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April 22, 2011

U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

Attn: Document Control Desk

Subject: Submission of Supplemental Information to Amend the U.S. Nuclear Regulatory Commission Certificate of Compliance No. 1031 for the NAC International MAGNASTOR® Cask System

Docket No. 72-1031

References:
1. U.S. Nuclear Regulatory Commission (NRC) Certificate of Compliance (CoC) No. 1031 for the NAC International MAGNASTOR Cask System, Amendment No. 1, August 30, 2010
2. MAGNASTOR Cask System Final Safety Analysis Report (FSAR), Revision 1, NAC International, January 2011
3. Submission of a Request to Amend the U.S. Nuclear Regulatory Commission Certificate of Compliance No. 1031 for the NAC International MAGNASTOR Cask System, NAC International, March 22, 2010
4. Resubmission of a Request to Amend the U.S. Nuclear Regulatory Commission Certificate of Compliance No. 1031 for the NAC International MAGNASTOR Cask System, NAC International, March 30, 2010

NAC International (NAC) hereby wishes to supplement Reference 4. This supplement consists of two replacement pages (see Attachment 1) for Appendix A to Reference 1, Technical Specifications and Design Features for the MAGNASTOR System. The specific changes being requested are:

- Replacement of Item d) "Minimum fuel tube orthogonal (x, y) pitch" by "Minimum fuel tube outer diagonal dimension" in Section 4.0, Design Features, Subsection 4.1.1, Criticality Control. The affected page is A4-1.
- Correction of the reference to 10 CFR 72.212(b)(2)(i)(C) to read 10 CFR 72.212(b)(5)(iii) in Section 5.5, Radiation Protection Program, item 5.5.3 on page A5-3.

Resulting from the NRC technical review of the original MAGNASTOR application, Reference 1 was issued with a limitation defined by the minimum fuel tube orthogonal (x, y) pitch (PWR basket – 9.249 inches and BWR basket – 6.166 inches). This technical specification requirement represents a measurement between two points in space within the PWR and BWR baskets.

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During the fabrication process, the fuel tube final configuration is controlled and verified by the minimum fuel tube outer diagonal dimension. Since this parameter is controlled to ensure fuel tube geometry and subsequent basket performance characteristics, it is more appropriate to reference the minimum fuel tube outer diagonal dimension in the Technical Specification.

As a practical matter, it is very difficult to measure the orthogonal pitch between two points in space accurately and, in hindsight, this was a poorly defined detail of the Technical Specification. NAC is requesting replacement of the fuel tube orthogonal pitch Technical Specification with a readily measurable and verifiable minimum fuel tube outer diagonal dimension (PWR basket – 13.08 inches and BWR basket – 8.72 inches). Control of this minimum fuel tube outer diagonal dimension provides technical and measurable validation that criticality control for both the PWR and BWR final basket assemblies is met.

The minimum fuel tube outer diagonal dimension defines the tightest fuel tube basket array and the respective orthogonal pitch of the fuel tube relative fuel assembly position. In order to ensure that the appropriate criticality control is maintained, NAC has performed additional criticality analyses evaluating the influence of assembly tolerances permitting variations from the tightest square array to a modified rectangular array. These analyses demonstrate that there is an insignificant impact on system criticality.

Applying Reference 1 as the licensing basis, NAC expanded the previous criticality analysis on dimensional variations of the fuel tube components performed under a prior 72.48 Determination and has incorporated its findings into Reference 2 via two 72.48 Determinations. Copies of the associated MAGNASTOR FSAR Chapter 6 changed pages reflecting the text changes are provided in Attachment 2 for information. All changes made via 72.48 Determinations are in bold italicized text as in the original Amendment 2 request. The current changes in the 72.48 text also have revision bars for easy recognition. Due to text flow, a number of pages are included containing no revision bars. Since the Chapter 6 changed pages contain both NAC proprietary and nonproprietary information, the affected proprietary changed pages are being provided in a separate sealed envelope. An affidavit executed by Mr. Thomas A. Danner, Vice President, Engineering attesting to the proprietary nature of the information in accordance with 10 CFR 2.390 is enclosed.

The change of the reference to 10 CFR 72.212(b)(2)(i)(C) is an administrative correction necessitated by the ongoing rule change in 10 CFR Part 72, as this section has been renumbered in the revised rule to 10 CFR 72.212(b)(5)(iii). The Part 72 rule change will become effective May 17, 2011. Therefore, changing this reference as requested will maintain the correct cross-reference in the Technical Specification. This change has no impact on any other aspect of the MAGNASTOR FSAR (Reference 2), the CoC or the Technical Specifications.

NAC hereby requests the NRC to incorporate the herein-described changes into the MAGNASTOR Amendment 2 Certificate of Compliance/Technical Specifications.

Approval of this supplement to Amendment 2 to Reference 1, its incorporation into the Safety Evaluation Report (SER) and the issuance of a draft CoC/SER are requested in a timely manner to minimize the impact on the rulemaking process and to achieve a direct final rule effective date in 2011.

If you have any comments or questions, please contact me on my direct line at 678-328-1274.

Sincerely,

Anthony L. Patko

Anthony L. Patko
Director, Licensing
Engineering

Attachments:

Attachment 1	Replacement Pages for Appendix A, MAGNASTOR CoC No. 1031, Amendment No. 2
Attachment 2	Additional Text Incorporated into the MAGNASTOR FSAR via 10 CFR 72.48 Determination (Nonproprietary Version) Note: The proprietary version of the affected pages is provided in a separate sealed envelope labeled NAC Proprietary Information.

Enclosure

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AFFIDAVIT PURSUANT TO 10 CFR 2.390

Thomas A. Danner (Affiant), Vice President, Engineering, of NAC International, hereinafter referred to as NAC, at 3930 East Jones Bridge Road, Norcross, Georgia 30092, being duly sworn, deposes and says that:

1. Affiant has reviewed the information described in Item 2 and is personally familiar with the trade secrets and privileged information contained therein, and is authorized to request its withholding.

2. The information to be withheld consists of Pages 6.7.3-11, 6.7.3-12, 6.7.3-13, 6.7.6-12, 6.7.6-13 and 6.7.6-14 of Attachment 2 of NAC's Submission of Supplemental Information to Amend Certificate of Compliance (CoC) No. 1031 for the NAC International MAGNASTOR® Cask System. These MAGNASTOR FSAR pages are provided for information only to support the requested change to Page A4-1 of the MAGNASTOR Technical Specifications. NAC is the owner of the information contained on the aforementioned pages, so they are considered NAC Proprietary Information.

3. NAC makes this application for withholding of proprietary information based upon the exemption from disclosure set forth in: the Freedom of Information Act ("FOIA"); 5 USC Sec. 552(b)(4) and the Trade Secrets Act; 18 USC Sec. 1905; and NRC Regulations 10 CFR Part 9.17(a)(4), 2.390(a)(4), and 2.390(b)(1) for "trade secrets and commercial financial information obtained from a person, and privileged or confidential" (Exemption 4). The information for which exemption from disclosure is herein sought is all "confidential commercial information," and some portions may also qualify under the narrower definition of "trade secret," within the meanings assigned to those terms for purposes of FOIA Exemption 4.

4. Examples of categories of information that fit into the definition of proprietary information are:

   a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by competitors of NAC, without license from NAC, constitutes a competitive economic advantage over other companies.

   b. Information that, if used by a competitor, would reduce their expenditure of resources or improve their competitive position in the design, manufacture, shipment, installation, assurance of quality or licensing of a similar product.

   c. Information that reveals cost or price information, production capacities, budget levels or commercial strategies of NAC, its customers, or its suppliers.

   d. Information that reveals aspects of past, present or future NAC customer-funded development plans and programs of potential commercial value to NAC.

   e. Information that discloses patentable subject matter for which it may be desirable to obtain patent protection.

   The information that is sought to be withheld is considered to be proprietary for the reasons set forth in Items 4.a, 4.b, and 4.d.

5. The information to be withheld is being transmitted to the NRC in confidence.

6. The information sought to be withheld, including that compiled from many sources, is of a sort customarily held in confidence by NAC, and is, in fact, so held. This information has, to the best of my knowledge and belief, consistently been held in confidence by NAC. No public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements, which provide for maintenance of the information in confidence. Its initial designation as proprietary information and the subsequent steps taken to prevent its unauthorized disclosure are as set forth in Items 7 and 8 following.

7. Initial approval of proprietary treatment of a document/information is made by the Vice President, Engineering, the Project Manager, the Licensing Engineer, or the Director, Licensing – the persons most likely to know the value and sensitivity of the information in relation to industry knowledge. Access to proprietary documents within NAC is limited via "controlled distribution" to individuals on a "need to know" basis. The procedure for external release of NAC proprietary documents typically requires the approval of the Project Manager based on a review of the documents for technical content, competitive effect and accuracy of the proprietary designation. Disclosures of proprietary documents outside of NAC are limited to regulatory agencies, customers and potential customers and their agents, suppliers, licensees and contractors with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

8. NAC has invested a significant amount of time and money in the research, development, engineering and analytical costs to develop the information that is sought to be withheld as proprietary. This information is considered to be proprietary because it contains detailed descriptions of analytical approaches, methodologies, technical data and/or evaluation results not available elsewhere. The precise value of the expertise required to develop the proprietary information is difficult to quantify, but it is clearly substantial.

   Public disclosure of the information to be withheld is likely to cause substantial harm to the competitive position of NAC, as the owner of the information, and reduce or eliminate the availability of profit-making opportunities. The proprietary information is part of NAC's comprehensive spent fuel storage and transport technology base, and its commercial value extends beyond the original development cost to include the development of the expertise to determine and apply the appropriate evaluation process. The value of this proprietary information and the competitive advantage that it provides to NAC would be lost if the information were disclosed to the public. Making such information available to other parties, including competitors, without their having to make similar investments of time, labor and money would provide competitors with an unfair advantage and deprive NAC of the opportunity to seek an adequate return on its large investment.

STATE OF GEORGIA, COUNTY OF GWINNETT

Mr. Thomas A. Danner, being duly sworn, deposes and says:

That he has read the foregoing affidavit and the matters stated herein are true and correct to the best of his knowledge, information and belief.

Executed at Norcross, Georgia, this 22st day of April 2011.

Thomas A. Danner
Vice President, Engineering
NAC International

Subscribed and sworn before me this 22nd day of April, 2011.

Notary Public

JEANNIE KLINETOB
MY COMMISSION EXPIRES
SEPT. 25 2011
GWINNETT CO., GEORGIA
NOTARY PUBLIC

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Attachment 1

Replacement Pages for Appendix A

MAGNASTOR CoC No. 1031

Amendment No. 2

4.0 DESIGN FEATURES

4.1 Design Features Significant to Safety

4.1.1 Criticality Control

a) Minimum ^{10}B loading in the neutron absorber material:

Neutron Absorber Type	Required Minimum Effective Areal Density (^{10}B g/cm^2)		% Credit Used in Criticality Analyses	Required Minimum Actual Areal Density (^{10}B g/cm^2)	
	PWR Fuel	BWR Fuel		PWR Fuel	BWR Fuel
Borated Aluminum Alloy	0.036	0.027	90	0.04	0.03
	0.030	0.0225		0.334	0.025
	0.027	0.020		0.03	0.0223
Borated MMC	0.036	0.027	90	0.04	0.03
	0.030	0.0225		0.334	0.025
	0.027	0.020		0.03	0.0223
Boral	0.036	0.027	75	0.048	0.036
	0.030	0.0225		0.04	0.030
	0.027	0.020		0.036	0.0267

Enrichment//soluble boron limits for PWR systems and enrichment limits for BWR systems are incorporated in Appendix B Section 2.0.

b) Acceptance and qualification testing of borated aluminum alloy and borated MMC neutron absorber material shall be in accordance with Sections 10.1.6.4.5, 10.1.6.4.6 and 10.1.6.4.7. Acceptance testing of Boral shall be in accordance with Section 10.1.6.4.8. These sections of the FSAR are hereby incorporated into the MAGNASTOR CoC.

c) Soluble boron concentration in the PWR fuel pool and water in the TSC shall be in accordance with LCO 3.2.1, with a minimum water temperature 5-10°F higher than the minimum needed to ensure solubility.

d) Minimum fuel tube outer diagonal dimension

PWR basket — 13.08 inches
BWR basket — 8.72 inches

4.1.2 Fuel Cladding Integrity

The licensee shall ensure that fuel oxidation and the resultant consequences are precluded during canister loading and unloading operations.

4.1.3 Transfer Cask Shielding

The nominal configuration transfer cask radial bulk shielding (i.e., shielding integral to the transfer cask; excludes supplemental shielding) must provide a

(continued)

5.5 Radiation Protection Program

5.5.1 Each cask user shall ensure that the 10 CFR 50 radiation protection program appropriately addresses dry storage cask loading and unloading, and ISFSI operations, including transport of the loaded CONCRETE CASK outside of facilities governed by 10 CFR 50. The radiation protection program shall include appropriate controls and monitoring for direct radiation and surface contamination, ensuring compliance with applicable regulations, and implementing actions to maintain personnel occupational exposures ALARA. The actions and criteria to be included in the program are provided as follows.

5.5.2 Each user shall perform a written evaluation of the TRANSFER CASK and associated operations, 30 days prior to first use, to verify that it meets public, occupational, and ALARA requirements (including shielding design and dose characteristics) in 10 CFR Part 20, and that it is consistent with the program elements of each user's radiation protection program. The evaluation should consider both normal operations and unanticipated occurrences, such as handling equipment malfunctions, during use of the transfer cask.

5.5.3 As part of the evaluation pursuant to 10 CFR 72.212(b)(5)(iii), the licensee shall perform an analysis to confirm that the dose limits of 10 CFR 72.104(a) will be satisfied under actual site conditions and ISFSI configuration, considering the number of casks to be deployed and the cask contents.

5.5.4 Each user shall establish limits on the surface contamination of the CONCRETE CASK, TSC and TRANSFER CASK, and procedures for the verification of meeting the established limits prior to removal of the components from the 10 CFR 50 structure. Surface contamination limits for the TSC prior to placement in STORAGE OPERATIONS shall meet the limits established in LCO 3.3.2.

5.6 Special Requirements for the First System Placed in Service

The heat transfer characteristics and thermal performance of the MAGNASTOR SYSTEM will be validated by recorded mass flow measurements in the air flow cooling passages of the first system placed in service with a heat load equal to or greater than 30 kW. A letter report summarizing the results of the measurements with respect to analyses of the actual canister content will be submitted to the NRC in accordance with 10 CFR 72.4 within 60 days of placing the loaded cask on the ISFSI pad. The report will include a comparison of the calculated mass flow of the MAGNASTOR SYSTEM at the loaded heat load to the measured mass flow. A report is not required to be submitted for the MAGNASTOR SYSTEMs that are subsequently loaded, provided that the performance of the first system placed in service with a heat load of ≥30 kW is demonstrated by the comparison of the calculated and measured mass flow rates.

