



1101 Market Street, Chattanooga, Tennessee 37402

CNL-21-053

July 23, 2021

10 CFR 50.90

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Browns Ferry Nuclear Plant, Units 1, 2, and 3
Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68
NRC Docket Nos. 50-259, 50-260, and 50-296

Subject: **Request for License Amendment Regarding Application of Advanced Framatome Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry Nuclear Plant Units 1, 2, and 3, in Support of ATRIUM 11 Fuel Use at Browns Ferry (TS-535)**

In accordance with the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) 50.90, "Application for amendment of license, construction permit, or early site permit," Tennessee Valley Authority (TVA) is submitting a request for amendment to Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68 for Browns Ferry Nuclear Plant (BFN), Units 1, 2, and 3, respectively. The proposed license amendments revise Technical Specification (TS) 5.6.5.b, "Core Operating Limits Report (COLR)," to allow application of Advanced Framatome Methodologies for determining core operating limits in support of loading Framatome fuel type ATRIUM^{TM1} 11. The proposed amendment also deletes a footnote from Table 3.3.1.1-1, "Reactor Protection System Instrumentation," which no longer applies.

Additionally, TVA requests adoption of TSTF-564-A, "Safety Limit MCPR," Revision 2, which is an approved change to the Improved Standard Technical Specifications (ISTS), into the BFN TS. The proposed amendment revises the TS safety limit (SL) on minimum critical power ratio (MCPR) to reduce the need for cycle-specific changes to the value while still meeting the regulatory requirement for an SL.

¹ ATRIUM 11 is a trademark or registered trademarks of Framatome, Inc., its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.

Proprietary Information - Withhold Under 10 CFR 2.390
This letter is decontrolled when separated from Attachments 5a, 6a, 7a, 8a, 9a, 10a, 11a, 12a, 13a, 14a, 15a, and 16a to the Enclosure

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The enclosure to this submittal provides a description and technical evaluation of the proposed change, a regulatory evaluation, and a discussion of environmental considerations for the proposed change. Attachment 1 to this enclosure provides the existing BFN Units 1, 2, and 3 TS pages marked up to show the proposed changes. Attachment 2 to this enclosure provides the existing BFN Units 1, 2, and 3 TS pages retyped to show the proposed change. Attachment 3 to this enclosure provides the proposed marked up TS Bases pages for BFN Unit 1 (the Unit 2 and 3 Bases are nearly identical). Changes to the existing TS Bases are provided for information only and will be implemented under the Technical Specification Bases Control Program.

The Enclosure to this letter contains Attachments (i.e., Enclosure Attachments 5a, 6a, 7a, 8a, 9a, 10a, 11a, 12a, 13a, 14a, 15a, and 16a) that Framatome considers proprietary in nature pursuant to 10 CFR 2.390, "Public inspections, exemptions, requests for withholding," paragraph (a)(4), and request that they be withheld from public disclosure. Enclosure Attachments 5b, 6b, 7b, 8b, 9b, 10b, 11b, 12b, 13b, 14b, 15b, and 16b, are the non-proprietary versions of the corresponding (a) attachments. Attachment 17 provides the Framatome affidavits supporting these proprietary information withholding requests. Accordingly, TVA requests that the information, which is proprietary to Framatome, be withheld from public disclosure in accordance with 10 CFR Section 2.390. Correspondence with respect to the copyright or proprietary aspects of the items listed above or the supporting Framatome affidavits should reference the corresponding report and should be addressed to Alan Meginnis, Framatome, Manager, Product Licensing, 2101 Horn Rapids Road, Richland, Washington 99354.

Approval of the proposed amendments is requested by January 11, 2023, to support reactor startup following the BFN Unit 2 Cycle 22 refueling outage (U2R22). Once approved, the Unit 2 amendment will be implemented prior to start-up from U2R22 scheduled for spring 2023. The Unit 3 amendment will be implemented prior to startup from U3R21 scheduled for spring 2024. The Unit 1 amendment will be implemented prior to startup from U1R15 scheduled for fall 2024.

