

1.36 MEMBER(S) OF THE PUBLIC shall include all persons who are not occupationally associated with the plant. This category does not include employees of the utility, its contractors or its vendors. Also excluded from this category are persons who enter the site to service equipment or to make deliveries. This category does include persons who use portions of the site for recreational, occupational or other purposes not associated with the plant.

The term "REAL MEMBER OF THE PUBLIC" means an individual who is exposed to existing dose pathways at one particular location.

SITE BOUNDARY

1.37 The SITE BOUNDARY shall be that line beyond which the land is not owned, leased or otherwise controlled by the licensee.

UNRESTRICTED AREA

1.38 An UNRESTRICTED AREA shall be any area at or beyond the SITE BOUNDARY to which access is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials or any area within the SITE BOUNDARY used for residential quarters or industrial, commercial institutional and/or recreational purposes.

STORAGE PATTERN

1.39 The Region B spent fuel racks contain a cell blocking device in every 4th rack location for administrative control. This 4th location will be referred to as the blocked location. A STORAGE PATTERN refers to a blocked location and all adjacent and diagonal cell locations surrounding the blocked location within the respective region.

Insert T.1

Insert T.1 to TS 1.39 and TS 1.40 (new)

1.39 A STORAGE PATTERN designates acceptable fuel assembly storage in a 2 x 2 storage array (4 spent fuel rack storage locations) within Regions 1, 2, and 4 of the spent fuel racks. Each 2 x 2 storage array includes at least one location in which storage is NOT permitted (fuel or non-fuel).

1.40 A NON-STANDARD FUEL CONFIGURATION is an object containing fuel that does not conform to the standard fuel configuration. The standard fuel configuration is a 14 x 14 array of fuel rods (or fuel rods replaced by un-enriched fuel rods or stainless steel rods) with five (5) guide tubes that occupy four lattice pitch locations each. Fuel in any other array is a "Non-standard Fuel Configuration." Reconstituted fuel in which one or more fuel rods have been replaced by either un-enriched fuel rods or stainless steel rods is considered to be a standard fuel configuration.

SPENT FUEL POOL BORON CONCENTRATION

assembly or Non-standard Fuel Configuration

LIMITING CONDITION FOR OPERATION

3.9.17 The boron concentration in the spent fuel pool shall be greater than or equal to ~~1720~~ parts per million (ppm).

APPLICABILITY: Whenever any fuel ~~assembly or consolidated fuel storage box~~, is stored in the spent fuel pool.

2100

ACTION:

With the boron concentration less than ~~1720~~ ppm, suspend the movement of all ~~fuel, consolidated fuel storage boxes,~~ and shielded casks, and immediately initiate action to restore the spent fuel pool boron concentration to within its limit.

fuel assemblies, Non-standard Fuel Configurations,

The provisions of specification 3.0.3 are not applicable.

SURVEILLANCE REQUIREMENTS

4.9.17 Verify that the boron concentration is greater than or equal to ~~1720~~ ppm every 7 days, and within 24 hours prior to the initial movement of a fuel assembly or ~~consolidated fuel storage box~~ in the Spent Fuel Pool, or shielded cask over the cask laydown area.

Non-standard Fuel Configuration

REFUELING OPERATIONS

SPENT FUEL POOL - STORAGE

LIMITING CONDITION FOR OPERATION

3.9.18 The following spent fuel pool storage requirement will be met:

(a) The combination of initial enrichment and burnup of each fuel assembly stored in Region A shall be within the acceptable burnup domain of Figure 3.9-4; and

(b) (1) The combination of initial enrichment and burnup of a fuel assembly stored in Region C shall be within the acceptable burnup domain of Figure 3.9-1A;

OR

(2) The combination of initial enrichment and burnup of a fuel assembly stored in Region C shall be within the acceptable burnup domain of Figure 3.9-1B, and borated stainless steel poison pins are installed in the assembly's center guide tube and in two diagonally opposite guide tubes; and

(c) The combination of initial enrichment and burnup of each consolidated fuel storage box stored in Region C shall be within the acceptable burnup domain of Figure 3.9-3.

Replace with Insert T.2

APPLICABILITY: Whenever any fuel assembly or consolidated fuel storage box is stored in the spent fuel pool.

Non-standard Fuel Configuration

ACTION:

Immediately initiate action to move the non-complying fuel assembly or consolidated fuel storage box to an acceptable location.

The provisions of specification 3.0.3 are not applicable.

SURVEILLANCE REQUIREMENTS

planar average

4.9.18 Prior to storing a fuel assembly or consolidated fuel storage box in the spent fuel racks, verify by administrative means the initial enrichment and burnup of the fuel assembly or consolidated fuel storage box is in accordance with the acceptable specifications for that Storage Region.

Prior to storing a Non-standard Fuel Configuration in the spent fuel racks, verify by administrative means the Non-standard Fuel Configuration is qualified for that Storage Region.

* Full-length, reduced-strength Control Element Assemblies and part-length Control Element Assemblies shall NOT be used in Region 3.

Insert T.2 to TS 3.9.18

(a) Region 1 fuel assemblies have a maximum initial planar average enrichment of 4.85 weight percent of U-235. A fuel rod shall have a maximum enrichment of 5.0 weight percent of U-235. No burnup credit is required.
(b) Region 2 has two types of storage locations:
    (1) The combination of initial planar average enrichment and burnup of a fuel assembly stored in Region 2 Type 2A shall be within the acceptable burnup domain of Figure 3.9-1A.
    (2) The combination of initial planar average enrichment and burnup of a fuel assembly stored in Region 2 Type 2B shall be within the acceptable burnup domain of Figure 3.9-1B.
(c) Fuel assemblies stored in Region 3 shall contain either Borated Stainless Steel Poison Rodlets or a full length, full strength Control Element Assembly:
    (1) The combination of initial planar average enrichment and burnup of a fuel assembly containing Borated Stainless Steel Poison Rodlets stored in Region 3 shall be within the acceptable burnup domain of Figure 3.9-1C. The Borated Stainless Steel Poison Rodlets shall be installed in the assembly's center guide tube and in two diagonally opposite guide tubes.
    (2) The combination of initial planar average enrichment and burnup of a fuel assembly containing a full length, full strength Control Element Assembly stored in Region 3 shall be within the acceptable burnup domain of Figure 3.9-1D. *
(d) The combination of initial planar average enrichment and burnup of a fuel assembly stored in Region 4 shall be within the acceptable burnup domain of Figure 3.9-1E.
(e) Each Non-standard Fuel Configuration must have a separate criticality analysis to determine where it can be stored in the spent fuel racks. The analysis may qualify storage in one or multiple Regions, and may or may not require Borated Stainless Steel Poison Rodlets or a full length, full strength Control Element Assembly if stored in Region 3.

Replace old Figures 3.9-1A and 3.9-1B with new Figures 3.9-1A through 3.9-1E.

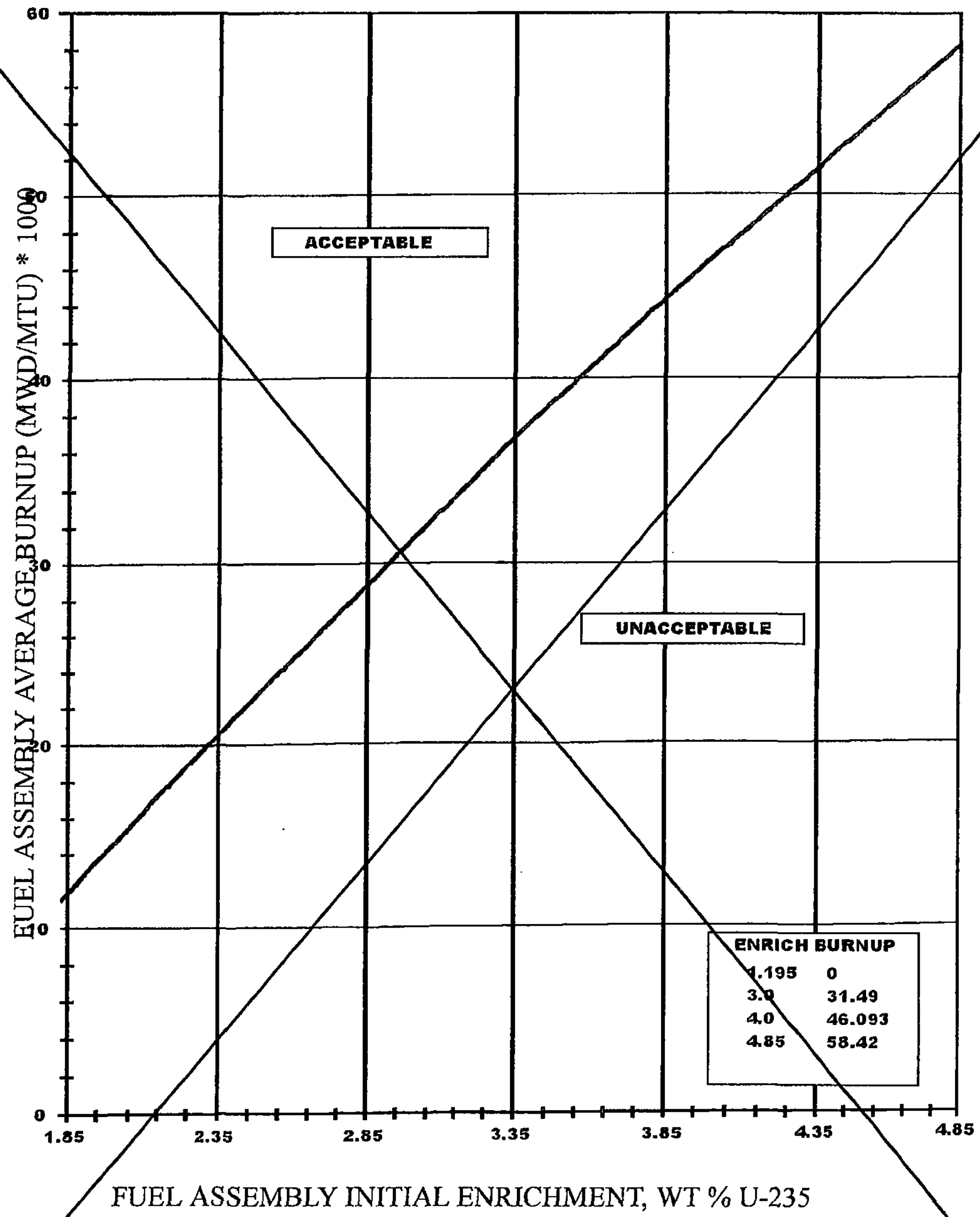
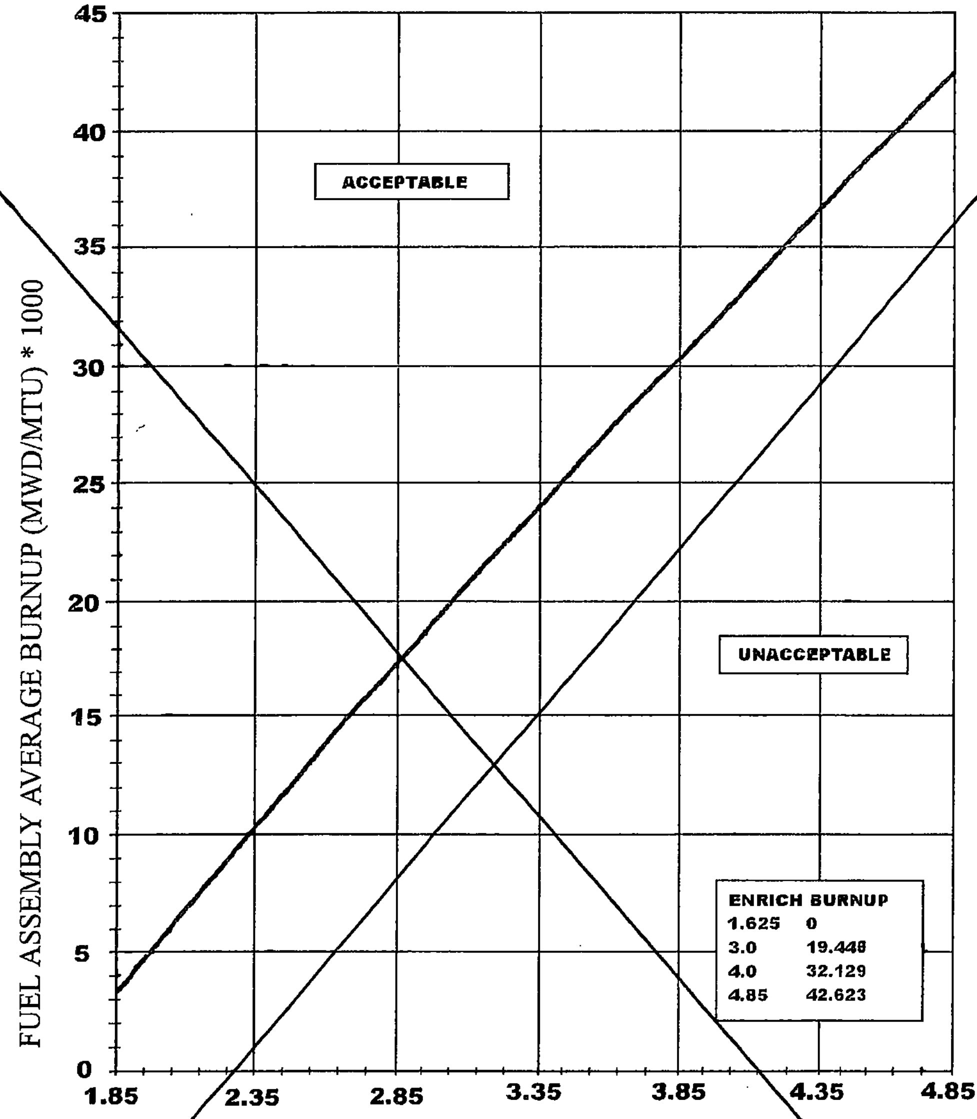