(continued)

Attachment 2

Additional Text Incorporated into the

MAGNASTOR FSAR via

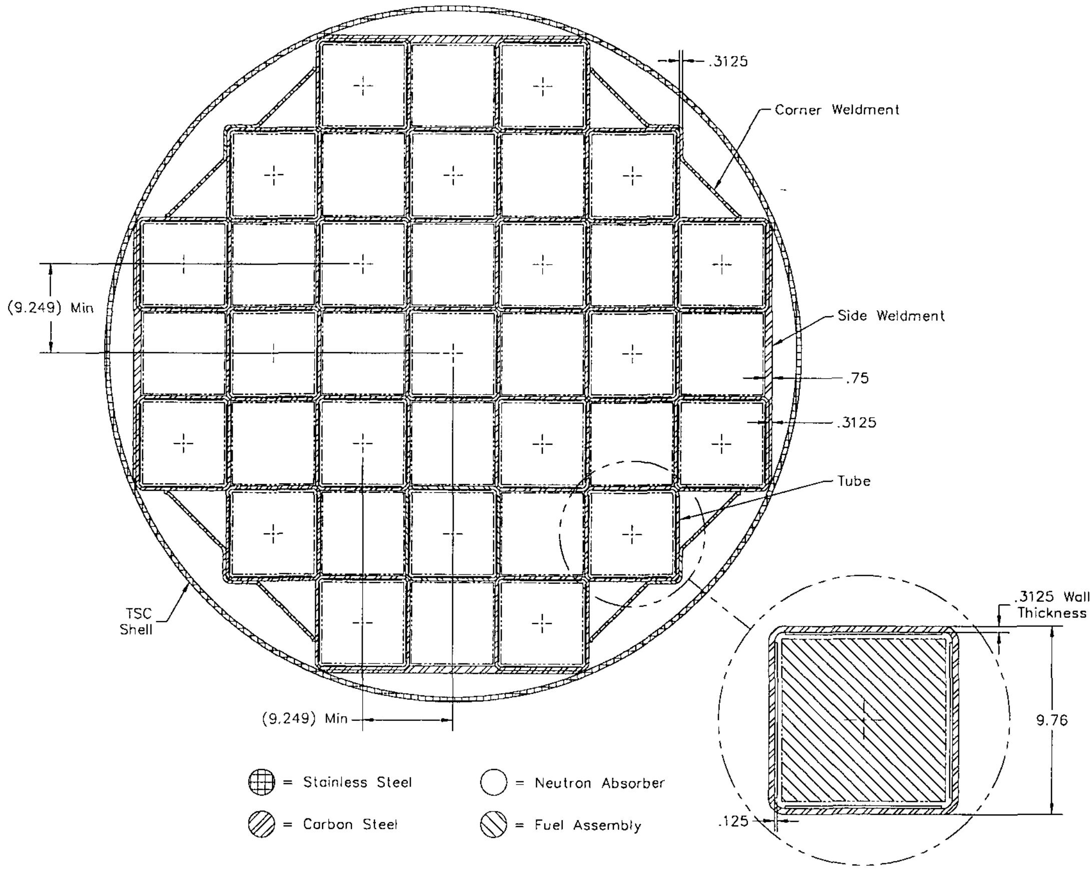
10 CFR 72.48 Determination

(Nonproprietary Version)

NOTE: The enclosed MAGNASTOR FSAR changed pages are provided for information only. The affected pages will be incorporated into the MAGNASTOR FSAR at the next scheduled FSAR update.

LIST OF AFFECTED PAGES

Figure 6.7.1-2 PWR Basket Structure



Notes:

1. Dimensions in inches.
2. Assembly fuel pin array is explicitly modeled. Shown as homogenized area for illustration purposes only.
3. ***Represents square tube basket aligned at 45° with 13.08-inch minimum interface (diagonal flat-to-flat) width.***

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related tolerances, with the exception of maximum tube wall thickness, produce significant reactivity increases when taken independently.

Further evaluations of the component tolerances, including combinations of tolerances, are performed in conjunction with the shifted component configuration.

Component Shift

In addition to the component tolerances, a reactivity study on component shifts is required. Based on the pinned tube arrangement, the only radial shift to be evaluated is the shift of the fuel assembly within the tubes. The tubes are restrained in the corner by pins, ***minimizing tube shift potential. Evaluations on tube shift are included within the Phase 3 Design Modifications subsection (pages 6.7.3-5 through 6.7.3-7).*** The results of shift evaluations are shown in Table 6.7.3-2, indicating that shifting the fuel assembly towards the basket center clearly increases system reactivity.

Combined Shift and Tolerance Study

This section evaluates the effect of combining various basket tolerances with the maximum reactivity shift configuration (radial in). The results for this evaluation are shown in Table 6.7.3-3. Similar to the results of the independent basket tolerance evaluation, only fuel tube thickness affects system reactivity to a statistically significant level.

While no statistically significant reactivity difference is found between the cases with and without tolerances applied, the maximum reactivity configuration chosen for the evaluations of all fuel hybrids is shown below.

Minimum tube width and interface width

Maximum tube thickness

Minimum absorber width and maximum thickness

Fuel assemblies shifted to basket center

This configuration produced reactivities within a 3σ uncertainty band of the maximum reported value for all fuel types evaluated, and provides for the minimum separation between adjacent assemblies. The minimum separation reduces the amount of moderation and the corresponding effectiveness of both the borated water and absorber sheet, which depend on the ^{10}B neutron capture cross-section in the thermal energy range.

Neutron Absorber and Tube Modifications

Phase 1 Design Modifications

Design options permit the replacement or removal of up to 16 neutron absorber sheets in basket peripheral fuel tubes. Locations for the optional absorber sheets are shown in Figure 6.7.3-3. Replacement sheets for the neutron absorber in the peripheral basket locations are composed of

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neutron absorber panels and are, therefore, applied in the revised absorber tolerance models evaluated in Section 6.7.3.2.

To evaluate the design changes, each maximum reactivity fuel type/enrichment/soluble boron combination in Section 6.7.3.2 is evaluated at the increased sheet thickness tolerance band and modified weld post geometry. Results for this analysis are shown in Table 6.7.3-7 and Table 6.7.3-8. The average change in reactivity of updated cases was 0.86σ (Δk = 0.0004). All cases with updated absorber tolerances had resulting reactivities under the USL (0.9372).

Phase 3 Design Modifications

PWR tube drawing dimensions were modified to list the outer width as a reference dimension with the tube corner chamfer specifying a minimum and maximum quantity of material to be removed. The tube interface width is retained as a toleranced dimension (13.08-inch minimum/13.12-inch maximum). The drawing changes provide additional flexibility on the tube width, while ensuring criticality control is retained. Modifications of the tube dimensions and pin and slot configuration have a secondary effect of allowing increased relative shift of the tube centers. To demonstrate that this design modification does not result in significant reactivity changes, additional criticality evaluations are performed.

Variations in system configuration are evaluated that shift from the baseline model that relied on square tubes located at a 45° angle (i.e., even grind tube flats are touching at their midpoints). The 45° aligned model with relatively square tubes is expected to be the as-built configuration of the final basket assembly since the basket: (a) is assembled horizontally producing tube-to-tube contact, with a drawing limitation on the gap allowed between tubes (maximum continuous gap of 0.02 inch over a 24-inch interval); and (b) includes installation of side and corner weldments and placement of the basket into the cylindrical TSC, which would not be feasible for a significantly out-of-alignment tube array. As the basket is composed of individual fuel tubes connected by pin-slot connectors and tubes are attached to the weldment by mounting bosses, each with manufacturing tolerances and gaps, localized variations in tube spacing are allowed by the basket drawings. An additional set of analyses is performed to confirm that the interface width is the primary criticality control dimension and that changes in reactivity associated with (a) the potential tube shift away from a 45° alignment, and (b) system tolerances associated with the tube and tube-to-weldment interface are either not statistically resolvable or reduce reactivity. In these analyses, maximum shifts in tube relative location are applied to the entire basket rather than to a localized basket area to magnify any potential reactivity effects. Applying the changes to the basket globally results

in a configuration that could not be built since corner and side weldments had to be modified beyond drawing allowables to produce a model fitting into the TSC shell.

System variables were modified to produce the maximum shift from the baseline analysis dimensions. Tube minimum interface, or a face-to-face diagonal distance of 13.08 inches, is maintained during the shift/tolerance studies. Maximum perturbation from the baseline may either be a reduced orthogonal dimension (x and/or y) or a reduction in tube center-to-center diagonal spacing. Tube shift reduces the developed cell size by reducing one orthogonal dimension while increasing the other. Figure 6.7.3-4 through Figure 6.7.3-9 contain sketches for the bounding shift/tolerance configurations. There are three even grind and three biased configurations considered in this evaluation. The grind produces the flat at the tube corner and is expected to be uniform during tube fabrication, but drawings allow for a minimum 0.006-inch grind with a maximum 0.04-inch grind. The starting point for the analysis is the baseline square tube aligned at 45° with the even grind shown in Figure 6.7.3-4. This represents the configuration on which maximum allowed enrichments are calculated. Figure 6.7.3-5 modified this configuration to evaluate the impact of a biased grind while retaining the 45° alignment. Next, both even and biased grind configurations were evaluated to determine the maximum shift that could occur between square tubes. The resulting dimension sets are shown in Figure 6.7.3-6 and Figure 6.7.3-7 indicating that the biased grind condition produces the minimum tube center-to-center diagonal spacing, while the even grind condition produces the minimum orthogonal dimension. Note that without regard to the overall basket structure constraints, the developed cell opening is reduced in these scenarios. A sample graphic representation of the MCNP geometry for the shifted tube is shown in Figure 6.7.3-10 to illustrate the potential tube movement. The third set of analyses builds on the shifted tube model while considering the possibility of tubes having a rectangular rather than square cross-section. Sketches of the tube position under the rectangular tube assumption are included in Figure 6.7.3-8 and Figure 6.7.3-9. As the rectangular biased grind dimensions bound the even grind dimensions in both minimum orthogonal and diagonal center-to-center distance, only the biased grind configuration is evaluated.

To address the range of neutron absorber, soluble boron and fuel types allowed in the system, each of the configurations specified in Section 6.7.3.2 was evaluated for potential reactivity change. The fuel assembly configuration containing nonfuel hardware inserts was used in this comparison. Inclusion or removal of the nonfuel hardware from the model does not affect the conclusion of the study, as basket-related reactivity changes were studied, not absolute system reactivity. Effects of the nonfuel hardware, in relation to allowed enrichment, are accounted for in Section 6.7.3.2. Reactivity effects in terms of $\Delta k/\sigma$ are listed in Table 6.7.3-12 for each of the scenarios, demonstrating either no statistically resolvable change in reactivity or a decrease in system reactivity occurs. A breakdown of the analysis results by fuel

type and soluble boron level for the 0.036 gm/cm² effective absorber is shown in Table 6.7.3-13.

Based on the studies described in the previous section, the interface (tube grind flat-to-flat) width controls the critical tube spacing and, therefore, assembly spacing and system reactivity.

6.7.3.2 Allowable Loading Definitions and Maximum System Reactivities

Based on the most reactive basket configuration, each of the fuel assembly types is evaluated at various enrichment levels to determine the minimum soluble boron level required with and without insert. The pellet-to-clad gap is flooded with unborated water in all cases. The goal of this evaluation is for $k_{eff} + 2\sigma$ to remain below the USL of 0.9372. Limiting physical assembly characteristics for each of the evaluated fuel types is summarized in Table ***6.7.3-11***. The number of guide tubes in both tables refers to the number of instrument and guide tubes combined. All fuel geometry information is based on nominal, unirradiated dimensions. Enrichment and minimum soluble boron load limits for the 0.036 ^{10}B g/cm^2 neutron absorber sheet configuration without insert in the active fuel region are listed in Table ***6.7.3-9***. Table ***6.7.3-10*** contains similar data for fuel with nonfuel insert in the active fuel region. A generic definition taking the bounding values from the insert and no-insert evaluation is listed in Table ***6.7.3-11*** in conjunction with the assembly physical characteristics. Table ***6.7.3-14*** lists the corresponding enrichment/soluble boron limitations for each of the assembly types at two reduced neutron absorber sheet specifications. Reduced absorber contents evaluated are effective areal densities of 0.030 and 0.027 ^{10}B g/cm^2.

Summarized as follows are maximum system reactivities. Analysis results represent maximum reactivity basket and fuel geometry. There are no design basis off-normal or accident transfer cask conditions affecting system reactivity. Therefore, only normal condition results are presented. An accident condition for the concrete cask represents a flooding of the concrete cask to canister annulus. Concrete cask results are based on the maximum fuel mass assembly at the highest allowed enrichment (5.0 wt % ^{235}U).

Condition	Pellet to Clad Gap Condition	Maximum Multiplication Factors ($k_{eff} + 2\sigma$)	
		Transfer Cask	Concrete Cask
Normal	Dry	0.93183	0.48145
Normal	Wet	0.93712	N/A
Accident / Off-Normal	Dry	N/A	0.47104

No analysis has been performed on PWR radial enrichment patterns. Therefore, the enrichment limits specified in this analysis are applied as peak rod enrichments.

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Figure 6.7.3-1 PWR Water Density Variations (2500 ppm B, Unborated Wet Gap)

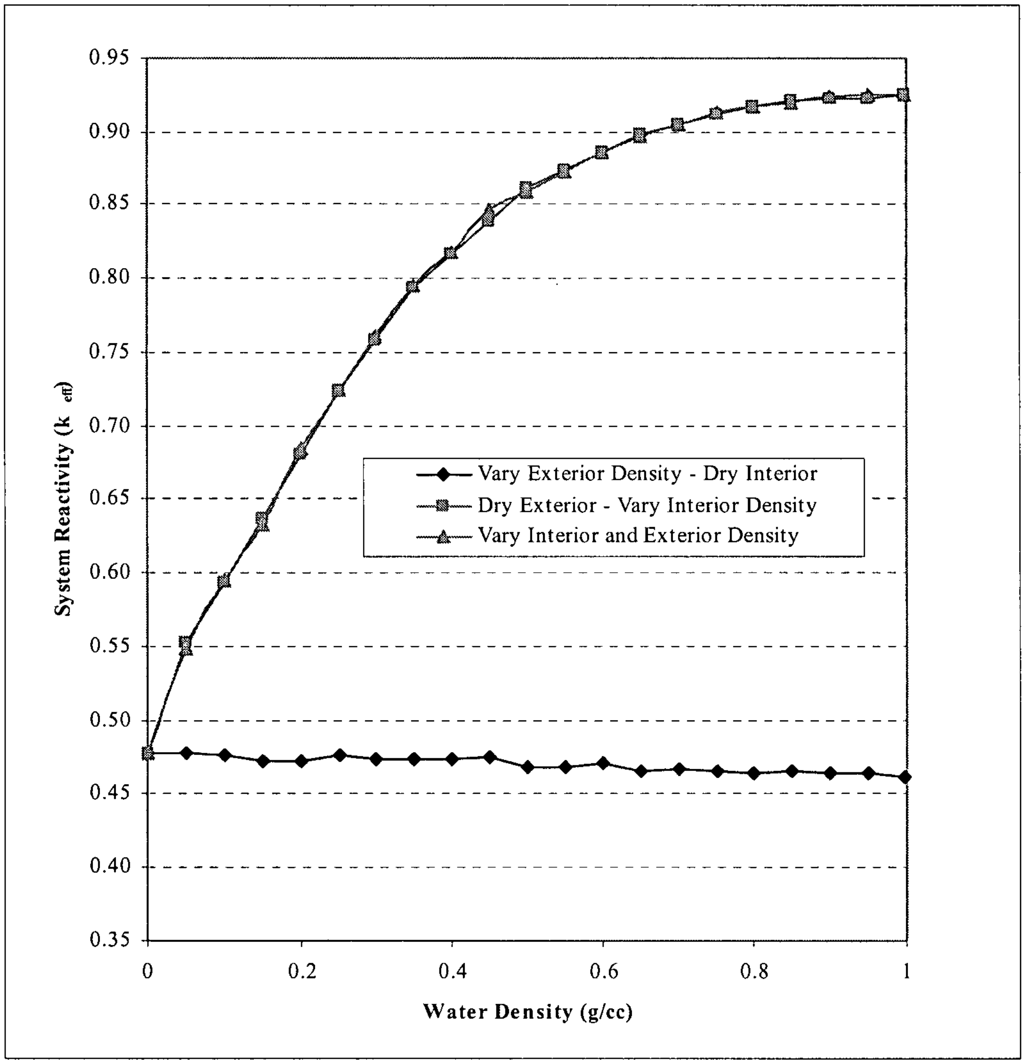

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Figure 6.7.3-2 PWR Water Density Variations for Varying Gap Conditions (2500 ppm B)