TVA determined that there are no significant hazards consideration associated with the proposed change and that the change qualifies for a categorical exclusion from environmental review pursuant to the provisions of 10 CFR 51.22(c)(9). Additionally, in accordance with 10 CFR 50.91(b)(1), TVA is sending a copy of this letter and enclosure to the Alabama Department of Public Health.

Attachment 4 contains the new regulatory commitments associated with this submittal. Please address any questions regarding this request to Kimberly D. Hulvey, Senior Manager, Fleet Licensing, at (423) 751-3275.

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I declare under penalty of perjury that the foregoing is true and correct. Executed on this 23rd day of June 2021.

Respectfully,



James Barstow
Vice President, Nuclear Regulatory Affairs and Support Services

Enclosure

Evaluation of the Proposed Change

Attachments:

1. Proposed TS Changes (Mark Ups) for BFN Units 1, 2, and 3
2. Proposed TS Changes (Final Typed) for BFN Units 1, 2, and 3
3. Proposed TS Bases Changes (Mark Ups for Information Only) for BFN Unit 1
4. List of Regulatory Commitments
- 5a. ANP-3857P, Revision 2, Design Limits for Framatome Critical Power Correlations, Framatome Inc., July 2020 (proprietary)
- 5b. ANP-3857NP, Revision 2, Design Limits for Framatome Critical Power Correlations, Framatome Inc., July 2020 (non-proprietary)
- 6a. ANP-3854P, Revision 1, Browns Ferry ATRIUM 11 Equilibrium Cycle Fuel Cycle Design Report, Framatome Inc., June 2020 (proprietary)
- 6b. ANP-3854NP, Revision 1, Browns Ferry ATRIUM 11 Equilibrium Cycle Fuel Cycle Design Report, Framatome, Inc. June 2020 (non-proprietary)
- 7a. ANP-3850P, Revision 0, Browns Ferry ATRIUM 11 Equilibrium Cycle Nuclear Fuel Design Report, Framatome Inc., May 2020 (proprietary)
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- 8a. ANP-3860P, Revision 0, Mechanical Design Report for Browns Ferry ATRIUM 11 Fuel Assemblies Licensing Report, Framatome Inc., April 2021 (proprietary)
- 8b. ANP-3860NP, Revision 0, Mechanical Design Report for Browns Ferry ATRIUM 11 Fuel Assemblies Licensing Report, Framatome Inc., April 2021 (non-proprietary)

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- 14b ANP-3906NP, Revision 0, Browns Ferry ATWS-I Evaluation for ATRIUM 11 Fuel, Framatome Inc., April 2021 (non-proprietary)
- 15a ANP-3874P, Revision 2, Browns Ferry ATRIUM 11 Control Rod Drop Accident Analysis with the AURORA-B CRDA Methodology, Framatome Inc., March 2021 (proprietary)
- 15b ANP-3874NP, Revision 2, Browns Ferry ATRIUM 11 Control Rod Drop Accident Analysis with the AURORA-B CRDA Methodology, Framatome Inc., March 2021 (non-proprietary)

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- 17 Affidavits

cc (Enclosure):

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant
NRC Project Manager - Browns Ferry Nuclear Plant
State Health Officer, Alabama Department of Public Health

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Evaluation of the Proposed Change

SUBJECT: Request for License Amendment Regarding Application of Advanced Framatome Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry Nuclear Plant Units 1, 2, and 3, in Support of ATRIUM 11 Fuel Use at Browns Ferry (TS-535)

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1.0 SUMMARY DESCRIPTION

In accordance with the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) 50.90, "Application for amendment of license, construction permit, or early site permit," Tennessee Valley Authority (TVA) is requesting a license amendment to Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68 for the Browns Ferry Nuclear Plant (BFN), Units 1, 2, and 3, respectively. The proposed change revises the BFN Units 1, 2, and 3 Technical Specifications (TS) to add additional Framatome analytical methodologies for all three BFN units, to support a planned transition to the ATRIUM^{TM1} 11 fuel design. TVA intends to transition BFN to the ATRIUM 11 fuel design commencing with the Unit 2 cycle 23 reload batch to be loaded in spring 2023. Unit 3 would transition to ATRIUM 11 fuel in spring 2024, followed by Unit 1 in fall 2024.