FIGURE 3.9-1A MINIMUM REQUIRED FUEL ASSEMBLY EXPOSURE AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION C

Replace old Figures 3.9-1A and 3.9-1B with new Figures 3.9-1A through 3.9-1E.



FUEL ASSEMBLY INITIAL ENRICHMENT, WT% U-235

FIGURE 3.9-1B MINIMUM REQUIRED FUEL ASSEMBLY EXPOSURE AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION C WITH POISON PINS INSTALLED

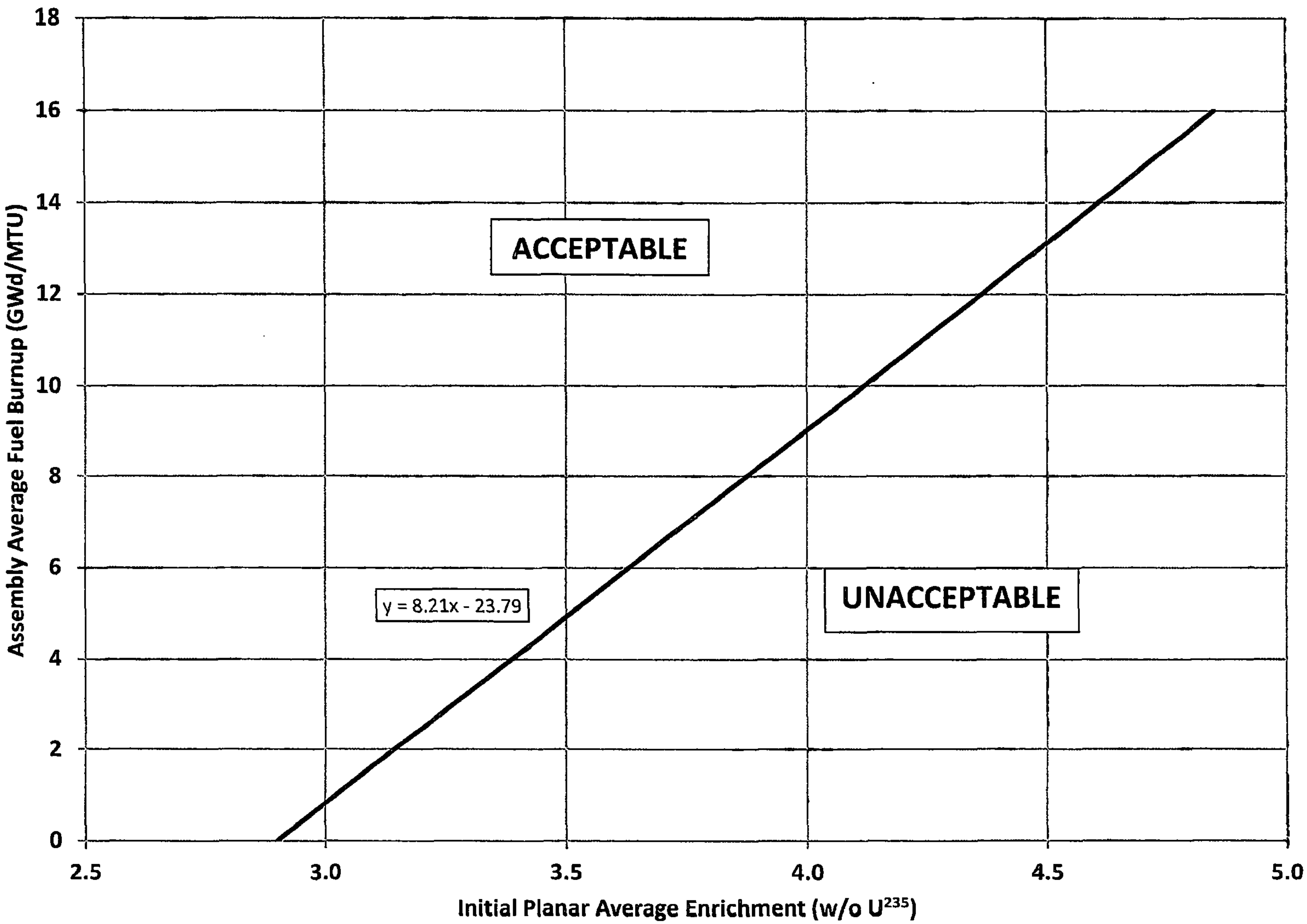


FIGURE 3.9-1A MINIMUM REQUIRED AVERAGE FUEL ASSEMBLY BURNUP AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION 2A

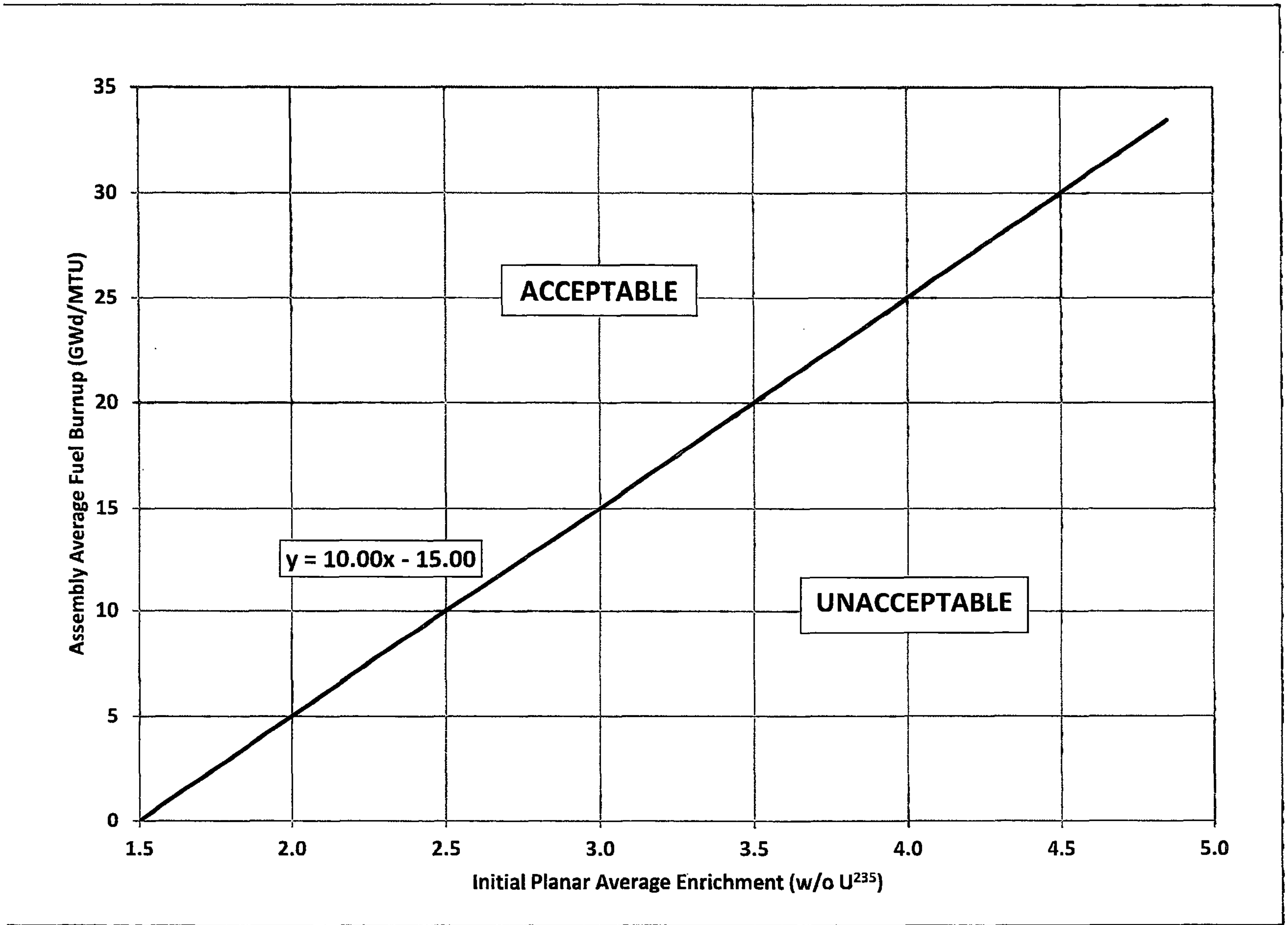