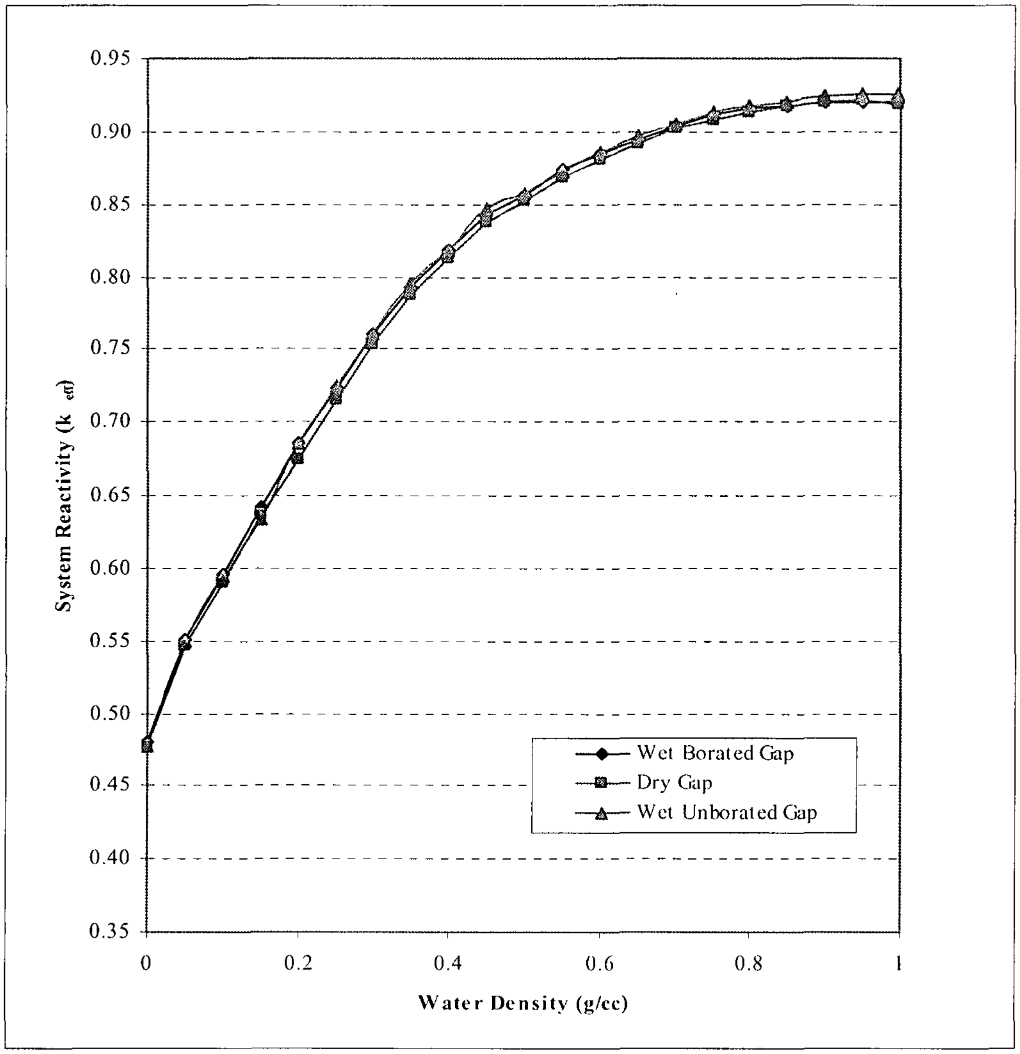

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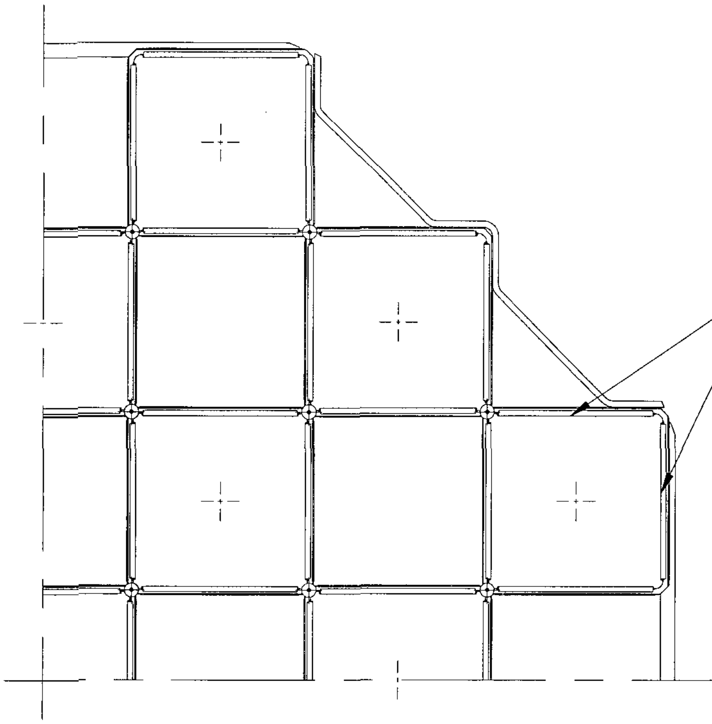
Figure 6.7.3-3 PWR Basket Optional Neutron Absorber Sheet Locations[a]



[a] Quarter basket model is shown for clarity. Symmetric locations are affected in all four basket quadrants.

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Figure 6.7.3-4 PWR Minimum Tube Spacing – Baseline Configuration – Square Tube – Even Grind – 45° Aligned

[redacted]

Figure 6.7.3-5 PWR Minimum Tube Spacing – Square Tube – Biased Grind – 45° Aligned

[redacted]

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Figure 6.7.3-6 PWR Minimum Tube Spacing – Square Tube – Even Grind – Shifted

[redacted]

Figure 6.7.3-7 PWR Minimum Tube Spacing – Square Tube – Biased Grind – Shifted

[redacted]

UPDATED

Figure 6.7.3-8 PWR Minimum Tube Spacing – Rectangular Tube – Even Grind – Shifted

[redacted]

Figure 6.7.3-9 PWR Minimum Tube Spacing – Rectangular Tube – Biased Grind – Shifted

[redacted]

Figure 6.7.3-10 Sample VISED Image – PWR Shifted Tube

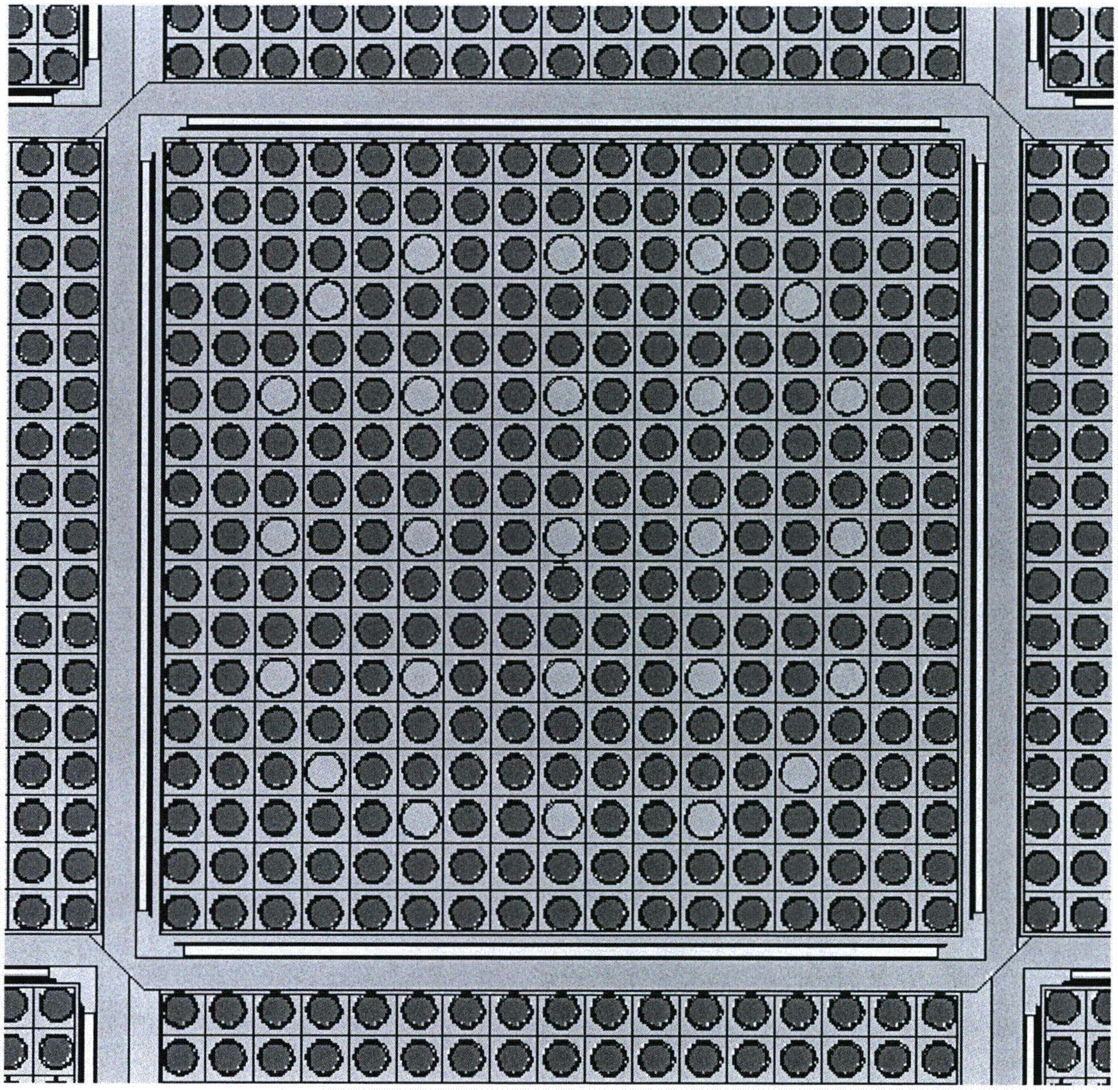

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Table 6.7.3-1 PWR System Partial TSC Flood Evaluation

Assembly Type	2,500 ppm B 5.0 wt % Dry Gap No Insert k_{eff}	2,500 ppm B 5.0 wt % Dry Partial Flood k_{eff}	$\Delta k_{eff}/\sigma$
CE14H1	0.86225	0.86130	-0.9
CE16H1	0.86700	0.86614	-0.8
BW15H1	0.92089	0.92000	-0.8
BW15H2	0.92674	0.92454	-2.2
BW15H3	0.92727	0.92743	0.1
BW15H4	0.91301	0.91130	-1.6
BW17H1	0.92595	0.92743	1.3
WE14H1	0.84955	0.84950	0.0
WE15H1	0.91177	0.91244	0.6
WE15H2	0.90023	0.89936	-0.8
WE17H1	0.91897	0.91826	-0.7
WE17H2	0.89962	0.89887	-0.7

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Table 6.7.3-2 PWR Basket Component Tolerance and Shift Study Results (Independent Variations)

Tube			Absorber		Shift	WE17H1		BW15H3		CE16H1	
Outer Width	Thick.	Interface Width	Width	Thick.	Rad Fuel	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$
Nom	Nom	Nom	Nom	Nom	Centered	0.91897	--	0.92727	--	0.86700	--
Nom	Nom	Nom	Min	Nom	Centered	0.91820	-0.7	0.92779	0.7	0.86990	2.6
Nom	Nom	Nom	Max	Nom	Centered	0.91988	0.9	0.92717	-0.1	0.86969	2.5
Nom	Nom	Nom	Nom	Min	Centered	0.91935	0.4	0.92862	1.8	0.86862	1.5
Nom	Nom	Nom	Nom	Max	Centered	0.91969	0.7	0.92723	-0.1	0.86928	2.2
Min	Nom	Nom	Nom	Nom	Centered	0.91940	0.4	0.92777	0.7	0.86734	0.3
Max	Nom	Nom	Nom	Nom	Centered	0.91865	-0.3	0.92650	-1.0	0.86667	-0.3
Nom	Min	Nom	Nom	Nom	Centered	0.91637	-2.5	0.92603	-1.6	0.86569	-1.2
Nom	Max	Nom	Nom	Nom	Centered	0.91976	0.8	0.93003	3.8	0.87116	4.0
Nom	Nom	Min	Nom	Nom	Centered	0.91912	0.1	0.92839	1.5	0.86837	1.3
Nom	Nom	Max	Nom	Nom	Centered	0.91801	-0.9	0.92873	2.0	0.86646	-0.5
Nom	Nom	Nom	Nom	Nom	In	0.92342	4.3	0.93137	5.5	0.87494	7.4
Nom	Nom	Nom	Nom	Nom	Out	0.90671	-11.6	0.91903	-11.1	0.83718	-27.9

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Table 6.7.3-3 PWR Basket Component Tolerance and Shift Study Results (Combined Variations; Radial In Shift)

Tube			Absorber		Shift	WE17H1		BW15H3		CE16H1	
Outer Width	Thick.	Interface Width	Width	Thick.	Rad Fuel	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$
Nom	Nom	Nom	Nom	Nom	In	0.92342	--	0.93137	--	0.87494	--
Nom	Nom	Nom	Min	Nom	In	0.92421	0.8	0.93253	1.6	0.87493	0.0
Nom	Nom	Nom	Max	Nom	In	0.92451	1.1	0.93073	-0.9	0.87539	0.4
Nom	Nom	Nom	Nom	Min	In	0.92540	1.8	0.93350	2.9	0.87616	1.1
Nom	Nom	Nom	Nom	Max	In	0.92490	1.5	0.93292	2.1	0.87717	2.1
Min	Nom	Nom	Nom	Nom	In	0.92445	1.0	0.93111	-0.4	0.87498	0.0
Max	Nom	Nom	Nom	Nom	In	0.92504	1.6	0.93270	1.8	0.87563	0.6
Nom	Min	Nom	Nom	Nom	In	0.92209	-1.3	0.93102	-0.5	0.87505	0.1
Nom	Max	Nom	Nom	Nom	In	0.92668	3.1	0.93368	3.2	0.87864	3.5
Nom	Nom	Min	Nom	Nom	In	0.92510	1.6	0.93035	-1.4	0.87658	1.6
Nom	Nom	Max	Nom	Nom	In	0.92401	0.5	0.93214	1.0	0.87625	1.2
Min	Min	Min	Min	Min	In	0.92268	-0.7	0.93279	1.9	0.87464	-0.3
Min	Nom	Min	Min	Nom	In	0.92391	0.5	0.93335	2.6	0.87735	2.3
Max	Nom	Min	Min	Nom	In	0.92497	1.5	0.93348	2.9	0.87700	1.9
Nom	Nom	Min	Min	Nom	In	0.92531	1.8	0.93243	1.4	0.87823	3.1
Nom	Max	Nom	Nom	Max	In	0.92698	3.5	0.93303	2.3	0.87770	2.5
Min	Max	Min	Min	Max	In	0.92832	4.6	0.93373	3.1	0.88005	4.7