Additionally, the proposed change would adopt Technical Specifications Task Force (TSTF) Traveler TSTF-564, "Safety Limit MCPR," Revision 2, (Reference 1), which is an approved change to the Improved Standard Technical Specifications (ISTS), into the BFN Units 1, 2, and 3 TS. The proposed amendment revises the TS safety limit (SL) on minimum critical power ratio (MCPR) to reduce the need for cycle-specific changes to the value while still meeting the regulatory requirement for a SL.

2.0 DETAILED DESCRIPTION

2.1 System Design and Operation

Core operating limits are established each operating cycle. These operating limits ensure that the fuel design limits are not exceeded during any conditions of normal operation and in the event of any Anticipated Operational Occurrence (AOO).

2.2 Current Technical Specification Requirements

BFN Units 1, 2, and 3 TS 2.1.1.2, "Reactor Core SLs," establishes the requirement that at reactor steam dome pressure greater than or equal to ($\geq$) 585 pounds per square inch gauge (psig) and core flow $\geq$ 10 percent rated core flow, the MCPR shall be $\geq$ 1.06 when two recirculation loops are in operation or $\geq$ 1.08 with only one recirculation loop in operation.

BFN Units 1, 2, and 3 TS Table 3.3.1.1-1, "Reactor Protection System Instrumentation (RPS)," Note f states, "Following Detect and Suppress Solution - Confirmation Density (DSS-CD) implementation, DSS-CD is not required to be armed while in the DSS-CD Armed Region during the first reactor startup and during the first controlled shutdown that passes completely through the DSS-CD Armed Region. However, DSS-CD is considered OPERABLE and shall be maintained OPERABLE and capable of automatically arming for operation at recirculation drive flow rates above the DSS-CD Armed Region."

The Core Operating Limits Report (COLR) is the unit specific document that provides cycle specific parameter limits for the current reload cycle. These cycle specific limits are determined for each reload cycle in accordance with BFN Units 1, 2, and 3 TS 5.6.5, "Core Operating Limits Report (COLR)."

¹ ATRIUM is a trademark or registered trademarks of Framatome, Inc., its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.

TS 5.6.5.a lists the core operating limits required to be established for each cycle. The methods used to determine the operating limits are those previously found acceptable by the Nuclear Regulatory Commission (NRC) and listed in TS 5.6.5.b.

2.3 Reason for the Proposed Change

Advanced Framatome Methodologies

TVA plans to transition to the Framatome fuel type ATRIUM 11. The proposed license amendment to allow application of Advanced Framatome Methodologies is necessary for this fuel transition. TVA is pursuing the ATRIUM 11 fuel type due to the improved fuel cycle economics and safety margins.

The ATRIUM 11 fuel type consists of an array of 11 by 11 fuel rods; whereas the current fuel design (i.e., ATRIUM 10XM) consists of an array of 10 by 10 fuel rods. This increase in the number of fuel rods significantly reduces Linear Heat Generation Rate (LHGR) and fuel duty, thereby improving safety margin.

The ATRIUM 11 fuel type incorporates enhanced debris protection features which make the fuel design less susceptible to debris related fuel failures. In addition, the channel design changes incorporated with ATRIUM 11 make the fuel design less susceptible to channel bow and bulge.