FIGURE 3.9-1B MINIMUM REQUIRED AVERAGE FUEL ASSEMBLY BURNUP AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION 2B

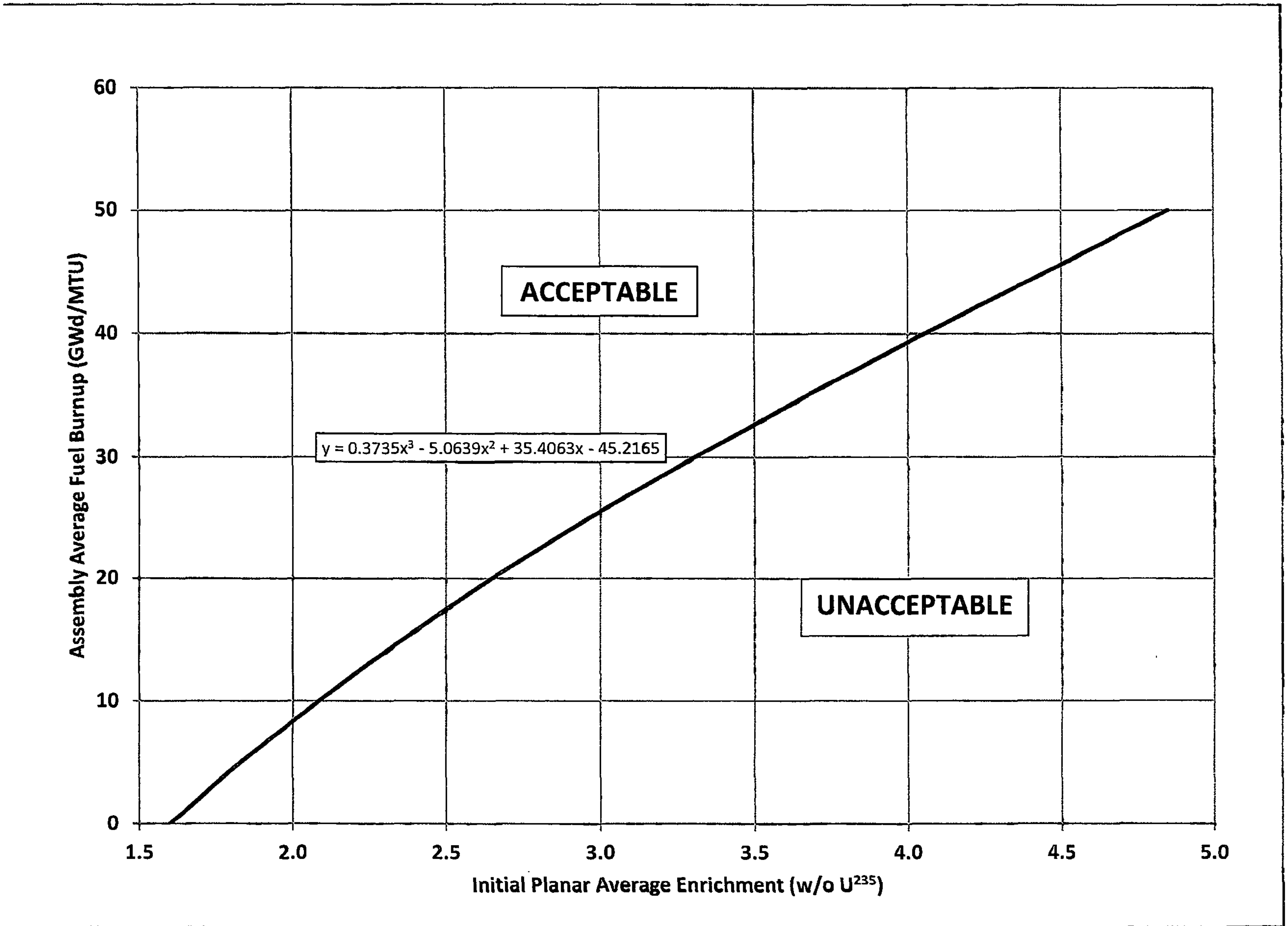


FIGURE 3.9-1C MINIMUM REQUIRED AVERAGE FUEL ASSEMBLY BURNUP AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION 3 (with insertion of 3 Borated Stainless Steel Poison Rodlets)

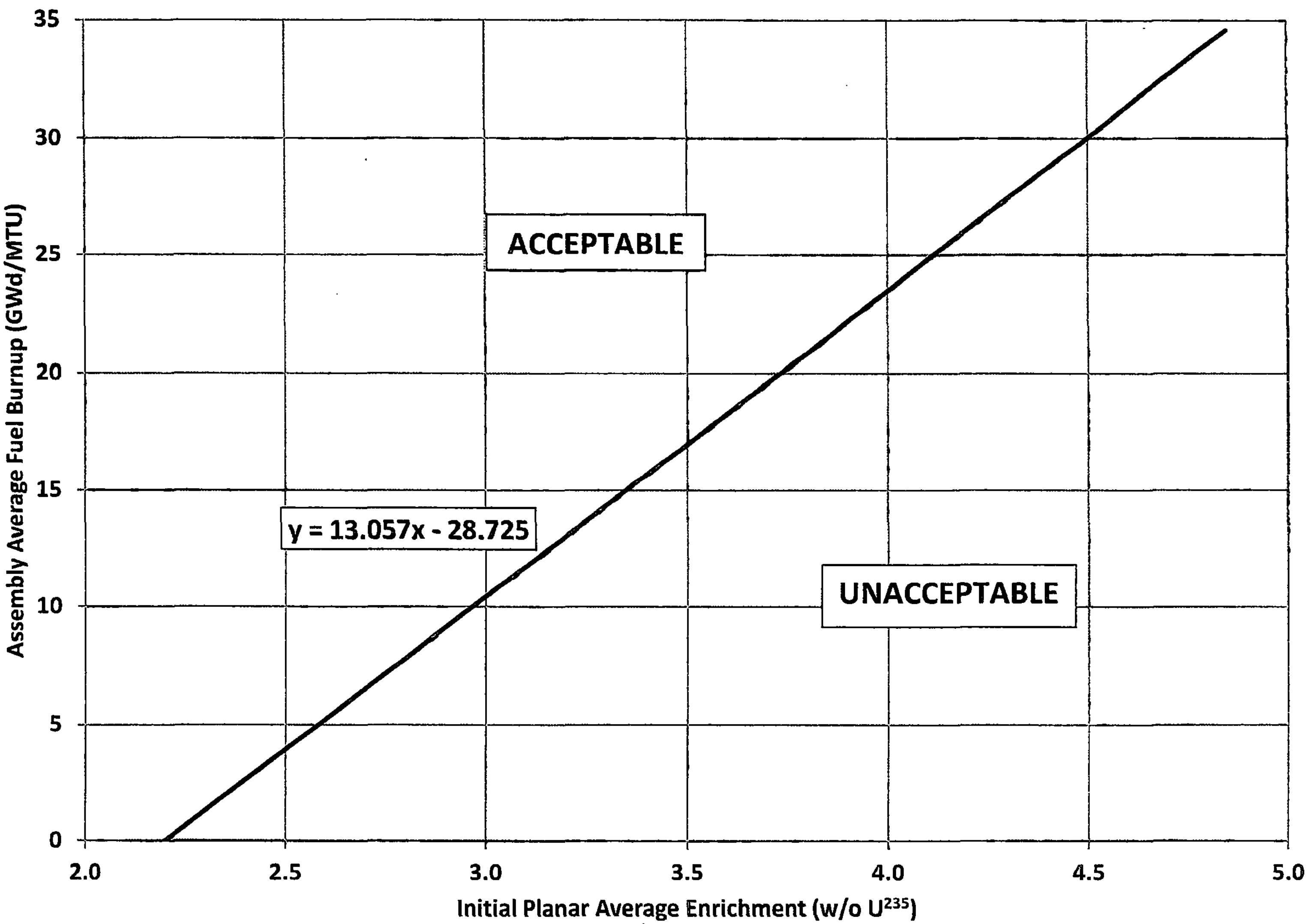


FIGURE 3.9-1D MINIMUM REQUIRED AVERAGE FUEL ASSEMBLY BURNUP AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION 3 (with insertion of a full length, full strength Control Element Assembly)