UPDATED

Table 6.7.3-4 PWR Neutron Absorber Removal Study Results

Assembly	Enrichment (wt % ^{235}U)	PPM	Nominal Absorber k_{eff}	Absorber Removal k_{eff}	Δk_{eff}	$\Delta k_{eff}/\sigma$
BW15H1	4.1	1500	0.95628	0.95700	0.00072	1.0
BW15H2	4.1	1500	0.96131	0.96122	-0.00009	-0.1
BW15H3	4.1	1500	0.96306	0.96262	-0.00044	-0.6
BW15H4	4.1	1500	0.95204	0.95077	-0.00127	-1.7
BW17H1	4.1	1500	0.95934	0.95953	0.00019	0.3
CE14H1	4.1	1500	0.90677	0.90511	-0.00166	-2.2
CE16H1	4.1	1500	0.91264	0.91224	-0.00040	-0.5
WE14H1	4.1	1500	0.89824	0.89709	-0.00115	-1.6
WE15H1	4.1	1500	0.95057	0.95214	0.00157	2.1
WE15H2	4.1	1500	0.93889	0.93913	0.00024	0.3
WE17H1	4.1	1500	0.95524	0.95621	0.00097	1.3
WE17H2	4.1	1500	0.93827	0.93869	0.00042	0.6
BW15H1	4.7	2000	0.95283	0.95367	0.00084	1.1
BW15H2	4.7	2000	0.95579	0.95655	0.00076	1.0
BW15H3	4.7	2000	0.95764	0.95937	0.00173	2.4
BW15H4	4.7	2000	0.94416	0.94346	-0.00070	-0.9
BW17H1	4.7	2000	0.95540	0.95632	0.00092	1.3
CE14H1	4.7	2000	0.89746	0.89772	0.00026	0.3
CE16H1	4.7	2000	0.90516	0.90405	-0.00111	-1.5
WE14H1	4.7	2000	0.88709	0.88928	0.00219	2.9
WE15H1	4.7	2000	0.94472	0.94687	0.00215	2.9
WE15H2	4.7	2000	0.93172	0.93213	0.00041	0.6
WE17H1	4.7	2000	0.95205	0.95331	0.00126	1.7
WE17H2	4.7	2000	0.93229	0.93178	-0.00051	-0.7
BW15H1	5.0	2500	0.92987	0.93071	0.00084	1.2
BW15H2	5.0	2500	0.93574	0.93677	0.00103	1.4
BW15H3	5.0	2500	0.93761	0.93746	-0.00015	-0.2
BW15H4	5.0	2500	0.92108	0.92159	0.00051	0.7
BW17H1	5.0	2500	0.93495	0.93465	-0.00030	-0.4
CE14H1	5.0	2500	0.87406	0.87402	-0.00004	-0.1
CE16H1	5.0	2500	0.88307	0.88259	-0.00048	-0.6
WE14H1	5.0	2500	0.86436	0.86481	0.00045	0.6
WE15H1	5.0	2500	0.92197	0.92214	0.00017	0.2
WE15H2	5.0	2500	0.90838	0.90962	0.00124	1.7
WE17H1	5.0	2500	0.93090	0.93071	-0.00019	-0.3
WE17H2	5.0	2500	0.90755	0.90832	0.00077	1.0

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Table 6.7.3-5 PWR Neutron Absorber Replacement Study Results

Assembly	Enrichment (wt % ^{235}U)	PPM	Nominal Absorber k_{eff}	Absorber Replacement k_{eff}	Δk_{eff}	$\Delta k_{eff}/\sigma$
BW15H1	4.1	1500	0.95628	0.95638	0.00010	0.1
BW15H2	4.1	1500	0.96131	0.96210	0.00079	1.1
BW15H3	4.1	1500	0.96306	0.96353	0.00047	0.6
BW15H4	4.1	1500	0.95204	0.95242	0.00038	0.5
BW17H1	4.1	1500	0.95934	0.96135	0.00201	2.9
CE14H1	4.1	1500	0.90677	0.90498	-0.00179	-2.4
CE16H1	4.1	1500	0.91264	0.91071	-0.00193	-2.5
WE14H1	4.1	1500	0.89824	0.89911	0.00087	1.2
WE15H1	4.1	1500	0.95057	0.95153	0.00096	1.3
WE15H2	4.1	1500	0.93889	0.93999	0.00110	1.5
WE17H1	4.1	1500	0.95524	0.95710	0.00186	2.5
WE17H2	4.1	1500	0.93827	0.93999	0.00172	2.4
BW15H1	4.7	2000	0.95283	0.95152	-0.00131	-1.8
BW15H2	4.7	2000	0.95579	0.95610	0.00031	0.4
BW15H3	4.7	2000	0.95764	0.95910	0.00146	1.9
BW15H4	4.7	2000	0.94416	0.94404	-0.00012	-0.2
BW17H1	4.7	2000	0.95540	0.95596	0.00056	0.8
CE14H1	4.7	2000	0.89746	0.89731	-0.00015	-0.2
CE16H1	4.7	2000	0.90516	0.90482	-0.00034	-0.5
WE14H1	4.7	2000	0.88709	0.88604	-0.00105	-1.4
WE15H1	4.7	2000	0.94472	0.94447	-0.00025	-0.3
WE15H2	4.7	2000	0.93172	0.93154	-0.00018	-0.2
WE17H1	4.7	2000	0.95205	0.95160	-0.00045	-0.6
WE17H2	4.7	2000	0.93229	0.93157	-0.00072	-1.0
BW15H1	5.0	2500	0.92987	0.93182	0.00195	2.7
BW15H2	5.0	2500	0.93574	0.93579	0.00005	0.1
BW15H3	5.0	2500	0.93761	0.93805	0.00044	0.6
BW15H4	5.0	2500	0.92108	0.92183	0.00075	1.0
BW17H1	5.0	2500	0.93495	0.93666	0.00171	2.3
CE14H1	5.0	2500	0.87406	0.87526	0.00120	1.6
CE16H1	5.0	2500	0.88307	0.88408	0.00101	1.4
WE14H1	5.0	2500	0.86436	0.86399	-0.00037	-0.5
WE15H1	5.0	2500	0.92197	0.92273	0.00076	1.0
WE15H2	5.0	2500	0.90838	0.90955	0.00117	1.5
WE17H1	5.0	2500	0.93090	0.93241	0.00151	1.9
WE17H2	5.0	2500	0.90755	0.90782	0.00027	0.4

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Table 6.7.3-6 PWR Neutron Absorber Attachment *Study Results for Two Columns of Weld Posts*

Assembly	Enrichment (wt % ^{235}U)	PPM	*Single Column* Base Evaluation		*Two Column* Modified Attachment			
			Weld Posts	k_{eff}	Weld Posts	k_{eff}	Δk	Δk/σ
BW15H1	5.0	2500	18	0.92987	34	0.93143	0.00156	2.1
BW15H2	5.0	2500	18	0.93574	34	0.93648	0.00074	1.0
BW15H3	4.9	2500	18	0.93244	34	0.93326	0.00082	1.1
BW15H4	5.0	2500	18	0.92108	34	0.92053	-0.00055	-0.7
BW17H1	5.0	2500	18	0.93495	34	0.93611	0.00116	1.5
CE14H1	5.0	2500	18	0.87406	34	0.87521	0.00115	1.5
CE16H1	5.0	2500	18	0.88307	36	0.88357	0.00050	0.7
WE14H1	5.0	2500	18	0.86436	34	0.86574	0.00138	1.8
WE15H1	5.0	2500	18	0.92197	34	0.92241	0.00044	0.6
WE15H2	5.0	2500	18	0.90838	34	0.90816	-0.00022	-0.3
WE17H1	5.0	2500	18	0.93090	34	0.93294	0.00204	2.7
WE17H2	5.0	2500	18	0.90755	34	0.90832	0.00077	1.0

UPDATED

Table 6.7.3-7 Absorber Tolerance and Tube Reactivity Change of PWR Models with No Inserts

Assembly Type	Minimum 1500 ppm B Max. Initial Enrichment		Minimum 1750 ppm B Max. Initial Enrichment		Minimum 2000 ppm B Max. Initial Enrichment		Minimum 2250 ppm B Max. Initial Enrichment		Minimum 2500 ppm B Max. Initial Enrichment	
	Δk	Δk/σ	Δk	Δk/σ	Δk	Δk/σ	Δk	Δk/σ	Δk	Δk/σ
BW15H1	-0.00067	-0.66	0.00158	1.51	-0.00009	-0.09	0.00092	0.90	-0.00016	-0.15
BW15H2	0.00027	0.27	-0.00066	-0.63	0.00114	1.11	0.00026	0.24	0.00073	0.70
BW15H3	0.00162	1.61	-0.00195	-1.91	-0.00014	-0.13	-0.00105	-1.00	0.00001	0.01
BW15H4	-0.00043	-0.42	-0.00333	-3.10	0.00078	0.77	-0.00078	-0.75	-0.00093	-0.91
BW17H1	-0.00015	-0.15	0.00048	0.46	0.00141	1.41	0.00012	0.11	0.00027	0.26
CE14H1	0.00194	1.89	0.00171	1.57	0.00022	0.21	-0.00056	-0.52	0.00057	0.52
CE16H1	-0.00021	-0.20	0.00094	0.85	0.00052	0.48	0.00299	2.80	0.00024	0.22
WE14H1	0.00009	0.09	-0.00077	-0.71	-0.00132	-1.25	-0.00036	-0.33	-0.00159	-1.52
WE15H1	0.00207	2.02	-0.00153	-1.46	0.00199	1.86	0.00158	1.51	0.00030	0.29
WE15H2	0.00048	0.45	-0.00005	-0.05	-0.00010	-0.10	0.00007	0.07	0.00174	1.72
WE17H1	-0.00070	-0.68	0.00009	0.09	0.00122	1.14	0.00026	0.26	0.00094	0.94
WE17H2	-0.00013	-0.13	-0.00012	-0.12	0.00012	0.12	0.00164	1.55	0.00080	0.78

Table 6.7.3-8 Absorber Tolerance and Tube Reactivity Change of PWR Models with Inserts

Assembly Type	Minimum 1500 ppm B Max. Initial Enrichment		Minimum 1750 ppm B Max. Initial Enrichment		Minimum 2000 ppm B Max. Initial Enrichment		Minimum 2250 ppm B Max. Initial Enrichment		Minimum 2500 ppm B Max. Initial Enrichment	
	Δk	Δk/σ	Δk	Δk/σ	Δk	Δk/σ	Δk	Δk/σ	Δk	Δk/σ
BW15H1	0.00113	1.06	0.00030	0.29	0.00100	0.95	-0.00050	-0.49	0.00172	1.67
BW15H2	0.00235	2.26	0.00042	0.41	0.00238	2.27	0.00176	1.75	-0.00013	-0.12
BW15H3	0.00148	1.43	0.00111	1.06	0.00212	2.07	0.00242	2.37	0.00062	0.60
BW15H4	-0.00088	-0.83	0.00039	0.38	0.00191	1.79	-0.00050	-0.49	0.00148	1.43
BW17H1	0.00125	1.16	0.00023	0.22	-0.00001	-0.01	0.00163	1.65	-0.00020	-0.19
CE14H1	0.00126	1.14	0.00197	1.92	0.00036	0.33	-0.00048	-0.45	0.00053	0.50
CE16H1	-0.00086	-0.83	-0.00013	-0.12	-0.00078	-0.73	0.00142	1.33	0.00184	1.76
WE14H1	0.00017	0.15	0.00155	1.37	0.00067	0.62	-0.00144	-1.33	-0.00087	-0.83
WE15H1	-0.00025	-0.25	-0.00046	-0.46	0.00046	0.45	0.00216	2.02	0.00118	1.15
WE15H2	0.00038	0.36	0.00001	0.01	-0.00105	-1.06	-0.00012	-0.12	0.00211	2.03
WE17H1	0.00072	0.70	0.00133	1.30	-0.00145	-1.38	-0.00062	-0.60	-0.00017	-0.17
WE17H2	0.00148	1.48	-0.00005	-0.05	0.00001	0.01	0.00109	1.03	-0.00012	-0.12

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Table *6.7.3-9* PWR System Load Limits (*without Nonfuel* Insert in Active Fuel Region and 0.036 ^{10}B g/cm^2 Absorber)

Assembly Type	Minimum 1500 ppm B		Minimum 1750 ppm B		Minimum 2000 ppm B		Minimum 2250 ppm B		Minimum 2500 ppm B	
	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$
BW15H1	3.70%	0.93032	4.10%	0.93514	4.40%	0.93547	4.70%	0.93489	5.00%	0.93432
BW15H2	3.70%	0.93554	4.00%	0.93451	4.30%	0.93384	4.60%	0.93295	4.90%	0.93244
BW15H3	3.70%	0.93538	4.00%	0.93613	4.30%	0.93528	4.60%	0.93569	4.90%	0.93414
BW15H4	3.80%	0.93189	4.20%	0.93697	4.50%	0.93286	4.80%	0.93228	5.00%	0.92461
BW17H1	3.70%	0.93311	4.00%	0.93204	4.30%	0.93241	4.60%	0.93215	5.00%	0.93689
CE14H1	4.50%	0.93324	4.90%	0.93148	5.00%	0.91561	5.00%	0.89718	5.00%	0.87709
CE16H1	4.40%	0.93350	4.80%	0.93457	5.00%	0.92463	5.00%	0.90197	5.00%	0.88620
WE14H1	4.70%	0.93673	5.00%	0.92958	5.00%	0.90757	5.00%	0.88721	5.00%	0.86816
WE15H1	3.80%	0.93088	4.20%	0.93699	4.50%	0.93415	4.80%	0.93224	5.00%	0.92440
WE15H2	4.00%	0.93406	4.40%	0.93674	4.70%	0.93530	5.00%	0.93129	5.00%	0.91181
WE17H1	3.70%	0.92991	4.10%	0.93553	4.40%	0.93506	4.70%	0.93425	5.00%	0.93308
WE17H2	4.00%	0.93428	4.30%	0.92952	4.70%	0.93330	5.00%	0.93079	5.00%	0.91229

UPDATED

Table *6.7.3-10* PWR System Load Limits (*with Nonfuel* Insert in Active Fuel Region and 0.036 ^{10}B g/cm^2 Absorber)

Assembly Type	Minimum 1500 ppm B		Minimum 1750 ppm B		Minimum 2000 ppm B		Minimum 2250 ppm B		Minimum 2500 ppm B	
	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$	Max Initial Enrich. (wt% ^{235}U)	Reactivity $k_{eff} + 2\sigma$
BW15H1	3.80%	0.93273	4.10%	0.93540	4.40%	0.93380	4.70%	0.93644	5.00%	0.93468
BW15H2	3.70%	0.92923	4.00%	0.93281	4.30%	0.93250	4.60%	0.93389	4.90%	0.93451
BW15H3	3.70%	0.93169	4.00%	0.93345	4.30%	0.93311	4.60%	0.93475	4.90%	0.93564
BW15H4	3.80%	0.92945	4.20%	0.93582	4.50%	0.93322	4.80%	0.93247	5.00%	0.92658
BW17H1	3.80%	0.93545	4.10%	0.93648	4.40%	0.93695	4.60%	0.93200	4.90%	0.93284
CE14H1	4.50%	0.93588	4.80%	0.93066	5.00%	0.92489	5.00%	0.90699	5.00%	0.89106
CE16H1	4.40%	0.93241	4.80%	0.93602	5.00%	0.92723	5.00%	0.90831	5.00%	0.89213
WE14H1	4.80%	0.93574	5.00%	0.92232	5.00%	0.90377	5.00%	0.88564	5.00%	0.86589
WE15H1	3.90%	0.93411	4.20%	0.93343	4.50%	0.93351	4.80%	0.93262	5.00%	0.92694
WE15H2	4.00%	0.93138	4.40%	0.93683	4.70%	0.93626	5.00%	0.93357	5.00%	0.91454
WE17H1	3.90%	0.93532	4.20%	0.93495	4.50%	0.93712	4.80%	0.93706	5.00%	0.93241
WE17H2	4.10%	0.93359	4.40%	0.93279	4.80%	0.93707	5.00%	0.92966	5.00%	0.91118

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Table *6.7.3-11* **PWR System Generic Load Limits (0.036 ^{10}B g/cm^2 Absorber)**

Assembly Type	# of Fuel Rods	# of Guide Tubes[a]	Max Pitch (inch)	Min Clad OD (inch)	Min Clad Thick. (inch)	Max Pellet OD (inch)	Max Active Length (inch)	Max Load (MTU)	Max. Initial Enrichment (wt % ^{235}U) Soluble Boron 1500 ppm	Soluble Boron 1750 ppm	Soluble Boron 2000 ppm	Soluble Boron 2250 pm	Soluble Boron 2500 ppm
BW15H1	208	17	0.568	0.43	0.0265	0.3686	144.0	0.4858	3.70%	4.10%	4.40%	4.70%	5.00%
BW15H2	208	17	0.568	0.43	0.025	0.3735	144.0	0.4988	3.70%	4.00%	4.30%	4.60%	4.90%
BW15H3	208	17	0.568	0.428	0.023	0.3742	144.0	0.5006	3.70%	4.00%	4.30%	4.60%	4.90%
BW15H4	208	17	0.568	0.414	0.022	0.3622	144.0	0.4690	3.80%	4.20%	4.50%	4.80%	5.00%
BW17H1	264	25	0.502	0.377	0.022	0.3252	144.0	0.4799	3.70%	4.00%	4.30%	4.60%	4.90%
CE14H1	176	5	0.58	0.44	0.026	0.3805	137.0	0.4167	4.50%	4.80%	5.00%	5.00%	5.00%
CE16H1	236	5	0.5063	0.382	0.025	0.325	150.0	0.4463	4.40%	4.80%	5.00%	5.00%	5.00%
WE14H1	179	17	0.556	0.40	0.0162	0.3674	145.2	0.4188	4.70%	5.00%	5.00%	5.00%	5.00%
WE15H1	204	21	0.563	0.422	0.0242	0.3669	144.0	0.4720	3.80%	4.20%	4.50%	4.80%	5.00%
WE15H2	204	21	0.563	0.417	0.0265	0.357	144.0	0.4469	4.00%	4.40%	4.70%	5.00%	5.00%
WE17H1	264	25	0.496	0.372	0.0205	0.3232	144.0	0.4740	3.70%	4.10%	4.40%	4.70%	5.00%
WE17H2	264	25	0.496	0.36	0.0225	0.3088	144.0	0.4327	4.00%	4.30%	4.70%	5.00%	5.00%

Note: Assembly characteristics represent cold, unirradiated, nominal configurations.