The ATRIUM 11 product is a proven fuel design, having completed lead testing at three European plants, as well as at two domestic plants. One of the domestic plants was BFN, which had eight ATRIUM 11 lead use bundles inserted into Unit 2 in 2015. The ATRIUM 11 design is now being successfully used in reload quantities at two other domestic plants (Brunswick and Susquehanna). The implementation cycles for all three BFN units will contain a fresh reload of ATRIUM 11, with the balance of the core being composed of the ATRIUM 10XM fuel design. No legacy ATRIUM-10 fuel will be present in the transition cycle cores.

TSTF-564 Safety Limit MCPR

The current SLMCPR (i.e., $MCPR_{99.9\%}$) is affected by the cycle-specific design, such as core power distribution, fuel type, and operating power-flow domain. These factors generally vary enough from cycle-to-cycle that changes to the SLMCPR TS values are common. The proposed change substantially reduces the need for cycle-specific changes to the SLMCPR and eliminates the need for accelerated NRC review of those changes.

2.4 Description of the Proposed Change

TSTF-564 SLMCPR

The current SLMCPR value (referred to as $MCPR_{99.9\%}$) in TS 2.1.1.2 is relocated to the COLR, and replaced by a $MCPR_{95/95}$ value of 1.05, derived from the critical power correlation statistics.

TS 5.6.5.a is also modified to require that the $MCPR_{99.9\%}$ value be included in the COLR.

Advanced Framatome Methodologies

Methodologies currently listed in BFN Units 1, 2, and 3 TS 5.6.5.b that will be removed are:

- NEDE-24011-P-A, Revision 16, General Electric Standard Application for Reactor Fuel, October 2007 [Note: This methodology only appears in the Unit 1 TS. There is no Global Nuclear fuel (GNF) fuel remaining in the Unit 1 core. Therefore, this reference is being removed for consistency with the Unit 2 and Unit 3 TS.]
- XN-NF-84-105(P)(A) Volume 1 and Volume 1 Supplements 1 and 2, XCOBRA-T: A Computer Code for BWR Transient Thermal-Hydraulic Core Analysis, Exxon Nuclear Company, February 1987
- ANF-913(P)(A) Volume 1 Revision 1 and Volume 1 Supplements 2, 3, and 4, COTRANSA2: A Computer Program for Boiling Water Reactor Transient Analyses, Advanced Nuclear Fuels Corporation, August 1990
- BAW-10255(P)(A), Revision 2, Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code, AREVA NP, May 2008

The above methodologies are no longer applicable with addition of the Advanced Methodologies described below.

The advanced methodologies being added to BFN Units 1, 2, and 3 TS 5.6.5.b are:

- BAW-10247P-A, Supplement 2P-A, Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods, Framatome Inc., August 2018
- ANP-10300P-A Revision 1, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios, Framatome Inc., January 2018
- ANP-10332P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios, Framatome Inc., March 2019
- ANP-10333P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA), Framatome Inc., March 2018 (as supplemented by Section 6.4 of ANP-3908P Revision 3, Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel, Framatome Inc., July 2021)
- ANP-10335P-A Revision 0, ACE/ATRIUM 11 Critical Power Correlation, Framatome Inc., May 2018
- ANP-10340P-A Revision 0, Incorporation of Chromia-Doped Fuel Properties in AREVA Approved Methods, Framatome Inc., May 2018
- ANP-3907P Revision 0, Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry, Framatome Inc., April 2021

Additional Proposed Changes

Currently, TS 5.6.5.b references Revision 0 of ANP-10298 (Reference 2) for the ATRIUM 10XM ACE CPR correlation, supplemented by a plant-specific report ANP-3140P (Reference 3). The plant-specific supplement was required at the time of the ATRIUM 10XM fuel transition license amendment request (LAR) (approved in Reference 4) due to an error in the K factor method described in Reference 2. The NRC has subsequently approved Revision 1 of ANP-10298 (Reference 5), which includes the corrected K factor method. Therefore, the plant specific report is no longer required. TVA proposes to remove ANP-3140P from the TS, update the TS reference for ANP-10298 to Revision 1, and reflect the issued date of Revision 1. There are no actual changes to any methodology associated with this action. Additionally, for BFN Unit 3 there is a duplicate reference of ANP-3140P on TS 5.6.5.b, pg. 5.0-24c. This reference will also be deleted.