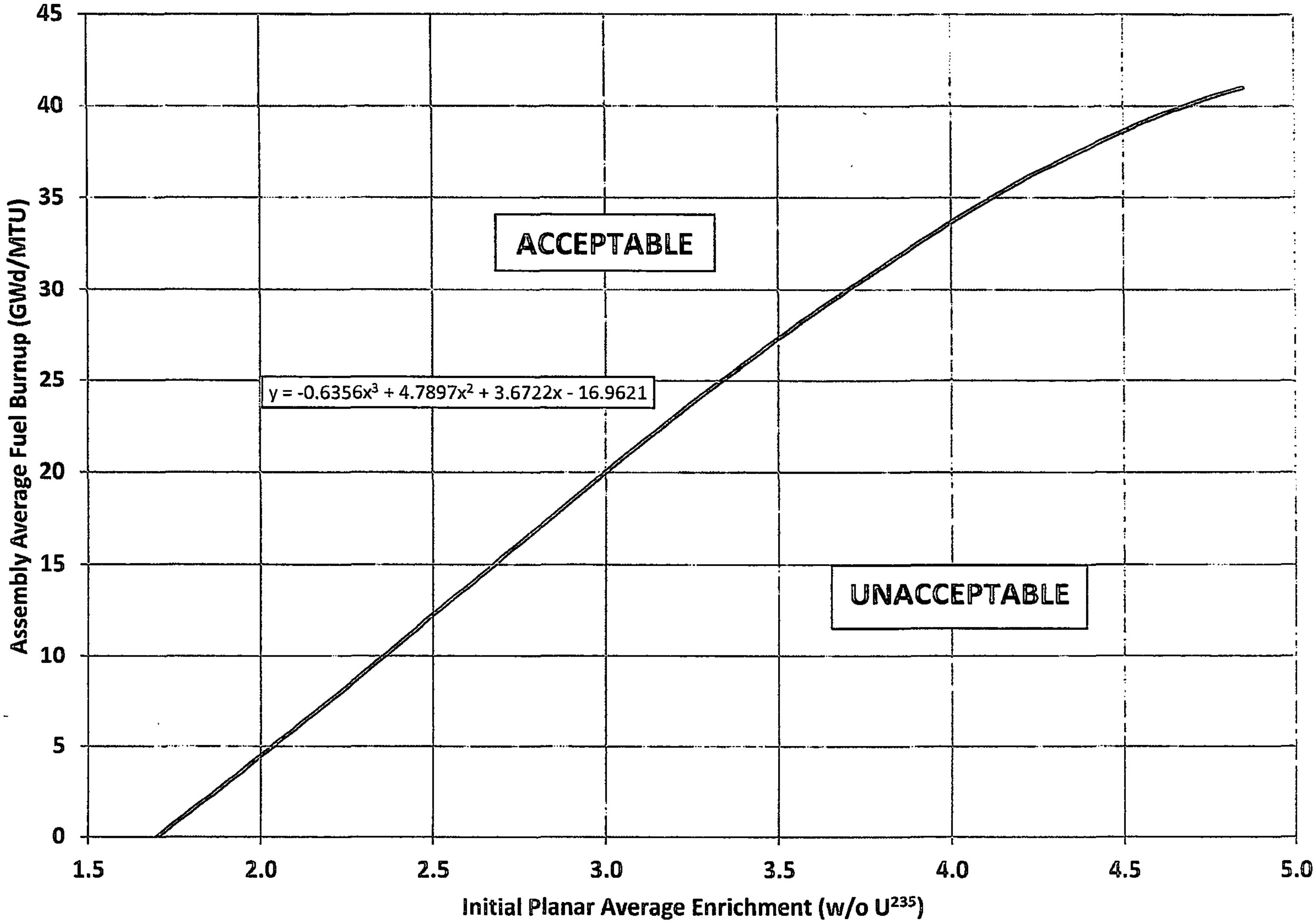
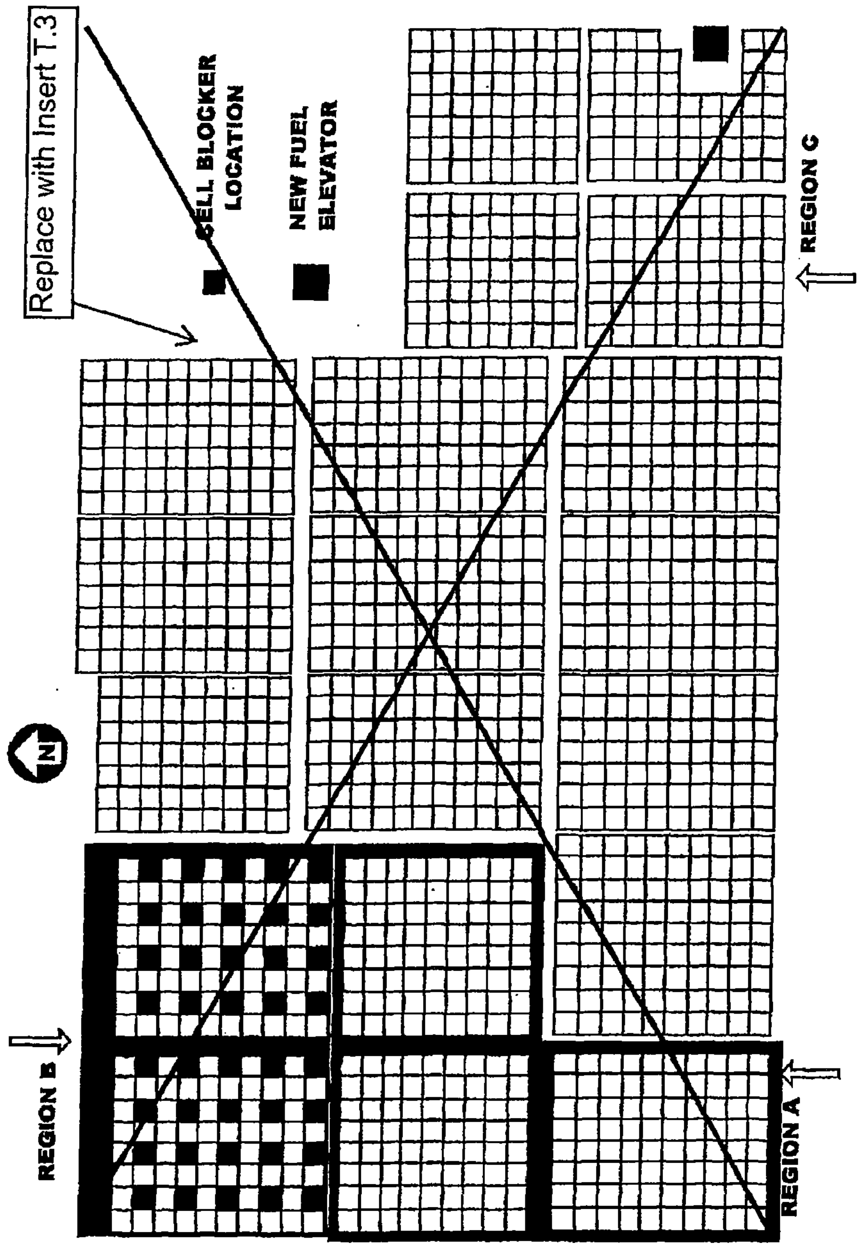
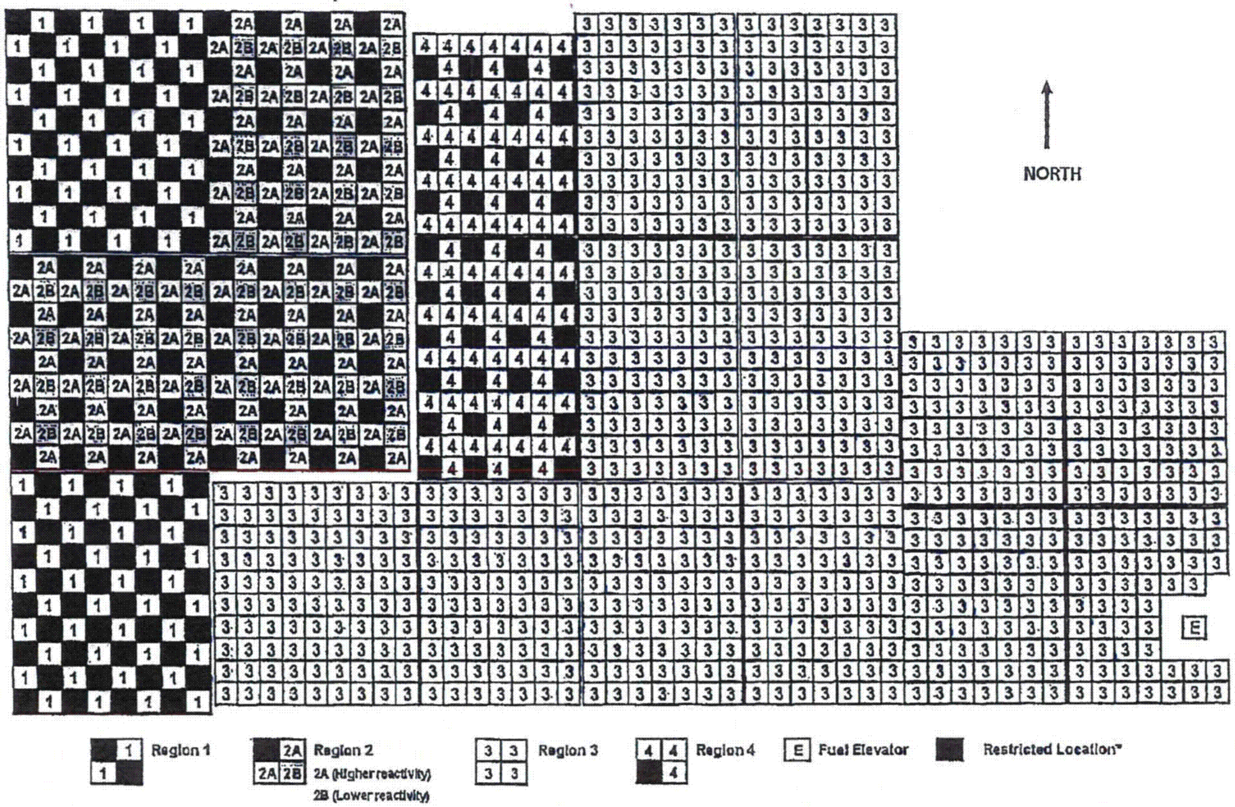


FIGURE 3.9-1E MINIMUM REQUIRED AVERAGE FUEL ASSEMBLY BURNUP AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION 4

SPENT FUEL POOL ARRANGEMENT
FIGURE 3.9-2
(NOT TO SCALE)



INSERT T.3



SPENT FUEL POOL ARRANGEMENT
FIGURE 3.9-2
(NOT TO SCALE)

* A Restricted Location shall remain empty. No fuel assembly, no Non-standard Fuel Configuration, no non-fuel component, nor any hardware/material of any kind may be stored in a Restricted Location.

DELETE - Figure to be deleted because existing Consolidated Fuel Storage Boxes have been analyzed for storage in all regions except for Restricted Locations.

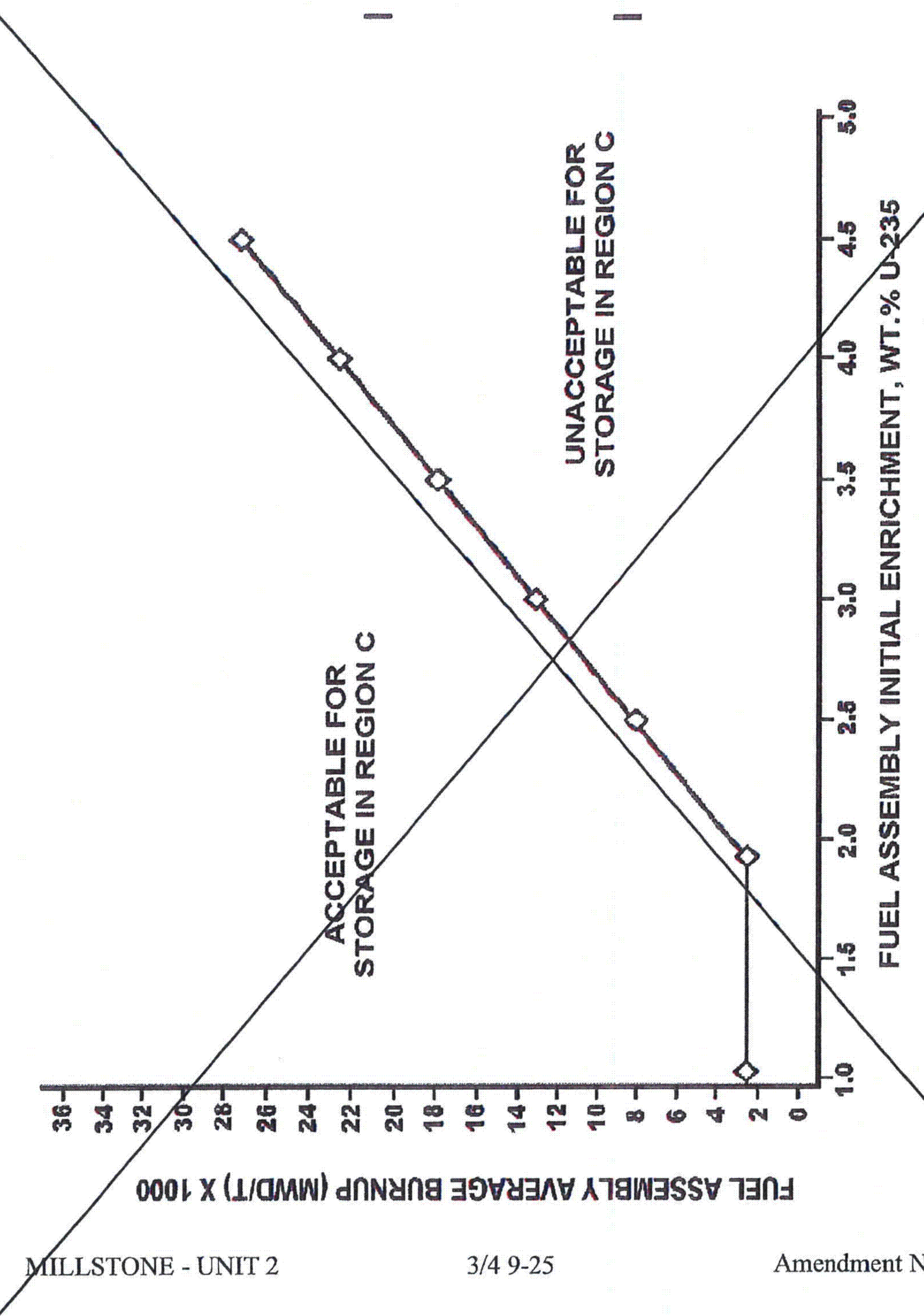


FIGURE 3.9.3 MINIMUM REQUIRED FUEL ASSEMBLY EXPOSURE AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION C AS CONSOLIDATED FUEL

DELETE - Figure to be deleted because Region1 does not utilize an enrichment/burnup curve.