[a] Combined number of guide and instrument tubes.

Table 6.7.3-12 PWR System Tube Location Study Summary

Configuration			Δk/σ from Baseline Square Tube @ 45°		
Tube	Tube Location	Grind	Average	Minimum	Maximum
Square	45°	Even	--		
Square	45°	Biased	0.6	-2.3	2.6
Square	Shift	Even	-1.3	-2.9	2.2
Square	Shift	Biased	0.3	-2.8	2.9
Rectangular	Shift	Even	N/A		
Rectangular	Shift	Biased	-5.7	-9.9	2.5

Table 6.7.3-13 PWR System Tube Location Study Detail – Baseline to Square Tube/Biased Grind/45° Alignment

Assembly Type	Minimum 1500 ppm B Change in Reactivity	Minimum 1750 ppm B Change in Reactivity	Minimum 2000 ppm B Change in Reactivity	Minimum 2250 ppm B Change in Reactivity	Minimum 2500 ppm B Change in Reactivity
	Δk/σ	Δk/σ	Δk/σ	Δk/σ	Δk/σ
BW15H1	0.4	-1.8	1.7	0.6	0.5
BW15H2	-0.6	-1.3	-2.3	-0.8	0.8
BW15H3	-0.1	1.1	0.5	-0.6	0.8
BW15H4	0.5	-0.1	1.7	2.1	-0.4
BW17H1	-0.2	0.7	-0.2	-1.4	1.9
CE14H1	-0.1	0.7	2.6	2.4	1.2
CE16H1	2.6	1.0	1.1	2.1	0.2
WE14H1	0.8	2.6	1.0	1.6	2.6
WE15H1	0.3	1.0	1.1	0.3	-0.1
WE15H2	-0.2	0.0	1.5	1.1	0.1
WE17H1	-0.7	-0.3	1.5	0.6	0.5
WE17H2	-0.1	1.3	0.1	-1.9	1.6

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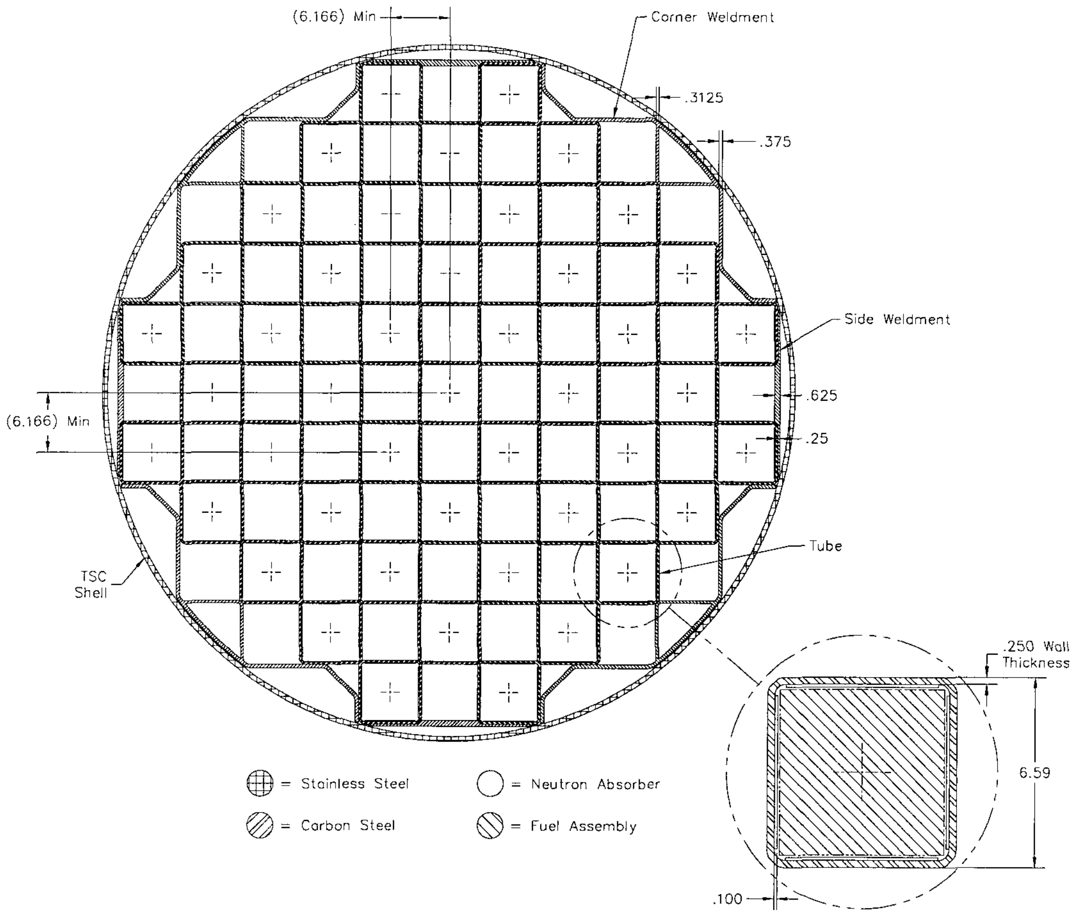
Table 6.7.3-14 PWR System Load Limits for Reduced Absorber

	Max. Initial Enrichment (wt % ^{235}U)									
	Absorber 0.030 ^{10}B g/cm^2					Absorber 0.027 ^{10}B g/cm^2				
Soluble Boron	1500 (ppm)	1750 (ppm)	2000 (ppm)	2250 (ppm)	2500 (ppm)	1500 (ppm)	1750 (ppm)	2000 (ppm)	2250 (ppm)	2500 (ppm)
BW15H1	3.6%	4.0%	4.2%	4.5%	4.8%	3.6%	3.9%	4.2%	4.5%	4.8%
BW15H2	3.6%	3.9%	4.2%	4.5%	4.8%	3.6%	3.8%	4.1%	4.4%	4.7%
BW15H3	3.6%	3.9%	4.2%	4.4%	4.7%	3.5%	3.8%	4.1%	4.4%	4.7%
BW15H4	3.7%	4.1%	4.4%	4.7%	5.0%	3.7%	4.0%	4.3%	4.6%	5.0%
BW17H1	3.6%	3.9%	4.2%	4.5%	4.8%	3.6%	3.9%	4.1%	4.5%	4.7%
CE14H1	4.3%	4.7%	5.0%	5.0%	5.0%	4.3%	4.6%	5.0%	5.0%	5.0%
CE16H1	4.3%	4.6%	5.0%	5.0%	5.0%	4.2%	4.6%	4.9%	5.0%	5.0%
WE14H1	4.6%	5.0%	5.0%	5.0%	5.0%	4.5%	5.0%	5.0%	5.0%	5.0%
WE15H1	3.7%	4.1%	4.4%	4.7%	5.0%	3.7%	4.0%	4.3%	4.6%	4.9%
WE15H2	3.9%	4.2%	4.6%	4.9%	5.0%	3.8%	4.2%	4.5%	4.8%	5.0%
WE17H1	3.7%	4.0%	4.3%	4.6%	4.9%	3.6%	3.9%	4.2%	4.5%	4.9%
WE17H2	3.9%	4.3%	4.6%	4.9%	5.0%	3.8%	4.2%	4.5%	4.9%	5.0%

- Specified soluble boron concentrations are independent of whether a fuel assembly contains a nonfuel insert.

Figure 6.7.4-2 BWR Basket Structure



Notes:

1. Dimensions in inches.
2. Assembly fuel pin array is explicitly modeled. Shown as homogenized area for illustration purposes only.
3. ***Represents square tube basket aligned at 45° with 8.72-inch minimum interface (diagonal flat-to-flat) width.***

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Further evaluations of the component tolerances, including combinations of tolerances, are performed in conjunction with the shifted component configuration.

Component Shift

In addition to the component tolerances, a reactivity study on component shifts is required. Based on the pinned tube arrangement, the only radial shift to be evaluated is the shift of the fuel assembly within the tubes. The tubes are restrained in the corner by pins, ***minimizing tube shift potential. Evaluations on tube shift are included within the Phase 3 Design Modifications subsection (pages 6.7.6-5 and 6.7.6-6).*** The results of shift evaluations are shown in Table 6.7.6-2, indicating that shifting the fuel assembly towards the basket center clearly increases system reactivity.

Combined Shift and Tolerance Study

This section evaluates the effect of combining various basket tolerances with the maximum reactivity shift configuration (radial in). The results for this evaluation are shown in Table 6.7.6-3. Similar to the results of the independent basket tolerance evaluation, only fuel tube thickness affects system reactivity to a statistically significant level.

While no statistically significant reactivity difference is found between the cases with and without tolerances applied, the maximum reactivity configuration chosen for the evaluations of all fuel hybrids is as follows.

Minimum tube width and interface width

Maximum tube thickness

Minimum absorber width and maximum thickness

Fuel assemblies shifted to basket center

This configuration produced reactivities within a 3σ uncertainty band of the maximum reported value for all fuel types evaluated, and provides for the minimum separation between adjacent assemblies. The minimum separation reduces the amount of moderation and the corresponding effectiveness of the absorber sheet, which depend on the ^{10}B neutron capture cross-section in the thermal energy range.

Shift and tolerance evaluations were based on a full, 87-assembly, basket loading. While fabrication tolerance impacts relate to tube and developed cell unit behavior, a limited set of evaluations is performed to verify that the radial shifting in a fuel assembly pattern remains bounding for the 82-assembly basket configuration. The results of this evaluation are shown in Table 6.7.6-4 and demonstrate that the radial shifting in a fuel assembly pattern is limiting.

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To evaluate the design change, each maximum reactivity fuel type/enrichment combination in Section 6.7.6.2 is evaluated at the increased tolerance band. Results for this analysis at the updated maximum tolerance thickness and minimum width cases are shown in Table 6.7.6-10.

The maximum change in reactivity due to the updated absorber tolerances for the BWR cases was 1.81σ. The overall average change in reactivity was 0.58σ. No case exceeded the USL. The change in the absorber tolerance had an insignificant effect on the reactivity of the BWR system.

Phase 3 Design Modifications

BWR tube drawing dimensions were modified to list the outer width as a reference dimension with the tube corner chamfer specifying a minimum and maximum quantity of material to be removed. This specification limits tube minimum and maximum outer width when applied to the fixed tube interface width. The tube interface width is retained as a toleranced dimension (8.72-inch minimum/8.76-inch maximum). The drawing changes provide additional flexibility on the tube width, while ensuring criticality control is retained. Modifications of the tube dimensions and pin and slot configuration have a secondary effect of allowing increased relative shift of the tube centers. To demonstrate that this design modification does not result in significant reactivity changes, additional criticality evaluations are performed.

Variations in system configuration are evaluated that shift from the baseline model that relied on square tubes located at a 45° angle (i.e., even grind tube flats are touching at their midpoints). The 45° aligned model with relative square tubes is expected to be the as-built configuration of the final basket assembly as the basket: (a) is assembled horizontally producing tube-to-tube contact, with a drawing limitation on the gap allowed between tubes (maximum continuous gap of 0.02 inch over 24-inch interval); and (b) includes installation of side and corner weldments and placement of the basket into the cylindrical TSC, which would not be feasible for a significantly out-of-alignment tube array. As the basket is composed of individual fuel tubes connected by pin-slot connectors and tubes are attached to the weldment by mounting bosses, each with manufacturing tolerances and gaps, localized variations in tube spacing are allowed by the basket drawings. An additional set of analyses is performed to confirm that the interface width is the primary criticality control dimension and that changes in reactivity associated with (a) the potential tube shift away from a 45° alignment and (b) system tolerances associated with the tube and tube-to-weldment interface are either not statistically resolvable or reduce reactivity. In these analyses, maximum shifts in tube relative location are applied to the entire basket rather than to a localized basket area to magnify any potential reactivity effects. Applying the changes to the basket globally results in a configuration that could not be built since corner and side weldments had to be modified beyond drawing allowables to produce a model fitting into the TSC shell.

System variables were modified to produce the maximum shift from the baseline analysis dimensions. Tube minimum interface, or diagonal face-to-face distance of 8.72 inches, is maintained during the shift/tolerance studies. Maximum perturbation from the baseline may either be a reduced orthogonal dimension (x and/or y) or a reduction in tube diagonal center-to-center spacing. Tube shift reduces the developed cell size by reducing one orthogonal dimension while increasing the other. Figure 6.7.6-5 through Figure 6.7.6-10 contain sketches for the bounding shift/tolerance configurations. There are three even grind and three biased configurations considered in this evaluation. The grind produces the flat at the tube corner and is expected to be uniform during tube fabrication, but drawings allow for a minimum 0.006-inch grind with a maximum 0.04-inch grind. The starting point for the analysis is the baseline square tube aligned at 45° with the even grind shown in Figure 6.7.6-5. This represents the configuration on which maximum allowed enrichments are calculated. Figure 6.7.6-6 modified this configuration to evaluate the impact of a biased grind while retaining the 45° alignment. Next, both even and biased grind configurations were evaluated to determine the maximum shift that could occur between square tubes. The resulting dimension sets are shown in Figure 6.7.6-7 and Figure 6.7.6-8 indicating that the biased grind condition produces the minimum tube center-to-center diagonal spacing, while the even grind condition produces the minimum orthogonal dimension. Note that without regard to the overall basket structure constraints, the developed cell opening is reduced in these scenarios. A sample graphic representation of the MCNP geometry for the shifted tube is shown in Figure 6.7.6-11 to illustrate the potential tube movement. The third set of analyses builds on the shifted tube model while considering the possibility of tubes having a rectangular rather than square cross-section. Sketches of the tube position under the rectangular tube assumption are included in Figure 6.7.6-9 and Figure 6.7.6-10. As the rectangular biased grind dimensions bound the even grind dimensions in both minimum orthogonal and center-to-center diagonal distance, only the biased grind configuration is evaluated.