The methodologies being added to TS 5.6.5.b have been reviewed and approved by the NRC, with the following exceptions. The approved control rod drop accident (CRDA) methodology in ANP-10333P (Reference 14) requires the addition of two plant specific methodology elements; these plant specific methods are discussed in more detail below. The plant-specific hybrid stability method described in ANP-3907P (Attachment 13a) references the approved Framatome BEO-III topical report (TR) (Reference 6) and the approved GE Hitachi Nuclear Energy (GEH) DSS-CD TR (Reference 7) as approved elements that make up a hybrid stability approach described below.

With the addition of the methodologies listed above, TVA plans to transition from the GEH TRACG04 based DSS-CD stability methodology to the Framatome RAMONA5-FA based Best Estimate Enhanced Option-III stability methodology (BEO-III). Similar to the approach used by the Brunswick Steam Electric Plant (BSEP), Unit Nos. 1 and 2 (Reference 8), a hybrid stability solution will be used where the RAMONA5-FA based stability methodology in the BEO-III TR is coupled with the Confirmation Density Algorithm (CDA) of DSS-CD. This hybrid solution is referred to as BEO-III w/CDA.

With BEO-III w/CDA, the CDA will remain the licensing basis trip, and identical Oscillation Power Range Monitor (OPRM) setpoints will be used, thereby minimizing the impact to BFN. As a result of the transition from DSS-CD to BEO-III w/CDA, TS Table 3.3.1.1-1 Note f will be removed from the TS. As noted in Reference 8, "Note (f) describes a condition placed upon arming DSS-CD that was applicable only during the first reactor startup and shutdown following implementation of that methodology. The NRC staff reviewed Note (f) and finds that implementation of the plant-specific BEO-III w/CDA approach would obviate the need for Note (f) to Table 3.3.1.1-1." Therefore, this note is no longer applicable and will be removed.

With the transition from ATRIUM 10XM fuel to ATRIUM 11 fuel, BFN will transition to the NRC-approved RAMONA5-FA based methodology for the licensing basis Anticipated Transient Without Scram with Instability (ATWS-I). The current licensing basis ATWS-I analysis utilized the GEH TRACG04 methodology with ATRIUM 10XM fuel, which was approved for BFN on December 26, 2019 (Reference 9).

Attachment 1 to this enclosure provides the existing BFN Units 1, 2, and 3 TS pages marked up to show the proposed changes. Attachment 2 to this enclosure provides the existing BFN Units 1, 2, and 3 TS pages retyped to show the proposed changes. Attachment 3 to this enclosure provides the proposed marked up TS Bases pages for BFN Unit 1 (the Unit 2 and 3 Bases are nearly identical). Changes to the existing TS Bases are provided for information only and will be

implemented under the Technical Specification Bases Control Program. Attachment 4 contains the regulatory commitments associated with this LAR.

3.0 TECHNICAL EVALUATION

3.1 TSTF-564 Assessment

3.1.1 Applicability of Published Safety Evaluation

TVA has reviewed the revised safety evaluation for TSTF-564 provided to the Technical Specifications Task Force in a letter dated May 13, 2020. This review included a review of the NRC staff's evaluation, as well as the information provided in TSTF-564. TVA has concluded that the justifications presented in TSTF-564 and the safety evaluation prepared by the NRC staff are applicable to BFN Units 1, 2, and 3, and justify this amendment for the incorporation of the changes to the BFN TS.