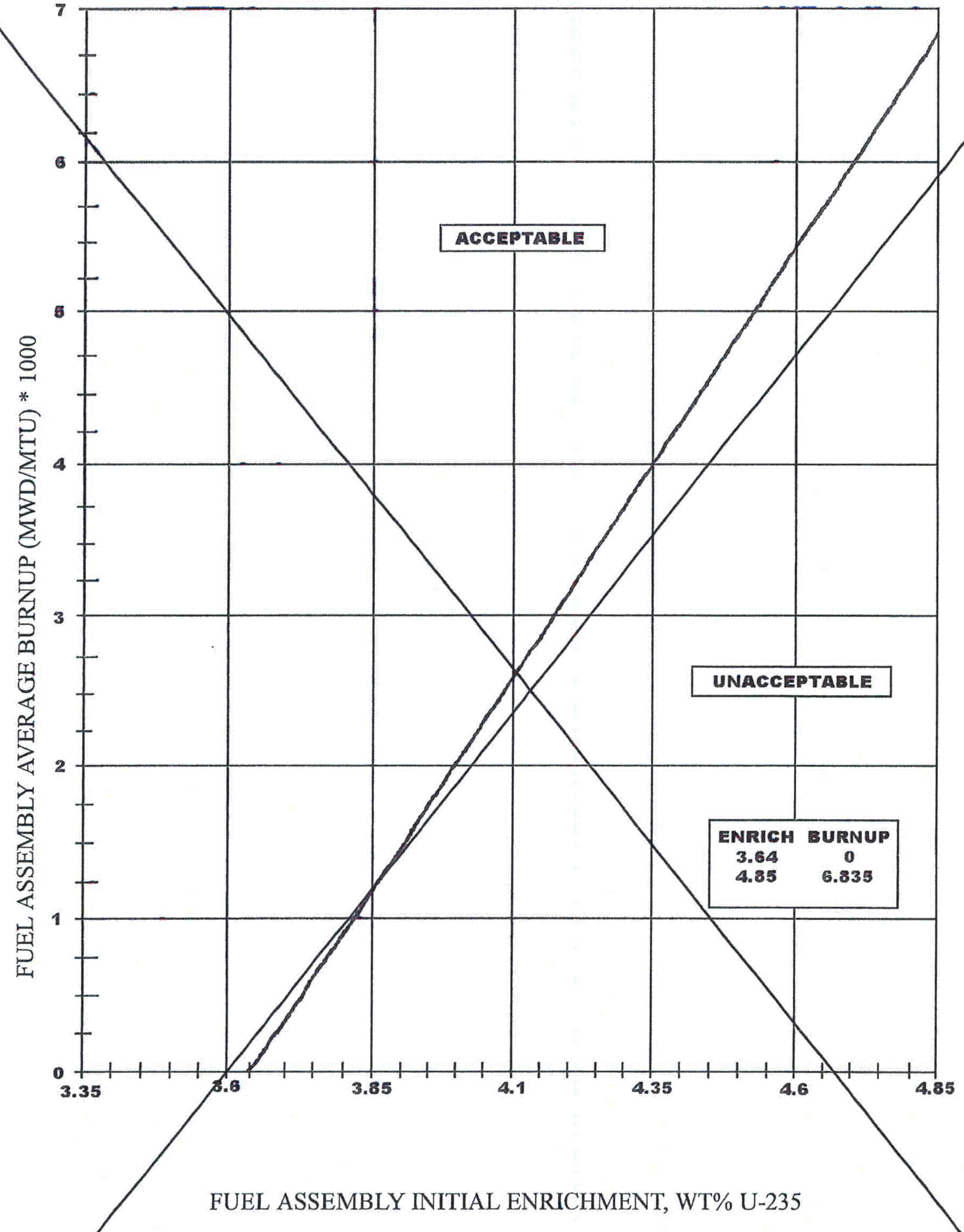


FIGURE 3.9-4 MINIMUM REQUIRED FUEL ASSEMBLY EXPOSURE AS A FUNCTION OF INITIAL ENRICHMENT TO PERMIT STORAGE IN REGION A

REFUELING OPERATIONS

SPENT FUEL POOL - ~~STORAGE PATTERN~~ STORAGE RESTRICTIONS

LIMITING CONDITION FOR OPERATION

3.9.19 ~~Each STORAGE PATTERN of the Region B spent fuel pool racks shall require that:~~

~~(1) A cell blocking device is installed in those cell locations shown in Figure 3.9-2. The blocked location may store a Batch B fuel assembly* underneath the cell blocker; or~~

~~(2) If a cell blocking device has been removed, all cells in the STORAGE PATTERN, except the location with the removed cell blocking device, must be vacant of stored fuel assemblies.~~

Replace with Insert T.4

APPLICABILITY: ~~Fuel in the spent fuel pool.**~~ Fuel assemblies, Non-standard Fuel Configurations, or non-fuel components in the spent fuel pool.

ACTION:

Take immediate action to comply with either 3.9.19(1) or (2).

The provisions of specification 3.0.3 are not applicable.

SURVEILLANCE REQUIREMENTS

4.9.19 Verify that 3.9.19 is satisfied prior to ~~removing a cell blocking device.~~ storing fuel assemblies, Non-standard Fuel Configurations, or non-fuel components in the spent fuel racks.

Insert T.5

~~* A Batch B fuel assembly refers to any of the Batch B fuel assemblies which were part of the first Millstone 2 core.~~

~~** This LCO is not applicable during the initial installation of Batch B fuel assemblies in the cell blocker locations.~~

Insert T.4 to TS 3.9.19

The following spent fuel pool storage restrictions will be met:

(1) Restricted Locations shall remain empty. No fuel assembly, no Non-standard Fuel Configuration, no non-fuel component, nor any hardware/material of any kind may be stored in a Restricted Location (shown in Figure 3.9-2).
(2) Fuel assemblies and Non-standard Fuel Configurations shall NOT be stored in Region 1 and 2 storage locations in which the Boraflex panel box has been removed. It is permissible to store non-fuel components in non-restricted locations with or without a Boraflex panel box. *

Insert T.5 to TS 3.9.19

* Note that Region 1 and 2 spent fuel pool rack storage locations contain removable Boraflex panel boxes which house the Boraflex panels. The Boraflex panel boxes were manufactured as an integral part the original spent fuel pool racks and as such are NOT stored components in SFP rack storage locations. Criticality analysis has shown that the Restricted Locations are acceptable with or without the Boraflex panel boxes.

5.3 REACTOR CORE

FUEL ASSEMBLIES

initial planar

5.3.1 The reactor core shall contain 217 fuel assemblies with each fuel assembly containing 176 rods. Reload ~~fuel~~ shall be similar in physical design to the initial core loading and shall have a maximum ~~nominal~~ average enrichment of 4.85 weight percent of U-235. A fuel rod shall have a maximum enrichment of 5.0 weight percent of U-235.

CONTROL ELEMENT ASSEMBLIES

5.3.2 The reactor core shall contain 73 control element assemblies. The control element assemblies shall be designed and maintained in accordance with the design provisions contained in Section 3.0 of the FSAR with allowance for normal degradation pursuant to the applicable Surveillance Requirements.

5.4 DELETED

5.5 DELETED

5.6 FUEL STORAGE

initial planar

CRITICALITY

5.6.1 a) The new fuel (dry) storage racks are designed and shall be maintained with sufficient center to center distance between assemblies to ensure a $K_{eff} \leq .95$. The maximum nominal average fuel assembly enrichment to be stored in these racks is 4.85 weight percent U-235. The maximum fuel rod enrichment to be stored in these racks is 5.0 weight percent of U-235.

initial

b) The spent fuel storage racks are designed and shall be maintained with fuel assemblies having a maximum nominal average enrichment of 4.85 weight percent U-235. The maximum fuel rod enrichment to be stored in these racks is 5.0 weight percent U-235.

c) The spent fuel storage racks are designed and shall be maintained with $K_{eff} < 1.00$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Westinghouse Report A-MP-FE-0011, Revision 1, "Millstone Unit 2 Spent Fuel Pool Criticality Analysis with Soluble Boron Credit."

and biases.

d) The spent fuel storage racks are designed and shall be maintained with $K_{eff} \leq .95$ if fully flooded with water borated to 600 ppm, which includes an allowance for uncertainties as described in Westinghouse Report A-MP-FE-0011, Revision 1, "Millstone Unit 2 Spent Fuel Pool Criticality Analysis with Soluble Boron Credit."

Insert T.6

e) Region A of the spent fuel storage pool is designed and shall be maintained with a nominal 9.8 inch center to center distance between storage locations. Fuel assemblies stored in this region must comply with Figure 3.9-4 to ensure that the design burnup has been sustained.

f) Region B of the spent fuel storage pool is designed and shall be maintained with a nominal 9.8 inch center to center distance between storage locations. Region B contains both blocked and un-blocked storage locations, shown in Figure 3.9-2. Fuel having a maximum nominal enrichment of 4.85 weight percent U-235, may be stored in un-blocked locations. Fuel stored in blocked locations must be Batch B fuel assemblies.

g) Region C of the spent fuel storage pool is designed and shall be maintained with a 9.0 inch center to center distance between storage locations. Fuel assemblies stored in this region must comply with Figures 3.9-la or 3.9-1b to ensure that the design burn-up has been sustained. Additionally, fuel assemblies utilizing Figure 3.9-1b require that borated stainless steel poison pins are installed in the fuel assembly's center guide tube and in two diagonally opposite guide tubes. The poison pins are solid 0.87 inch O.D. borated stainless steel, with a boron content of 2 weight percent boron.

h) Region C of the spent fuel storage pool is designed to permit storage of consolidated fuel. The contents of the consolidated fuel storage boxes to be stored in this region must comply with Figure 3.9-3 to ensure that the design burnup has been sustained.