To address the range of fuel types allowed in the 82-assembly and the 87-assembly system, each of the configurations specified in Section 6.7.6.2 was evaluated for potential reactivity change. Reactivity effects in terms of $\Delta k/\sigma$ are listed in Table 6.7.6-11 for each of the scenarios demonstrating either no statistically resolvable change in reactivity or a decrease in system reactivity occurs. A breakdown of the analysis results by fuel type for each basket consideration at a 0.027 gm/cm^2 effective absorber is shown in Table 6.7.6-12.

Based on the studies described in the previous section, the interface (tube grind flat-to-flat) width controls the critical tube spacing and, therefore, assembly spacing and system reactivity.

6.7.6.2 Allowable Loading Definitions and Maximum System Reactivities

Based on the most reactive basket configuration, each of the fuel assembly types is evaluated at various enrichment levels to determine the maximum enrichment at which $k_{eff} + 2\sigma$ remains below the USL. Physical limitation on the assemblies allowed for loading are listed in Table 6.7.6-9. The maximum allowed planar average initial enrichments are listed in Table ***6.7.6-10*** for assemblies with and without partial length rods, where applicable, for a 0.027 ^{10}B g/cm^2 absorber basket configuration. Table ***6.7.6-13*** summarizes the enrichment limits for both 87-assembly and 82-assembly basket configurations at neutron absorber sheet effective areal densities of 0.027, 0.0225, and 0.020 ^{10}B g/cm^2. In all evaluations, the pellet-to-clad gap is flooded.

Maximum system reactivities are summarized as follows. Analysis results represent maximum reactivity basket and fuel geometry. There are no design basis off-normal or accident transfer cask conditions affecting system reactivity. Therefore, only normal condition results are presented. An accident condition for the concrete cask represents a flooding of the concrete cask to canister annulus. Concrete cask results are based on the maximum fuel mass assembly at the highest allowed enrichment (4.5 wt % ^{235}U).

Condition	Pellet to Clad Gap Condition	Maximum Multiplication Factors ($k_{eff} + 2\sigma$)	
		Transfer Cask	Concrete Cask
Normal	Dry	0.92900	0.43685
Normal	Wet	0.93679	N/A
Accident / Off-Normal	Dry	N/A	0.42991

Note that there is no statistical difference between normal and accident condition cases, which differ only by the flooding of the pellet-to-clad gap under the "accident condition."

Figure 6.7.6-1 87-Assembly Basket BWR Water Density Variations

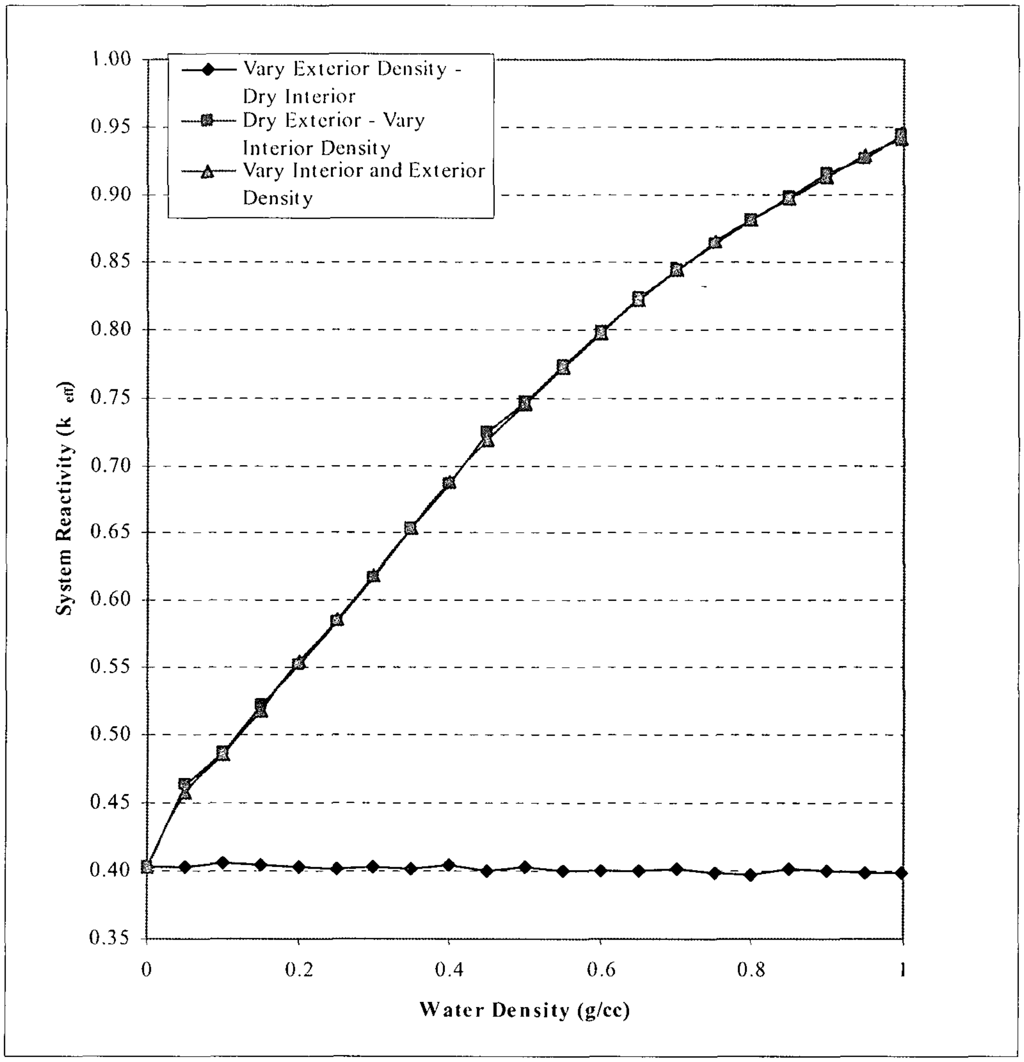

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Figure 6.7.6-2 82-Assembly Basket BWR Water Density Variations

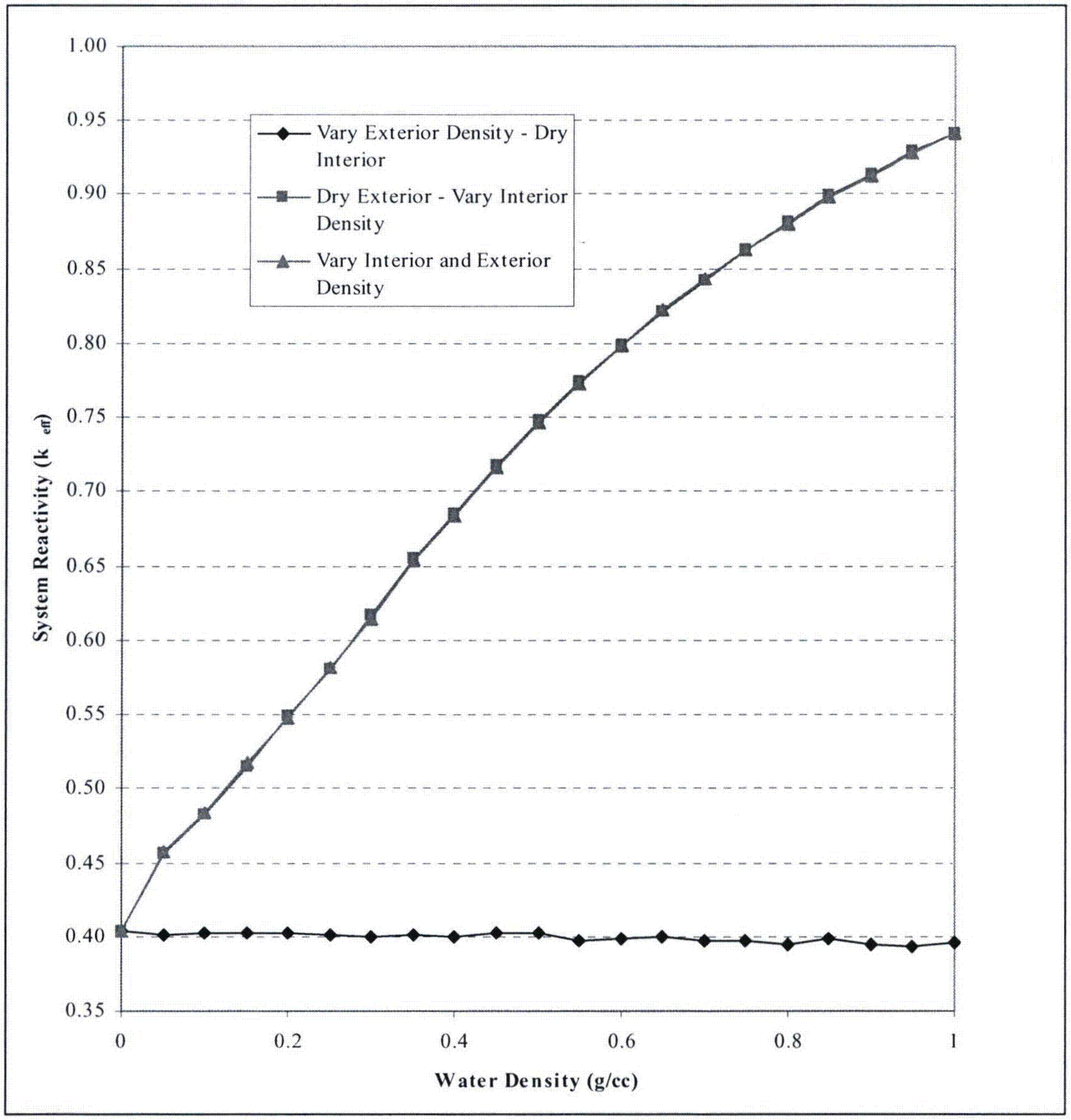

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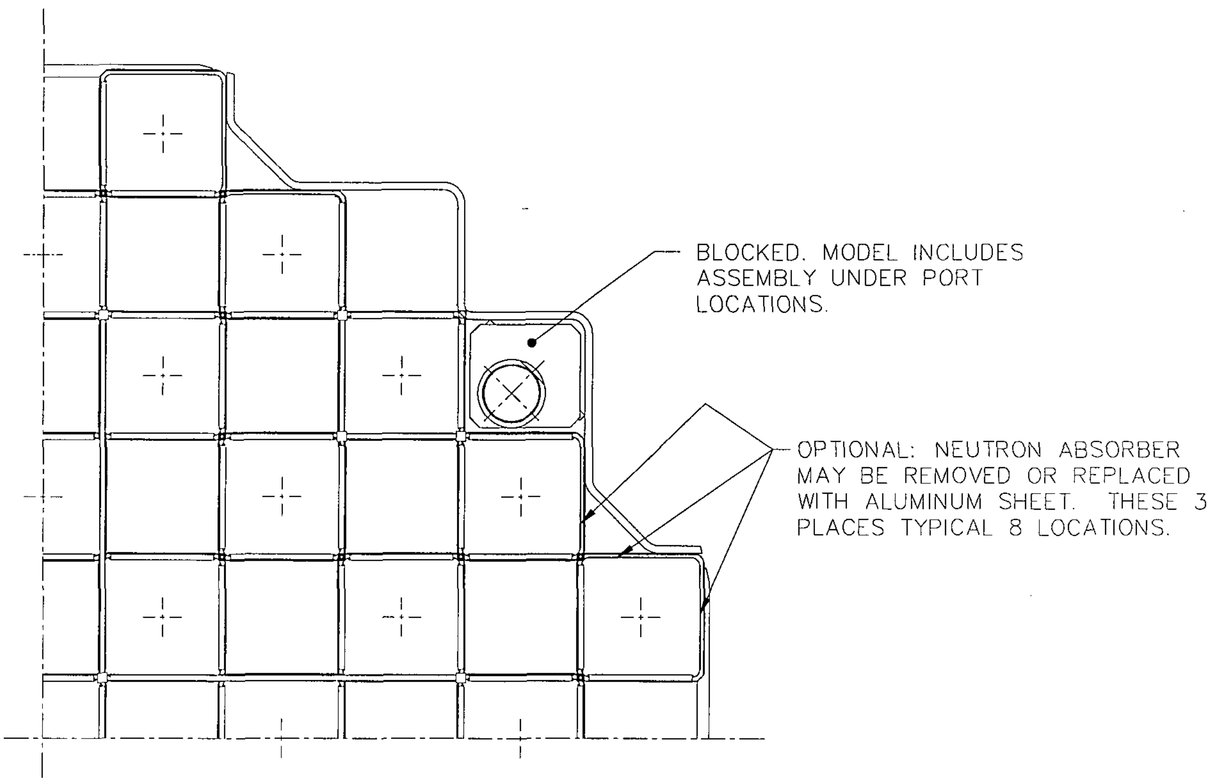
Figure 6.7.6-3 BWR 87-Assembly Basket Optional Neutron Absorber Sheet Locations[a]



[a] Quarter basket model is shown for clarity. Symmetric locations are affected in all four basket quadrants.

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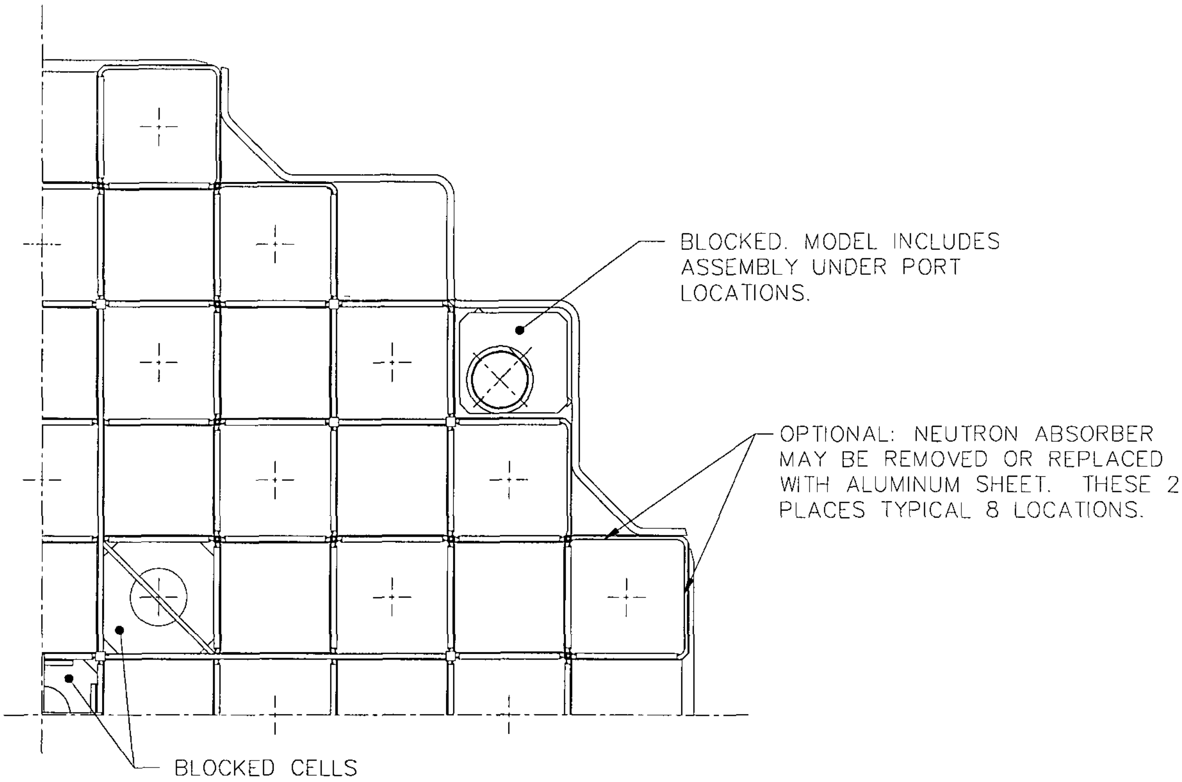
Figure 6.7.6-4 BWR 82-Assembly Basket Optional Neutron Absorber Sheet Locations[a]



[a] Quarter basket model is shown for clarity. Symmetric locations are affected in all four basket quadrants.