The BFN Units 1, 2 and 3 reactors are currently fueled with Framatome ATRIUM 10XM fuel assemblies and will be introducing ATRIUM 11 during the spring 2023 Unit 2 refueling outage, the spring 2024 Unit 3 refueling outage, and the fall 2024 Unit 1 refueling outage. The proposed Safety Limit in SL 2.1.1.2 is 1.05. This is the value calculated for both the ATRIUM 10XM and ATRIUM 11 fuel types using the equations in Attachment 5a. (Note: Attachment 5b contains the non-proprietary version of this information). ATRIUM 11 is identified in the TS Bases as the fuel type the SL is based upon because it will be the dominant fuel type at BFN going forward.

The MCPR value calculated as the point at which 99.9% of the fuel rods would not be susceptible to boiling transition (i.e., reduced heat transfer) during normal operation and anticipated operational occurrences is referred to as MCPR_{99.9%}. TS 5.6.5 is being revised to require the MCPR_{99.9%} value to be included in the cycle-specific COLR.

3.1.2 TSTF-564 Variations

TVA is proposing the following variations from the TS changes described in TSTF-564 or the applicable parts of the NRC staff's safety evaluation.

BFN uses Framatome ATRIUM 10XM and ATRIUM 11 fuel types which are not identified in TSTF-564 Table 1. However, as discussed in TSTF-564, other fuel vendors may determine the MCPR_{95/95} for other fuel designs using the methodology described in TSTF-564. TVA has included the required description of the derivation of the MCPR_{95/95} for ATRIUM 10XM and ATRIUM 11 in Attachment 5a based on the information contained in each fuel type's NRC-approved CPR correlation that is referenced in BFN TS 5.6.5.b. The equations in Attachment 5a modify the TSTF-564 MCPR_{95/95} formulation to reflect Framatome's definition of Experimental CPR (ECPR). This difference is within the scope of the TSTF-564 approval and does not affect the applicability of TSTF-564 to the BFN TS.

The BFN TS utilizes different numbering than the STS on which TSTF-564 was based. Specifically, BFN TS 5.6.5 corresponds to STS 5.6.3, "Core Operating Limits Report." This difference is administrative in nature and does not affect the applicability of TSTF-564 to the BFN TS.

3.2 Application of Framatome Advanced Methods in TS 5.6.5.b

Attachments 6a through 16a provide the detailed Technical Evaluation for the proposed change to the advanced Framatome methodologies outlined in Section 2.4 to this enclosure. The information presented in these Attachments demonstrates acceptable safety margin for the proposed change supporting operation of the new ATRIUM 11 fuel type in the currently approved operating domains. The currently approved operating domains include Extended Power Uprate (EPU) conditions (Reference 10), as well as MELLLA+ (Reference 9).

The sections below provide a brief summary of what is included in the Attachments. The table below is provided to correlate the Advanced Methodologies that will be added to TS 5.6.5.b with the Attachments in which the methodology is applied. Note that the Attachments with the 'a' designation provide the full report, while the Attachments with the 'b' designation provide the non-proprietary version of the full report (i.e., proprietary information is redacted). For ease of reference throughout this LAR, only the Attachments with the 'a' designation are referenced in the discussions.