Insert T.6 to TS 5.6.1

e) Region 1 of the spent fuel storage pool is designed and shall be maintained with a nominal 9.8 inch center to center distance between storage locations. Region 1 contains the Restricted Locations, shown in Figure 3.9-2. Fuel having an initial planar average enrichment of 4.85 weight percent U-235 may be stored in available locations.

f) Region 2 of the spent fuel storage pool is designed and shall be maintained with a nominal 9.8 inch center to center distance between storage locations. Region 2 contains Type 2A and Type 2B storage locations as well as the Restricted Locations shown in Figure 3.9-2. Fuel assemblies stored in this region must comply with Figure 3.9-1A or Figure 3.9-1B. Fuel assemblies utilizing Figure 3.9-1A must be stored in the Region 2 Type 2A storage locations, and fuel assemblies utilizing Figure 3.9-1B must be stored in the Region 2 Type 2B storage locations.

g) Region 3 of the spent fuel storage pool is designed and shall be maintained with a nominal 9.0 inch center to center distance between storage locations. Fuel assemblies stored in this region must comply with Figure 3.9-1C or Figure 3.9-1D. Additionally, fuel assemblies utilizing Figure 3.9-1C require that Borated Stainless Steel Poison Rodlets be inserted in the fuel assembly's center guide tube and in two diagonally opposite guide tubes. The poison rods are solid nominal 0.87 inch O.D. borated stainless steel, with a nominal boron content of 2.0 weight percent boron. Finally, fuel assemblies utilizing Figure 3.9-1D require that a full length, full strength Control Element Assembly be inserted in the fuel assembly (full-length, reduced-strength Control Element Assemblies and part-length Control Element Assemblies shall NOT be used in Region 3).

h) Region 4 of the spent fuel storage pool is designed and shall be maintained with a nominal 9.0 inch center to center distance between storage locations. Region 4 contains Restricted Locations as shown in Figure 3.9-2. Fuel assemblies stored in this region must comply with Figure 3.9-1E.

i) Each region of the spent fuel storage pool is designed to permit storage of Non-standard Fuel Configurations, except for the Restricted Locations. Each of the Non-standard Fuel Configurations must have a separate criticality analysis which may allow storage in one or multiple Regions, and which may or may not require Borated Stainless Steel Poison Rodlets or a full length, full strength Control Element Assembly if stored in Region 3.

j) Regions 1 and 2 spent fuel racks are equipped with boxes that contain the Boraflex panels which may be removed from both non-restricted and Restricted Locations. Fuel assemblies and Non-standard Fuel Configurations shall NOT be placed in storage locations in which the Boraflex panel box has been removed (however, it is permissible to store non-fuel components in a location in which the Boraflex panel box has been removed as long the location is NOT a Restricted Location).

DRAINAGE

5.6.2 The spent fuel storage pool is designed and shall be maintained to prevent inadvertent draining of the pool below elevation 22'6".

CAPACITY

5.6.3 The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 224 storage locations in Region A, 160 storage locations in Region B and 962 storage locations in Region C for a total of 1346 storage locations.

The spent fuel storage pool is designed and shall be maintained with the number of storage locations (including Restricted Locations) limited to no more than 160 storage locations in Region 1, 224 storage locations in Region 2, 822 storage locations in Region 3, and 140 storage locations in Region 4 for a total of 1346 storage locations.

ATTACHMENT 7

MARKED-UP TECHNICAL SPECIFICATIONS BASES PAGES (FOR INFORMATION ONLY)

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

FOR INFORMATION ONLY

LBDCR 06-MP2-029
July 27, 2006

or Non-standard Fuel Configuration, or a multiple mis-load of fuel assemblies.

3/4.9.16 SHIELDED CASK

The limitations of this specification ensure that in the event of a shielded cask drop accident the doses from ruptured fuel assemblies will be within the assumptions of the safety analyses.

3/4.9.17 SPENT FUEL POOL BORON CONCENTRATION

The limitations of this specification ensures that sufficient boron is present to maintain spent fuel pool $K_{eff} \leq 0.95$ under accident conditions.

is ≥ 2100

Postulated accident conditions which could cause an increase in spent fuel pool reactivity are: a single dropped or mis-loaded fuel assembly, a single dropped or mis-loaded Consolidated Fuel Storage Box, or a shielded cask drop onto the storage racks. A spent fuel pool soluble boron concentration of 1400 ppm is sufficient to ensure $K_{eff} \leq 0.95$ under these postulated accident conditions. The required spent fuel pool soluble boron concentration of ≥ 1720 ppm conservatively bounds the required 1400 ppm. The ACTION statement ensure that if the soluble boron concentration falls below the required amount, that fuel movement or shielded cask movement is stopped, until the boron concentration is restored to within limits.

2100

assembly or Non-standard Fuel Configuration

2100

An additional basis of this LCO is to establish 1720 ppm as the minimum spent fuel pool soluble boron concentration which is sufficient to ensure that the design basis value of 600 ppm soluble boron is not reached due to a postulated spent fuel pool boron dilution event. As part of the spent fuel pool criticality design, a spent fuel soluble boron concentration of 600 ppm is sufficient to ensure $K_{eff} \leq 0.95$, provided all fuel is stored consistent with LCO requirements. By maintaining the spent fuel pool soluble boron concentration ≥ 1720 ppm, sufficient time is provided to allow the operators to detect a boron dilution event, and terminate the event, prior to the spent fuel pool being diluted below 600 ppm. In the unlikely event that the spent fuel pool soluble boron concentration is decreased to 0 ppm, K_{eff} will be maintained <1.00, provided all fuel is stored consistent with LCO requirements. The ACTION statement ensures that if the soluble boron concentration falls below the required amount, that immediate action is taken to restore the soluble boron concentration to within limits, and that fuel movement or shielded cask movement is stopped. Fuel movement and shielded cask movement is stopped to prevent the possibility of creating an accident condition at the same time that the minimum soluble boron is below limits for a potential boron dilution event.

assembly or Non-standard Fuel Configuration

The surveillance of the spent fuel pool boron concentration within 24 hours of fuel movement, consolidated fuel movement, or cask movement over the cask layout area, verifies that the boron concentration is within limits just prior to the movement. The 7 day surveillance interval frequency is sufficient since no deliberate major replenishment of pool water is expected to take place over this short period of time.

(The actual analysis conservatively shows that 550 ppm is sufficient to ensure $K_{eff} \leq 0.95$).

Insert T.7

3/4.9.18 SPENT FUEL POOL - STORAGE

The limitations described by Figures 3.9-1a, 3.9-1b, and 3.9-3 ensure that the reactivity of fuel assemblies and consolidated fuel storage boxes, introduced into the Region C spent fuel racks, are conservatively within the assumptions of the safety analysis.

The limitations described by Figure 3.9-4 ensure that the reactivity of the fuel assemblies, introduced into the Region A spent fuel racks, are conservatively within the assumptions of the safety analysis.

3/4.9.19 SPENT FUEL POOL - STORAGE PATTERN

Regions 1, 2, and 4

The limitations of this specification ensure that the reactivity condition of the Region B storage racks and spent fuel pool K_{eff} will remain less than or equal to 0.95.

The Cell Blocking Devices in the 4th location of the Region B storage racks are designed to prevent inadvertent placement and/or storage in the blocked locations. The blocked location remains empty, or a Batch B fuel assembly may be stored in the blocked location, to maintain reactivity control for fuel assembly storage in any adjacent locations. Region B (non-cell blocker locations) is designed for the storage of new assemblies in the spent fuel pool, and for fuel assemblies which have not sustained sufficient burnup to be stored in Region A or Region C.

This LCO is not applicable during the initial installation of Batch B fuel assemblies in the cell blocker locations of Region B. This is acceptable because only Batch B fuel assemblies will be moved during the initial installation of Batch B fuel assemblies under the Region B cell blockers. Batch B fuel assemblies are qualified for storage in any spent fuel pool storage rack location, hence a fuel misloading event which causes a reactivity consequence is not credible. This exception is valid only during the initial installation of Batch B fuel assemblies in the cell blocker locations.

Replace with Insert T.8

3/4.9.20 SPENT FUEL POOL - CONSOLIDATION

The limitations of these specifications ensure that the decay heat rates and radioactive inventory of the candidate fuel assemblies for consolidation are conservatively within the assumptions of the safety analysis.

FOR INFORMATION ONLY

Insert T.7 to TS Basis 3/4.9.18

The limitations described by Figures 3.9-1A, 3.9-1B, 3.9-1C, 3.9-1D, and 3.9-1E ensure that the reactivity of fuel assemblies introduced into Region 2, 3, and 4 spent fuel racks is conservatively within the assumptions of the safety analysis.

In addition, the requirement that Region 3 fuel assemblies contain Borated Stainless Steel Poison Rodlets or a fuel length, full strength Control Element Assembly ensures that the reactivity of fuel assemblies is conservatively within the assumptions of the criticality analysis. Note that the full length, reduced strength Control Element Assemblies used in Cycles 1 through 6 (Control Element Assemblies with serial numbers 66 through 73, inclusive) and the part length Control Element Assemblies used in Cycle 1 (Control Element Assemblies with identifier letters A through H, inclusive) do not satisfy this requirement, and thus are not to be used in Region 3.

There are Non-standard Fuel Configurations and non-fuel components present in the fuel storage racks. Each region of the SFP is designed to permit storage of these items, except for the Restricted Locations. Each of the Non-standard Fuel Configurations must have a separate criticality analysis which may allow storage in one or multiple Regions, and which may or may not require Borated Stainless Steel Poison Rodlets or a Control Element Assembly if stored in Region 3.

Insert T.8 to TS Bases 3/4.9.19

Maintaining empty the fuel storage rack locations designated as Restricted Locations (Figure 3.9-2) helps assure that K_{eff} will remain $\leq$ 0.95 under all postulated normal and accident conditions.

ATTACHMENT 8

SUMMARY OF DELETIONS, REVISIONS, AND ADDITIONS TO THE MPS2 SPENT FUEL POOL CRITICALITY ANALYSIS WITH NO CREDIT FOR BORAFLEX

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

Summary of Deletions, Revisions and Additions to the MPS2 Spent Fuel Pool Criticality Analysis with No Credit for Boraflex

The deletions, revisions, and additions to the Spent Fuel Pool Criticality Analysis with No Credit for Boraflex (Attachment 4 of the December 2012 LAR) are identified in this attachment. Each section of the previously submitted criticality analysis is identified along with the changes to that section. Most changes are identified by Request for Additional Information (RAI) responses given in Attachment 1 of this letter which are not repeated here. Some of the changes are identified by reference to the appropriate section of Attachments 4 and 5 of this letter.

With the referenced revisions included, the MPS2 Spent Fuel Pool Criticality Analysis with No Credit for Boraflex (Attachment 4 of the December 2012 LAR) is the document referred to as the "proposed criticality analysis" in Attachment 3 of this letter.

1 INTRODUCTION

In the last paragraph of the Objective subsection, there is a discussion on the use of 5.0 wt% U-235. This discussion is still correct but now it applies to some of the analysis rather than the implied all. "Some" should be inserted before "results and data" of the first sentence of the last paragraph of the Objective section.

No other deletions, revisions or additions are required for the Introduction section.

2 CALCULATIONAL TOOLS

After the paragraph for Section 2.1, add, "The ENDF/B-VII 238 group cross section library, v7-238, is used for SCALE calculations (both criticality and depletion calculations)."