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Figure 6.7.6-5 BWR Minimum Tube Spacing – Baseline Configuration – Square Tube – Even Grind – 45° Aligned

[redacted]

Figure 6.7.6-6 BWR Minimum Tube Spacing – Square Tube – Biased Grind – 45° Aligned

[redacted]

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Figure 6.7.6-7 BWR Minimum Tube Spacing – Square Tube – Even Grind – Shifted

[redacted]

Figure 6.7.6-8 BWR Minimum Tube Spacing – Square Tube – Biased Grind – Shifted

[redacted]

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Figure 6.7.6-9 BWR Minimum Tube Spacing – Rectangular Tube – Even Grind – Shifted

[redacted]

Figure 6.7.6-10 BWR Minimum Tube Spacing – Rectangular Tube – Biased Grind – Shifted

[redacted]

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Figure 6.7.6-11 Sample VISED Image – BWR Shifted Tube

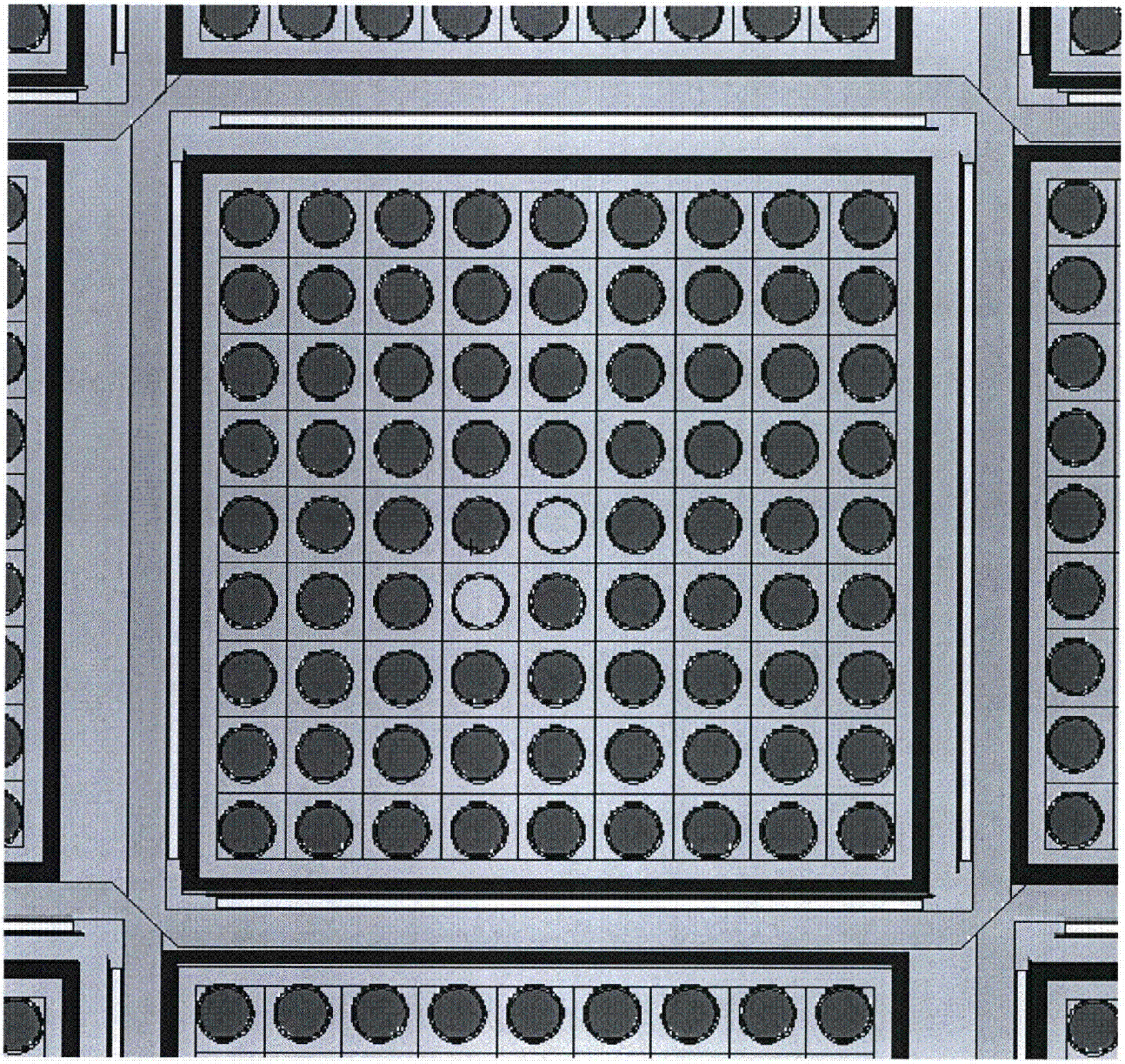

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Table 6.7.6-1 BWR System Partial TSC Flood Evaluation

Assembly Type	Dry Gap Full Flood k_{eff}	Dry Gap Partial Flood k_{eff}	$\Delta k_{eff}/\sigma$
B7_48A	0.91765	0.91775	0.1
B7_49A	0.92470	0.92290	-1.7
B7_49B	0.92610	0.92573	-0.3
B8_59A	0.91930	0.92071	1.3
B8_60A	0.92497	0.92501	0.0
B8_60B	0.92589	0.92556	-0.3
B8_61B	0.92650	0.92508	-1.3
B8_62A	0.93055	0.93021	-0.3
B8_63A	0.92687	0.92707	0.2
B8_64A	0.92594	0.92381	-2.0
B8_64B	0.94157	0.94100	-0.5
B9_72A	0.93299	0.93281	-0.2
B9_74A	0.94392	0.94389	0.0
B9_76A	0.95063	0.94907	-1.5
B9_79A	0.94155	0.94044	-1.1
B9_80A	0.92757	0.92671	-0.8
B10_91A	0.92961	0.92853	-1.0
B10_92A	0.92366	0.92532	1.5
B10_96A	0.93807	0.93749	-0.6
B10_100A	0.93827	0.93829	0.0

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Table 6.7.6-2 BWR 87-Assembly Basket Component Tolerance and Shift Study Results (Independent Variations)

Tube			Absorber		Shift	B7_49A		B8_62A		B9_76A		B9_79A		B10_92A	
Outer Width	Thick.	Interface Width	Width	Thick.	Rad Fuel	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$
Nom	Nom	Nom	Nom	Nom	Centered	0.92470	--	0.93055	--	0.95063	--	0.94155	--	0.92366	--
Nom	Nom	Nom	Min	Nom	Centered	0.92478	0.1	0.92946	-1.0	0.94894	-2.3	0.94026	-1.2	0.92559	1.8
Nom	Nom	Nom	Max	Nom	Centered	0.92400	-0.7	0.92923	-1.2	0.94751	-4.2	0.94124	-0.3	0.92542	1.7
Nom	Nom	Nom	Nom	Min	Centered	0.92329	-1.3	0.92996	-0.5	0.94914	-2.0	0.94168	0.1	0.92401	0.3
Nom	Nom	Nom	Nom	Max	Centered	0.92434	-0.3	0.92879	-1.6	0.94899	-2.2	0.94198	0.4	0.92519	1.4
Min	Nom	Nom	Nom	Nom	Centered	0.92485	0.1	0.93045	-0.1	0.94778	-3.8	0.94244	0.8	0.92430	0.6
Max	Nom	Nom	Nom	Nom	Centered	0.92329	-1.3	0.92768	-2.6	0.94892	-2.3	0.94192	0.3	0.92402	0.3
Nom	Min	Nom	Nom	Nom	Centered	0.92187	-2.8	0.92582	-4.2	0.94667	-5.2	0.93917	-2.2	0.92227	-1.3
Nom	Max	Nom	Nom	Nom	Centered	0.92660	1.8	0.93193	1.2	0.95095	0.4	0.94512	3.4	0.92850	4.5
Nom	Nom	Min	Nom	Nom	Centered	0.92481	0.1	0.92988	-0.6	0.94915	-2.0	0.94341	1.8	0.92487	1.1
Nom	Nom	Max	Nom	Nom	Centered	0.92248	-2.1	0.92926	-1.1	0.94718	-4.4	0.94155	--	0.92641	2.6
Nom	Nom	Nom	Nom	Nom	In	0.92890	3.9	0.93293	2.1	0.95324	3.5	0.94634	4.6	0.93168	7.5
Nom	Nom	Nom	Nom	Nom	Out	0.91191	-12.2	0.91606	-13.0	0.93809	-16.6	0.93148	-9.6	0.91466	-8.6

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Table 6.7.6-3 BWR 87-Assembly Basket Component Tolerance and Shift Study Results (Combined Variations; Radial In Shift)

Tube			Absorber		Shift	B7_49A		B8_62A		B9_76A		B9_79A		B10_92A	
Outer Width	Thick.	Interface Width	Width	Thick.	Rad Fuel	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$
Nom	Nom	Nom	Nom	Nom	In	0.92890	--	0.93293	--	0.95324	--	0.94634	--	0.93168	--
Min	Nom	Nom	Nom	Nom	In	0.93004	1.0	0.93433	1.3	0.95538	2.8	0.94814	1.7	0.93194	0.2
Max	Nom	Nom	Nom	Nom	In	0.92936	0.4	0.93435	1.3	0.95432	1.4	0.94558	-0.7	0.92987	-1.7
Nom	Min	Nom	Nom	Nom	In	0.92927	0.3	0.93188	-1.0	0.95412	1.2	0.94467	-1.5	0.92868	-2.7
Nom	Max	Nom	Nom	Nom	In	0.93194	2.8	0.93775	4.4	0.95475	2.0	0.94882	2.3	0.93563	3.7
Nom	Nom	Min	Nom	Nom	In	0.92865	-0.2	0.93379	0.8	0.95386	0.8	0.94770	1.3	0.93227	0.6
Nom	Nom	Max	Nom	Nom	In	0.92957	0.6	0.93290	0.0	0.95358	0.5	0.94679	0.4	0.93059	-1.0
Nom	Nom	Nom	Min	Nom	In	0.92964	0.7	0.93441	1.3	0.95188	-1.8	0.94832	1.8	0.93072	-0.9
Nom	Nom	Nom	Max	Nom	In	0.92801	-0.8	0.93396	1.0	0.95660	4.5	0.94514	-1.1	0.93082	-0.8
Nom	Nom	Nom	Nom	Min	In	0.93042	1.4	0.93469	1.6	0.95418	1.3	0.94708	0.7	0.93190	0.2
Nom	Nom	Nom	Nom	Max	In	0.92931	0.4	0.93533	2.3	0.95344	0.3	0.94530	-1.0	0.93019	-1.4
Min	Min	Min	Min	Min	In	0.92717	-1.6	0.93238	-0.5	0.95125	-2.6	0.94416	-2.0	0.92825	-3.2
Min	Nom	Min	Min	Nom	In	0.93058	1.6	0.93526	2.1	0.95631	4.0	0.94802	1.6	0.93081	-0.8
Max	Nom	Min	Min	Nom	In	0.92953	0.6	0.93465	1.6	0.95320	-0.1	0.94916	2.7	0.93372	1.9
Nom	Nom	Min	Min	Nom	In	0.93044	1.4	0.93504	1.9	0.95433	1.5	0.94750	1.1	0.93135	-0.3
Nom	Max	Nom	Nom	Max	In	0.93320	3.8	0.93701	3.8	0.95615	3.9	0.94918	2.7	0.93378	2.0
Min	Max	Min	Min	Max	In	0.93284	3.6	0.93816	4.9	0.95791	6.2	0.95034	3.8	0.93442	2.6

UPDATED

Table 6.7.6-4 BWR 82-Assembly Basket Component Tolerance and Shift Study Results (Combined Variations; Radial In Shift)

Tube			Absorber		Shift	B7_49A		B8_62A		B9_76A		B9_79A		B10_92A	
Outer Width	Thick.	Interface Width	Width	Thick.	Rad Fuel	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$	k_{eff}	$\Delta k_{eff}/\sigma$
Min	Max	Min	Min	Max	In	0.88693	--	0.89367	--	0.91528	--	0.90858	--	0.88953	--
Min	Max	Min	Min	Max	Centered	0.88706	0.1	0.89379	0.1	0.91574	0.7	0.90671	-1.7	0.89070	1.1
Min	Max	Min	Min	Max	Out	0.88251	-4.0	0.88855	-4.8	0.91035	-6.8	0.90190	-6.1	0.88389	-5.4

UPDATED

Table 6.7.6-5 BWR 87-Assembly Basket Neutron Absorber Removal & Replacement Study Results

Assembly	Enrichment (wt % ^{235}U)	Nominal Absorber k_{eff}	Absorber Removal			Absorber Replacement		
			k_{eff}	Δk	Δk/σ	k_{eff}	Δk	Δk/σ
B7_48A	4.0	0.93146	0.93023	-0.00123	-1.7	0.93170	0.00024	0.3
B7_49A	4.0	0.94139	0.93975	-0.00164	-2.2	0.94033	-0.00106	-1.4
B7_49B	4.0	0.93978	0.93960	-0.00018	-0.2	0.93971	-0.00007	-0.1
B8_59A	4.0	0.93354	0.93489	0.00135	1.8	0.93408	0.00054	0.7
B8_60A	4.0	0.93932	0.93854	-0.00078	-1.1	0.93844	-0.00088	-1.2
B8_60B	4.0	0.93981	0.93974	-0.00007	-0.1	0.93870	-0.00111	-1.4
B8_61B	4.0	0.94021	0.94108	0.00087	1.2	0.94021	0.00000	0.0
B8_62A	4.0	0.94468	0.94274	-0.00194	-2.5	0.94248	-0.00220	-2.8
B8_63A	4.0	0.94427	0.94310	-0.00117	-1.5	0.94277	-0.00150	-2.0
B8_64A	4.0	0.94133	0.94113	-0.00020	-0.3	0.93912	-0.00221	-3.0
B8_64B	4.0	0.95409	0.95256	-0.00153	-2.1	0.95382	-0.00027	-0.4
B9_72A	4.0	0.94508	0.94404	-0.00104	-1.5	0.94493	-0.00015	-0.2
B9_74A	4.0	0.95198	0.95062	-0.00136	-1.8	0.94971	-0.00227	-2.9
B9_76A	4.0	0.95816	0.95864	0.00048	0.6	0.95749	-0.00067	-0.9
B9_79A	4.0	0.95125	0.95033	-0.00092	-1.2	0.94961	-0.00164	-2.1
B9_80A	4.0	0.93990	0.93934	-0.00056	-0.7	0.93960	-0.00030	-0.4
B10_91A	4.0	0.94279	0.94220	-0.00059	-0.8	0.94135	-0.00144	-2.0
B10_92A	4.0	0.93784	0.93967	0.00183	2.4	0.93990	0.00206	2.8
B10_96A	4.0	0.95060	0.95001	-0.00059	-0.8	0.95152	0.00092	1.2
B10_100A	4.0	0.95219	0.95225	0.00006	0.1	0.95175	-0.00044	-0.6