At the end of Section 2.2 add the response to RAI 8.

At the end of Section 2.3 add the response to RAI 15.

3 METHODOLOGY

3.1.1 Fuel Assembly Selection

Add the following paragraph to the end of Section 3.1.1:

"*Likewise, all the fuel assembly designs were analyzed for the New Fuel Storage Rack (NFSR). This analysis included both full and optimum moderation. The limiting design for the NFSR is also the new proposed fuel design for both conditions.*"

3.1.2 Depletion Analysis

No changes are necessary to Section 3.1.2.1.

The last paragraph of Section 3.1.2.2 is replaced with:

"The uncertainty allowance for depleted fuel calculated isotopic concentrations used in this analysis is 5% of the depletion reactivity as specified in DSS-ISG-2010-01."

Section 3.1.2.3 is replaced by a comparison of SCALE 6.1 depletion analysis with CASMO depletion analysis. This material is the response to RAI 11. Replace Section 3.1.2.3 with the response to RAI 11.

Section 3.1.2.4 is replaced by the response to RAI 12.

3.1.3 Conservative Depletion Conditions

Section 3.1.3.1; add the following paragraph to the end of the section:

"At low burnup, a uniform axial burnup can be more limiting. Further, in accident conditions with fresh fuel, a uniform axial burnup may produce a more reactive condition than using the axial burnup distributions shown on Tables 3.1-2 and 3.1-3. The analysis considers both uniform and axially distributed burnup shapes."

Add the discussion on Group 9 burnup distribution (5 paragraphs including citation) from Attachment 5 to the end of Section 3.1.3.1.

No changes to Sections 3.1.3.2, 3.1.3.3, 3.1.3.4, 3.1.3.5, and 3.1.3.6.

The response from RAI 9 is used to augment Section 3.1.3.7.

No changes to Sections 3.1.3.8, 3.1.3.9, 3.1.3.10, and 3.1.3.11.

Add Section 3.1.3.12 (Fuel Rod Growth and Clad Creep) which is the response to RAI 22.b.

Add Section 3.1.3.13 (Asymmetric Fuel Placement) which is the response to RAI 23.

3.1.4 Criticality Code Validation

The second sentence of the second paragraph in Section 3.1.4 is replaced by:

"333 critical experiments were modeled, including cases containing soluble boron, borated poison materials, Ag-In-Cd absorbers, and fuel containing plutonium. The set also included 17 experiments which varied the temperature."

The second and third sentence of the third paragraph of Section 3.1.4 is replaced by:

"The code bias calculated in the SCALE 6.0 code validation is 0.00484 Δk 0.007 Δk for fuel in the NFSR. The code bias uncertainty used in this analysis is 0.00519 Δk for fuel in the SFP and 0.006 Δk for fuel in the NFSR. A temperature bias was added for conditions with fuel above room temperature."

3.1.5 Miscellaneous Items

No deletions, revisions or additions are required for this section.

3.2 SUPPLEMENTAL ANALYSIS GUIDANCE

No deletions, revisions or additions are required for this section.

3.3 REFERENCES

No deletions, revisions or additions are required for this section.

4 SPENT FUEL STORAGE RACKS & COMPONENTS

4.1 SPENT FUEL POOL STORAGE CONFIGURATION DESCRIPTION

No deletions, revisions or additions are required for this section.

4.2 INDIVIDUAL STORAGE RACK TYPE DESCRIPTIONS

The response to RAI 25b is added to the end of Section 4.2.1. No other deletions, revisions or additions are required for this section.

4.3 MISCELLANEOUS COMPONENTS

No deletions, revisions or additions are required for this section.

4.4 NON-STANDARD STORAGE CONFIGURATIONS

Replace Section 4.4 with the following, "There are non-standard fuel arrangements in the spent fuel pool. Non-standard fuel is described and analyzed in Appendix C (Non-Standard Fuel Configurations and Compoments)." Attachment 4 is the material for Appendix C.

4.5 REFERENCES

No deletions, revisions or additions are required for this section.

5. NEW FUEL STORAGE ANALYSIS

"Key Analysis Assumptions" item 4. Delete the last sentence and change the temperatures in the first sentence to 277 °K and 373 °K.

5.1 MODEL DESCRIPTION

Section 5.1 is replaced by the material contained in RAI 17.

5.2 METHODOLOGY

At the end of the fourth paragraph, delete "and eccentric fuel positioning" and move the "and" to between "enrichment," and "guide." The eccentric positioning is now part of the base model.

Delete the bullet on the sensitivity to concrete thickness.

5.3 ANALYSIS RESULTS

Delete the entire section. The analysis of the New Fuel Storage Racks has been redone with the new model described in RAI 17. The results of this analysis are found in RAI 10, 18, 19, and 20.

5.4 REFERENCES

The reference from RAI 17 is added.

6. SFP ENRICHMENT, BURNUP & BORON REQUIREMENTS

6.1 ANALYSIS OF ENRICHMENT & BURNUP REQUIREMENTS

Delete item 2. End of item 3 “Section 4.4” is replaced by “Appendix C.”

6.1.1 Model Description and General Calculations

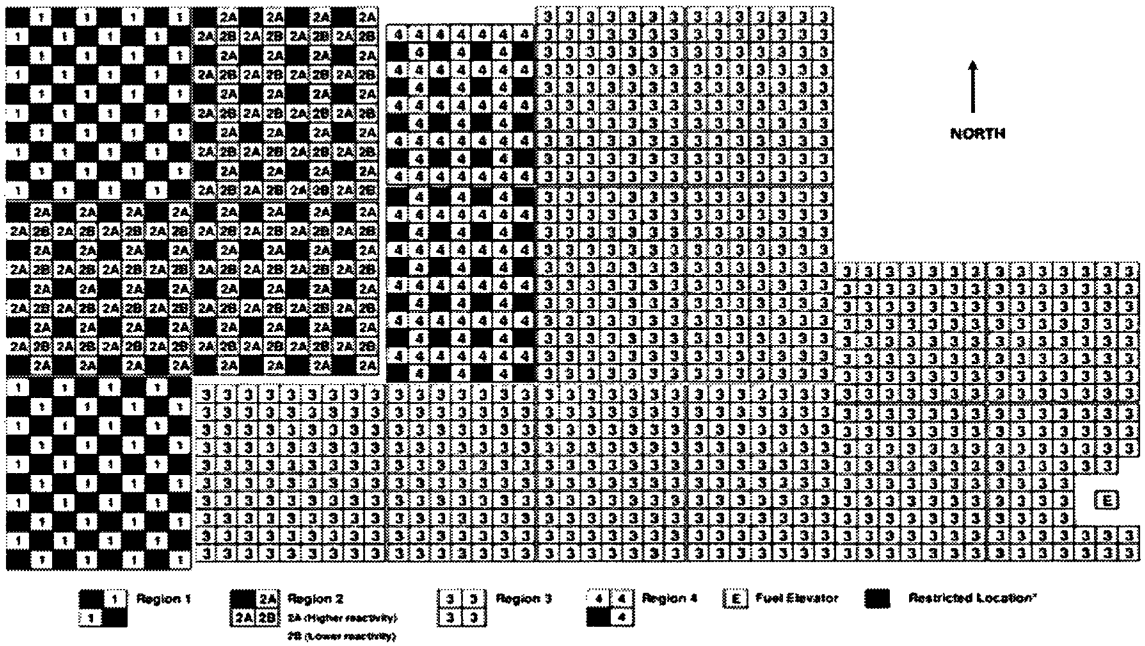
6.1.1.1 Model Description

In the first paragraph, change “The Boraflex boxes are removable.” to “The Boraflex boxes are wedged into place and removal is possible, but this analysis requires a Boraflex box to be present in each rack cell designated for fuel storage. Boraflex boxes may be removed from cells that are designated to be empty.”

Replace the note on Figure 6.1-1 with “A Restricted Location shall remain empty of fuel and non-fuel components”.

On Table 6.1-1 add the tolerance of +/- 0.0051 to the SS Boraflex cover sheet thickness. Add the SS angle bracket thickness tolerance found in the response to RAI 21.b.

Expand Table 6.1-1 to include the CEA information found on Table 25.1 of the RAI.



* A Restricted Location shall remain empty. No fuel assembly, no Non-standard Fuel Configuration, no non-fuel component, nor any hardware/material of any kind may be stored in a Restricted Location.

Revised Figure 6.1-1 MP2 SFP Spent Fuel Pool Layout

6.1.1.2 Calculation of Enrichment and Burnup Requirements with No Soluble Boron

Under Bias components considered:

- Remove (a) (Isotopic content bias). The isotopic content only is an uncertainty per DSS-ISG-2010.
- In (e), remove the example of "rodlet orientation in Region 3" since the limiting orientation is used in the analysis.
- Remove the example in (f). CEA content is conservatively modeled so there is no bias.
- Add Code Temperature Bias when elevated temperatures are limiting.
- Add asymmetric fuel placement.
- Add creep dimension assumption.

Under Uncertainty components considered, replace (f) "Symmetry assumptions (off-center fuel placement)" with "Symmetry assumptions (off-center CEA and rodlet placement in the guide tubes)".

The paragraph starting page 57, "a full pool model" is replaced with "an interface model."

Step 7 on page 57 is replaced by, "Deplete to the target enrichment and burnup for the burnup requirements and analyze the condition in the rack."

Step 8 on page 57 is not necessary since the analysis is limited to 4.85 wt% for burned fuel. In the paragraph under the numbered set, add "some" between "Although" and "evaluations." The second sentence in the paragraph under the numbered set is deleted since the analysis is limited to 4.85 wt% for burned fuel.

In the last paragraph before Section 6.1.1.3 add "+ 2* RSS (Sigma K1, Sigma K2) and values greater than 0 will be considered significant." after "Significance is defined as K2-K1" and delete the rest of the paragraph. The last sentence which addresses bias versus uncertainty is covered in the lists at the beginning of the section.

6.1.1.3 Calculation of Bias and Uncertainty – Specific Bias and Uncertainty Values

Table 6.1-2 needs the following changes:

- Off-center fuel placement is now at type "B" rather than "U" and the value is changes to "Maximum Expected Over Life of Plant"

- Fuel assembly structure is specified in Section 6.1.1.1. This does not show up as a bias so this row is deleted from the table. RAI 22 addresses the assembly structure.
- Rodlet orientation is done conservatively so it does not show up as a bias and this row is deleted from the table.
- The depletion code nuclide compositions uncertainty is changed from 4.55% to 5%. The reference is changed to DSS-ISG-2010.
- Add SS Boraflex cover sheet thickness, Type U, 0.07366 +/- 0.0076 cm, Design documents.
- Add Validation Temperature Bias, Type B, 0.000017*delta T (^{o}C), LEU-COMP-THERM-046.

6.1.2 Region 1 Analysis

Section 6.1.2 is replaced by the Region 1 analysis in Attachment 5, Section 5.1.

6.1.3 Region 2 Analysis

Section 6.1.3.2 is replaced by the Region 2 analysis in Attachment 5, Section 5.2.

6.1.4 Region 3 Analysis

Section 6.1.4 is replaced by the Region 3 analysis in Attachment 5, Section 5.3.

6.1.5 Region 4 Analysis

Section 6.1.5 is replaced by the Region 4 analysis in Attachment 5, Section 5.4.

6.2 ANALYSIS OF BORATED CONDITIONS (ANALYSIS OF SOLUBLE BORON REQUIREMENTS in December LAR)

The revised LAR changes the approach to borated analysis. Rather than determine the minimum soluble boron needed to meet the 0.95 condition, the new analysis determines the maximum k_{eff} given the minimum soluble determined by the boron dilution analysis (600 ppm) or for accident conditions the maximum k_{eff} using the minimum Technical Specification soluble boron (2100 ppm).

The following is substituted for the first sentence of Section 6.2, "Section 6.2 confirms that with the minimum boron determined by the boron dilution analysis (600 ppm [Ref. 6.2-2]) the spent fuel pool k_{eff} is less than 0.95 with

95/95 confidence. The analysis actually uses 550 ppm to provide additional margin."

In Key Analysis Assumptions 2, delete "in the empty guide tubes." This unnecessary conservatism is removed. Key Analysis Assumption 4 is deleted since the approximation is no longer used.

All subsections in Section 6.2 are deleted. After the key assumptions, the response to RAI 35 is inserted.

Section 6.2.1.4, Boron Dilution Analysis, is moved into the new Section 6.2. The last paragraph is deleted and replaced with:

"The 600 ppm soluble boron value for normal conditions is retained for this analysis, and the accident condition boron is increased to 2100 ppm. SFP minimum TS 3.9.17 boron is increased to 2100 ppm, which increases the time required to dilute to 600 ppm. The existing dilution volumes, flow rates and event mitigation response times remain unchanged for this analysis. The Reference 6.2-2 boron dilution analysis conclusions remain applicable and unchanged."

6.3 INTERFACE ANALYSIS (new section in new LAR)

This new section is the response to RAI 34.

6.4 NORMAL AND ACCIDENT ANALYSIS (new section in new LAR)

Section 6.4.1 is the old section 6.2.1.2. Section 6.4.2 is titled "Accident Analysis" and comes from the responses to RAI 37, 38, 39, 40, and 41.

7. SUMMARY OF RESULTS

Only a few changes are needed.

Last sentence of Section 7.1.2: "of Figure 7.1-2" changed to "also on Figure 7.1-1"

Replace:

Figures 7.1-1 and 7.1-2 with Figure 5.2-1 from Attachment 5.

Figure 7.1-3 with Figure 5.3.1-1 from Attachment 5.

Figure 7.1-4 with Figure 5.3.2-1 from Attachment 5.

Figure 7.1-5 with Figure 5.4-1 from Attachment 5.

Section 7.2.1 "540" changed to "less than 550"

Section 7.2.2 "1256" changed to "less than 2100". The second sentence is replaced by, "The Technical Specification for the minimum soluble boron is changed to 2100 ppm."

APPENDIX A CRITICALITY CODE VALIDATION

The current Appendix A is still correct but it has been augmented with additional calculations. Section A.6 is changed to "Additional Calculations" and the response to RAI 42 is inserted here. The current A.6 is renumbered A.7.

ATTACHMENT 9

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION AND AFFIDAVIT OF DOMINION NUCLEAR CONNECTICUT, INC.

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

10 CFR 2.390

<u>APPLICATION FOR WITHHOLDING INFORMATION</u>
<u>AND</u>
<u>AFFIDAVIT OF MARK D. SARTAIN</u>

I, Mark D. Sartain, Vice President – Nuclear Engineering, of Dominion Nuclear Connecticut, Inc. state that:

1. I am authorized to execute this affidavit on behalf of Dominion Nuclear Connecticut, Inc. (DNC).

2. DNC is providing information in response to a request for additional information (RAI) from the NRC related to DNC's license amendment request for Millstone Unit 2 dated December 17, 2012 proposing a technical specification change for spent fuel storage. Table 11.4, "Isotopic Content comparisons for MPS2-Specific CASMO/TRITON Cases," and Table 11.13, "In-Rack Comparison TRITON and CASMO Isotopic Content" were generated by DNC using software licensed to DNC by Studsvik Scandpower, Inc. (Studsvik). Use of the software by DNC is controlled by a commercial agreement between DNC and Studsvik which requires DNC to seek proprietary treatment for materials developed using Studsvik's methodology. Accordingly, Tables 11.4 and 11.13 constitute proprietary commercial information that should be held in confidence by the NRC pursuant to the policy reflected in 10 C.F.R. §§ 2.790 (a) (4) and 9.17 (a) (4) because:

   a. This information is being transmitted to the NRC in confidence.

   b. This information was generated solely for the RAI responses and is being transmitted to the NRC for that limited purpose.

   c. This information is not available in public sources and could not be gathered readily from other publicly available information.

   d. Public disclosure of the information generated by DNC would create harm to the commercial interests of Studsvik since review of the RAI responses is being performed for the NRC by a third party reviewer whose business interests overlap with Studsvik's business interests.

   e. DNC is obligated by commercial agreement to seek to protect the information from public disclosure.

3. Accordingly, DNC requests that Tables 11.4 and 11.13 be withheld from public disclosure pursuant to the policy reflected in 10 CFR 2.390(a)(4) and 10 CFR 9.17 (a)(4).

Mark D. Sartain
Vice President –Nuclear Engineering
Dominion Nuclear Connecticut, Inc.

STATE OF CONNECTICUT
COUNTY OF NEW LONDON

Acknowledged before me this 21st day of JULY, 2015.

Notary Public

My registration number is: ____________ and My Commission Expires: 2-28-16.

THOMAS CLEARY
NOTARY PUBLIC
MY COMMISSION EXPIRES
FEBRUARY 28, 2016

ATTACHMENT 10

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION AND AFFIDAVIT OF AREVA INC

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

AREVA

June 8, 2015
FAB15-00372

Mr. Rick Sterner
Dominion Nuclear Fuel
Millstone Power Station
Rope Ferry Road
Waterford, CT 06385

Subject: Affidavit Supporting AREVA Proprietary Information Contained in Dominion's RAI Responses Regarding Proposed TS Changes for Spent Fuel Storage

Reference 1: Fuel Fabrication and Related Services Contract between Dominion Nuclear Connecticut, Inc and AREVA NP, Inc. dated February 1, 2011 as amended through Amendment 2, dated December 1, 2013.
Reference 2: AREVA Letter FAB12-00646-001, AREVA Fuel Data for Millstone 2 Spent Fuel Pool Criticality Analysis
Reference 3: CORRES-OUT-AREVA-20150043, Rev. 1, Add. 0, "Dominion Request for Affidavit to Include Enclosed Proprietary Information to Support RAI Responses for LAR 12-678 for Changes to Millstone Unit 2 Spent Fuel Storage (Revision 1)," by M. S. Lico, dated MAY 29, 2015.

Dear Mr. Sterner,

The attached Affidavit supports Dominion's use of AREVA proprietary information in "Dominion Nuclear Connecticut, Inc. Millstone Power Station Unit 2 Response to Second Request for additional Information Regarding Proposed Technical Specification Change for Spent Fuel Storage" as requested in Reference 3. AREVA had previously supplied the information to Dominion in AREVA documents as proprietary. AREVA Letter FAB12-00646-001 was then issued to identify the specific AREVA proprietary information as that information contained in brackets "[ ]".

Note that the supplied information contains AREVA INC Proprietary data and is to be treated according to Reference 1. If you have any questions or comments, feel free to call me at (434) 832-5029, or you can e-mail me at Hunter.Marshall@areva.com.

Sincerely,

E. Hunter Marshall
Project Manager

Cc: Tom Brookmire, Chris Clemens, John Guerci, John Harrell, Stacey Nelson, Michael Lico

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF LYNCHBURG)

1. My name is Gayle Elliott. I am Manager, Product Licensing, for AREVA Inc. (AREVA) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA to determine whether certain AREVA information is proprietary. I am familiar with the policies established by AREVA to ensure the proper application of these criteria.

3. I am familiar with the AREVA information contained in the Attachment to a letter from Mr. Mark Sartain (Dominion) to U.S. NRC entitled, "Dominion Nuclear Connecticut, Inc. Millstone Power Station Unit 2 Response to Second Request for Additional Information Regarding Proposed Technical specification Change for Spent Fuel Storage," Cover Letter # 14-625, and referred to herein as "Document." Information contained in this Document has been classified by AREVA as proprietary in accordance with the policies established by AREVA Inc. for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by AREVA to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA, would be helpful to competitors to AREVA, and would likely cause substantial harm to the competitive position of AREVA.

The information in this Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside AREVA only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 2nd day of June, 2015.

Sherry L. McFaden
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 10/31/18
Reg. # 7079129

SHERRY L. MCFADEN
Notary Public
Commonwealth of Virginia
7079129
My Commission Expires Oct 31, 2018

ATTACHMENT 11

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION AND AFFIDAVIT OF WESTINGHOUSE ELECTRIC COMPANY, LLC

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

Westinghouse

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, Pennsylvania 16066
USA

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Direct tel: (412) 374-4643
Direct fax: (724) 940-8560
e-mail: greshaja@westinghouse.com
Proj letter:

CAW-15-4225

July 7, 2015

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: Attachment 1, "Response to Request for Additional Information Regarding Proposed Technical Specification Change for Spent Fuel Storage" (Proprietary)

The proprietary information for which withholding is being requested in the above-referenced document is further identified in Affidavit CAW-15-4225 signed by the owner of the proprietary information, Westinghouse Electric Company LLC. The Affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR Section 2.390 of the Commission's regulations.

Accordingly, this letter authorizes the utilization of the accompanying Affidavit by Dominion Nuclear Connecticut, Inc.

Correspondence with respect to the proprietary aspects of the Application for Withholding or the Westinghouse Affidavit should reference CAW-15-4225, and should be addressed to James A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 3 Suite 310, Cranberry Township, Pennsylvania 16066.

James A. Gresham, Manager

Regulatory Compliance

CAW-15-4225

July 7, 2015

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF BUTLER:

I, James A. Gresham, am authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

James A. Gresham, Manager

Regulatory Compliance

(1) I am Manager, Regulatory Compliance, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse Application for Withholding Proprietary Information from Public Disclosure accompanying this Affidavit.

(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 the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, 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.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitute Westinghouse policy and provide the rational basis required.

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.

(iii) There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iv) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.

(v) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(vi) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in CE-15-374, Attachment 1, "Response to Request for Additional Information Regarding Proposed Technical Specification Change for Spent Fuel Storage" (Proprietary), for submittal to the Commission, being transmitted by Dominion Nuclear Connecticut, Inc letter and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse is that associated with spent fuel pool storage information for criticality analysis and may be used only for that purpose.

(a) This information is part of that which will enable Westinghouse to:

(i) Perform spent fuel pool analysis.

(b) Further this information has substantial commercial value as follows:

(i) Westinghouse plans to sell the use of similar information to its customers for the purpose of spent fuel pool analysis.

(ii) Westinghouse can sell support and defense of industry guidelines and acceptance criteria for plant-specific applications.

(iii) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

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.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.