Table 6.7.6-6 BWR 82-Assembly Basket Neutron Absorber Removal & Replacement Study Results

Assembly	Enrichment (wt % ^{235}U)	Nominal Absorber k_{eff}	Absorber Removal			Absorber Replacement		
			k_{eff}	Δk	Δk/σ	k_{eff}	Δk	Δk/σ
B7_48A	4.5	0.91329	0.91427	0.00098	1.3	0.91435	0.00106	1.3
B7_49A	4.5	0.92148	0.92211	0.00063	0.8	0.92311	0.00163	2.1
B7_49B	4.5	0.92249	0.92244	-0.00005	-0.1	0.92115	-0.00134	-1.7
B8_59A	4.5	0.91678	0.91828	0.00150	2.0	0.91841	0.00163	2.2
B8_60A	4.5	0.92379	0.92406	0.00027	0.4	0.92460	0.00081	1.0
B8_60B	4.5	0.92363	0.92505	0.00142	2.0	0.92319	-0.00044	-0.6
B8_61B	4.5	0.92485	0.92597	0.00112	1.5	0.92466	-0.00019	-0.2
B8_62A	4.5	0.92685	0.92669	-0.00016	-0.2	0.92737	0.00052	0.6
B8_63A	4.5	0.92725	0.92723	-0.00002	0.0	0.92680	-0.00045	-0.5
B8_64A	4.5	0.92408	0.92392	-0.00016	-0.2	0.92524	0.00116	1.5
B8_64B	4.5	0.93936	0.93977	0.00041	0.5	0.93877	-0.00059	-0.8
B9_72A	4.5	0.93060	0.92841	-0.00219	-2.9	0.92850	-0.00210	-2.8
B9_74A	4.5	0.93649	0.93629	-0.00020	-0.3	0.93681	0.00032	0.4
B9_76A	4.5	0.94314	0.94277	-0.00037	-0.5	0.94299	-0.00015	-0.2
B9_79A	4.5	0.93237	0.93400	0.00163	2.1	0.93292	0.00055	0.7
B9_80A	4.5	0.92417	0.92364	-0.00053	-0.7	0.92458	0.00041	0.5
B10_91A	4.5	0.92684	0.92476	-0.00208	-2.7	0.92630	-0.00054	-0.7
B10_92A	4.5	0.92191	0.92287	0.00096	1.2	0.92232	0.00041	0.5
B10_96A	4.5	0.93438	0.93508	0.00070	0.9	0.93597	0.00159	2.0
B10_100A	4.5	0.93701	0.93720	0.00019	0.3	0.93767	0.00066	0.9

UPDATED

Table 6.7.6-7 BWR 87-Assembly Basket Neutron Absorber Attachment Modification Study Results

Assembly	Enrichment (wt % ^{235}U)	Base Evaluation		Modified Attachment			
		Weld Posts	k_{eff}	Weld Posts	k_{eff}	Δk	Δk/σ
B7_48A	4.1	4	0.93806	28	0.93891	0.00085	1.1
B7_49A	3.9	4	0.93303	28	0.93474	0.00171	2.3
B7_49B	3.9	4	0.93311	28	0.93471	0.00160	2.1
B8_59A	4.0	4	0.93354	28	0.93469	0.00115	1.6
B8_60A	3.9	4	0.93370	28	0.93473	0.00103	1.4
B8_60B	3.9	4	0.93355	28	0.93450	0.00095	1.3
B8_61B	3.9	4	0.93582	28	0.93547	-0.00035	-0.5
B8_62A	3.9	4	0.93668	28	0.93831	0.00163	2.1
B8_63A	3.8	4	0.93264	28	0.93369	0.00105	1.5
B8_64A	3.9	4	0.93416	28	0.93579	0.00163	2.2
B8_64B	3.7	4	0.93588	28	0.93778	0.00190	2.6
B9_72A	3.8	4	0.93198	28	0.93369	0.00171	2.3
B9_74A	3.7	4	0.93331	28	0.93392	0.00061	0.8
B9_76A	3.6	4	0.93391	28	0.93491	0.00100	1.3
B9_79A	3.7	4	0.93261	28	0.93227	-0.00034	-0.5
B9_80A	3.9	4	0.93383	28	0.93479	0.00096	1.3
B10_91A	3.8	4	0.93081	28	0.93256	0.00175	2.3
B10_92A	3.8	4	0.92729	28	0.92907	0.00178	2.4
B10_96A	3.7	4	0.93175	28	0.93355	0.00180	2.4
B10_100A	3.7	4	0.93318	28	0.93395	0.00077	1.0

Table *6.7.6-8* BWR System Maximum Reactivity Summary

Assembly Type	Number of Fuel Rods	87-Assembly Basket Max Initial Enrich. (wt % ^{235}U)	87-Assembly Basket Reactivity $k_{eff} + 2\sigma$	82-Assembly Basket Max Initial Enrich. (wt % ^{235}U)	82-Assembly Basket Reactivity $k_{eff} + 2\sigma$
B7_48A	48	4.00%	0.93601	4.50%	0.91816
B7_49A	49	3.80%	0.93206	4.50%	0.92623
B7_49B	49	3.80%	0.93335	4.50%	0.92750
B8_59A	59	3.90%	0.93132	4.50%	0.92395
B8_60A	60	3.80%	0.93167	4.50%	0.92748
B8_60B	60	3.80%	0.93143	4.50%	0.93014
B8_61B	61	3.80%	0.93322	4.50%	0.92787
B8_62A	62	3.80%	0.93469	4.50%	0.93102
B8_63A	63	3.80%	0.93679	4.50%	0.93126
B8_64A	64	3.80%	0.93298	4.50%	0.92949
B8_64B	64	3.60%	0.93222	4.30%	0.93539
B9_72A	72	3.80%	0.93632	4.50%	0.93408
B9_74A	74	3.70%	0.93578	4.40%	0.93440
B9_76A	76	3.50%	0.92937	4.20%	0.93158
B9_79A	79	3.70%	0.93665	4.40%	0.93406
B9_80A	80	3.80%	0.93143	4.50%	0.92882
B10_91A	91	3.80%	0.93566	4.50%	0.93093
B10_92A	92	3.90%	0.93620	4.50%	0.92773
B10_96A	96	3.70%	0.93534	4.40%	0.93498
B10_100A	100	3.60%	0.93295	4.40%	0.93505
B9_74A[a]	74	3.70%	0.93575	4.30%	0.93223
B10_91A[a]	91	3.70%	0.92844	4.50%	0.93477
B10_92A[a]	92	3.80%	0.93488	4.50%	0.93570
B10_96A[a]	96	3.70%	0.93368	4.30%	0.93310

[a] Assemblies contain partial length fuel rods. Partial length rod assemblies are evaluated by removing partial length rods from the lattice. This configuration bounds an assembly with full length rods and combinations of full and partial length rods.

UPDATED

Table 6.7.6-9 BWR System Generic Load Limits (Assembly Description)

Assembly Type	Number of Fuel Rods	Number of Partial Length Rods	Max Pitch (inch)	Min Clad OD (inch)	Min Clad Thick. (inch)	Max Pellet OD (inch)	Max Active Length (inch)	Max Loading (MTU)
B7_48A	48	N/A	0.7380	0.5700	0.03600	0.4900	144.0	0.1981
B7_49A	49	N/A	0.7380	0.5630	0.03200	0.4880	146.0	0.2034
B7_49B	49	N/A	0.7380	0.5630	0.03200	0.4910	150.0	0.2115
B8_59A	59	N/A	0.6400	0.4930	0.03400	0.4160	150.0	0.1828
B8_60A	60	N/A	0.6417	0.4840	0.03150	0.4110	150.0	0.1815
B8_60B	60	N/A	0.6400	0.4830	0.03000	0.4140	150.0	0.1841
B8_61B	61	N/A	0.6400	0.4830	0.03000	0.4140	150.0	0.1872
B8_62A	62	N/A	0.6417	0.4830	0.02900	0.4160	150.0	0.1921
B8_63A	63	N/A	0.6420	0.4840	0.02725	0.4195	150.0	0.1985
B8_64A	64	N/A	0.6420	0.4840	0.02725	0.4195	150.0	0.2017
B8_64B	64	N/A	0.6090	0.4576	0.02900	0.3913	150.0	0.1755
B9_72A	72	N/A	0.5720	0.4330	0.02600	0.3740	150.0	0.1803
B9_74A	74[a]	8	0.5720	0.4240	0.02390	0.3760	150.0	0.1873
B9_76A	76	N/A	0.5720	0.4170	0.02090	0.3750	150.0	0.1914
B9_79A	79	N/A	0.5720	0.4240	0.02390	0.3760	150.0	0.2000
B9_80A	80	N/A	0.5720	0.4230	0.02950	0.3565	150.0	0.1821
B10_91A	91[a]	8	0.5100	0.3957	0.02385	0.3420	150.0	0.1906
B10_92A	92[a]	14	0.5100	0.4040	0.02600	0.3455	150.0	0.1966
B10_96A	96[a]	12	0.4880	0.3780	0.02430	0.3224	150.0	0.1787
B10_100A	100	N/A	0.4880	0.3780	0.02430	0.3224	150.0	0.1861

Note: Assembly characteristics represent cold, unirradiated, nominal configurations.

[a] Assemblies may contain partial length fuel rods. Partial length rod assemblies are evaluated by removing partial length rods from the lattice. This configuration bounds an assembly with full length rods and combinations of full and partial length rods.

UPDATED

Table *6.7.6-10* ***Absorber Tolerance Reactivity Change of BWR Models***

Assembly Type	Maximum Enrichment 87 Assy.		Maximum Enrichment 82 Assy.	
	Δk	Δk/σ	Δk	Δk/σ
B7_48A	-0.00017	-0.16	-0.00016	-0.15
B7_49A	0.00116	1.12	0.00158	1.43
B7_49B	-0.00021	-0.20	0.00014	0.13
B8_59A	0.00062	0.62	-0.00026	-0.23
B8_60A	0.00045	0.41	0.00025	0.23
B8_60B	0.00057	0.54	-0.00018	-0.16
B8_61B	0.00009	0.09	0.00140	1.28
B8_62A	0.00123	1.14	0.00115	1.05
B8_63A	-0.00018	-0.17	0.00122	1.12
B8_64A	-0.00013	-0.12	-0.00046	-0.42
B8_64B	0.00005	0.05	-0.00049	-0.46
B9_72A	0.00009	0.09	-0.00023	-0.22
B9_74A	0.00000	0.00	0.00121	1.11
B9_76A	0.00130	1.23	0.00114	1.03
B9_79A	-0.00023	-0.22	0.00035	0.33
B9_80A	0.00009	0.08	-0.00010	-0.09
B10_91A	0.00016	0.16	-0.00037	-0.33
B10_92A	0.00096	0.89	0.00010	0.09
B10_96A	0.00047	0.45	0.00094	0.89
B10_100A	-0.00096	-0.94	0.00193	1.77
Partial Length Rods				
B9_74A	0.00139	1.35	0.00192	1.81
B10_91A	0.00124	1.19	0.00058	0.54
B10_92A	0.00161	1.57	-0.00002	-0.02
B10_96A	0.00006	0.06	0.00017	0.16

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Table 6.7.6-11 BWR System Tube Location Study Summary

Configuration			*Δk/σ from Baseline Square Tube @ 45°*		
Tube	*Tube Location*	*Grind*	*Average*	*Minimum*	*Maximum*
Square	*45°*	*Even*	--		
Square	*45°*	*Biased*	*0.9*	*-1.8*	*3.0*
Square	*Shift*	*Even*	*-1.1*	*-3.0*	*2.1*
Square	*Shift*	*Biased*	*0.2*	*-3.0*	*2.5*
Rectangular	*Shift*	*Even*	*N/A*		
Rectangular	*Shift*	*Biased*	*-8.7*	*-14.1*	*-5.0*

Table 6.7.6-12 BWR System Tube Location Study Detail – Baseline to Square Tube/Biased Grind/45° Alignment

Assembly Type	87 Assy (wt% ^{235}U)	Δk/σ	82 Assy (wt% ^{235}U)	Δk/σ
B7_48A	4.00%	1.2	4.50%	0.6
B7_49A	3.80%	2.0	4.50%	2.7
B7_49B	3.80%	1.7	4.50%	1.2
B8_59A	3.90%	2.3	4.50%	0.2
B8_60A	3.80%	-0.6	4.50%	1.5
B8_60B	3.80%	2.5	4.50%	-0.5
B8_61B	3.80%	1.4	4.50%	2.9
B8_62A	3.80%	2.0	4.50%	3.0
B8_63A	3.80%	1.2	4.50%	0.2
B8_64A	3.80%	1.5	4.50%	0.7
B8_64B	3.60%	1.2	4.30%	0.6
B9_72A	3.80%	-0.4	4.50%	2.3
B9_74A	3.70%	1.7	4.40%	1.1
B9_76A	3.50%	1.9	4.20%	2.9
B9_79A	3.70%	0.1	4.40%	0.8
B9_80A	3.80%	2.7	4.50%	0.7
B10_91A	3.80%	1.2	4.50%	0.1
B10_92A	3.90%	2.9	4.50%	-0.8
B10_96A	3.70%	1.2	4.40%	0.8
B10_100A	3.60%	-1.1	4.40%	1.8
B9_74A	3.70%	1.1	4.30%	2.0
B10_91A	3.70%	2.2	4.50%	1.7
B10_92A	3.80%	2.0	4.50%	0.7
B10_96A	3.70%	1.3	4.30%	-0.2

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Table *6.7.6-13* BWR Fuel Assembly Loading Criteria (Enrichment Limits)

	Max. Initial Enrichment[1] (wt % ^{235}U)					
	Absorber[2] 0.027 ^{10}B g/cm^2		Absorber 0.0225 ^{10}B g/cm^2		Absorber 0.02 ^{10}B g/cm^2	
	87-Assy Basket	82-Assy Basket	87-Assy Basket	82-Assy Basket	87-Assy Basket	82-Assy Basket
B7_48A	4.0%	4.5%	3.7%	4.5%	3.6%	4.4%
B7_49A	3.8%	4.5%	3.6%	4.4%	3.5%	4.3%
B7_49B	3.8%	4.5%	3.6%	4.4%	3.5%	4.2%
B8_59A	3.9%	4.5%	3.7%	4.5%	3.6%	4.3%
B8_60A	3.8%	4.5%	3.7%	4.4%	3.5%	4.2%
B8_60B	3.8%	4.5%	3.6%	4.3%	3.5%	4.2%
B8_61B	3.8%	4.5%	3.6%	4.3%	3.5%	4.2%
B8_62A	3.8%	4.5%	3.6%	4.3%	3.5%	4.1%
B8_63A	3.8%	4.5%	3.6%	4.3%	3.4%	4.2%
B8_64A	3.8%	4.5%	3.6%	4.3%	3.5%	4.2%
B8_64B	3.6%	4.3%	3.4%	4.1%	3.3%	4.0%
B9_72A	3.8%	4.5%	3.6%	4.3%	3.4%	4.1%
B9_74A	3.7%	4.3%	3.4%	4.1%	3.4%	4.0%
B9_76A	3.5%	4.2%	3.4%	4.0%	3.3%	3.9%
B9_79A	3.7%	4.4%	3.4%	4.2%	3.3%	4.0%
B9_80A	3.8%	4.5%	3.6%	4.3%	3.5%	4.2%
B10_91A	3.7%	4.5%	3.6%	4.3%	3.5%	4.1%
B10_92A	3.8%	4.5%	3.6%	4.3%	3.5%	4.1%
B10_96A	3.7%	4.3%	3.5%	4.1%	3.4%	4.0%
B10_100A	3.6%	4.4%	3.5%	4.1%	3.4%	4.0%

[1] Maximum planar average.

[2] Borated aluminum neutron absorber sheet effective areal ^{10}B density.