Attachment	Methodology Title
6a	ANP-3854P, Revision 1, Browns Ferry ATRIUM 11 Equilibrium Cycle Fuel Cycle Design Report, Framatome Inc., June 2020 (proprietary)
7a	ANP-3850P, Revision 0, Browns Ferry ATRIUM 11 Equilibrium Cycle Nuclear Fuel Design Report, Framatome Inc., May 2020 (proprietary)
8a	ANP-3860P, Revision 0, Mechanical Design Report for Browns Ferry ATRIUM 11 Fuel Assemblies Licensing Report, Framatome Inc., April 2021 (proprietary)
9a	ANP-3866P, Revision 0, ATRIUM 11 Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry LAR Licensing Report, Framatome Inc., October 2020 (proprietary)
10a	ANP-3859P, Revision 0, Browns Ferry Thermal-Hydraulic Design Report for ATRIUM 11 Fuel Assemblies, Framatome Inc., September 2020 (proprietary)
11a	ANP-3908P, Revision 3, Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel, Framatome Inc., July 2021 (proprietary)
12a	ANP-3905P, Revision 1, Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel, Framatome Inc., July 2021 (proprietary)
13a	ANP-3907P, Revision 0, Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry, Framatome Inc., April 2021 (proprietary)
14a	ANP-3906P, Revision 0, Browns Ferry ATWS-I Evaluation for ATRIUM 11 Fuel, Framatome Inc., April 2021 (proprietary)
15a	ANP-3874P, Revision 2, Browns Ferry ATRIUM 11 Control Rod Drop Accident Analysis with the AURORA-B CRDA Methodology, Framatome Inc., March 2021 (proprietary)
16a	ANP-3904P, Revision 4, Browns Ferry ATRIUM 11 Transient Demonstration, Framatome Inc., July 2021 (proprietary)

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In a pre-application meeting with TVA and the NRC on June 8, 2020 (Reference 11), the overall approach for the BFN ATRIUM 11 fuel transition submittal was discussed. In the meeting, TVA stated that the BFN LAR would follow the same approach used in the BSEP and the Susquehanna Steam Electric Station (SSES), Units 1 and 2, ATRIUM 11 transition NRC-approved LARs (References 8 and 12). The attachments to the BFN LAR provide demonstration analyses for the advanced Framatome methods similar to those provided for the two precedent submittals.

In the Reference 11 pre-application meeting summary, the NRC questioned whether TVA intended to submit a LAR to update the BFN source term to account for the use of ATRIUM 11. TVA has completed dose calculations using an ATRIUM 11 specific source term, and determined that the resulting doses remain bounded by the current licensing basis dose values. Therefore the current licensing basis source term bounds the ATRIUM 11 specific source term and a LAR to update the source term licensing basis is not required.

Additionally, the NRC requested that the LAR include discussions on the topics of decay heat and impacts to the containment. Decay heat is discussed in Section 5.1.1 of Attachment 16a, while containment impacts are discussed in Section 5.2 of Attachment 16a and Section 7.3 of Attachment 11a.

During the Reference 11 meeting, TVA stated that compliance with the Limitations and Conditions (L&Cs) associated with each of the advanced Framatome methodologies would be provided in a single summary report. TVA has decided, instead, to address the L&Cs of each new advanced methodology as a section of the associated demonstration analysis report that is included in the LAR. This approach allows the reviewer of a particular demonstration analysis to have more convenient access to the L&C dispositions for that methodology, without having to consult another document.

There are two plant-specific methodologies utilized in the control rod drop accident demonstration analysis. First, TVA stated that RG 1.236 (Reference 13) would be addressed in the LAR during the pre-application meeting with the NRC (Reference 11). Framatome noted that the hydrogen dependent fuel failure criteria in RG 1.236 assumes that hydrogen uptake in the cladding oxide layer must be accounted for in addition to the cladding itself. An adjustment to the calculated hydrogen uptake methodology was developed by Framatome and is presented in Section 6.4 of Attachment 11a to account for hydrogen uptake in the oxide. This adjustment constitutes a plant-specific modification to the approved method. TVA requests that this topic be reviewed and approved as part of this LAR.

Secondly, for the CRDA in the startup power range, Framatome applied an industry generic critical heat flux (CHF) correlation. The details are provided in Section 6.4 of Attachment 11a. The use of the particular generic CHF correlation for the stated purpose was previously reviewed and approved for BSEP by the NRC in Reference 8. TVA requests that this topic be reviewed for BFN as part of this LAR.

Attachment 6a: ANP-3854P, Revision 1, Browns Ferry ATRIUM 11 Equilibrium Cycle Fuel Cycle Design Report

In ANP-3854P Revision 1, Framatome documents an equilibrium fuel cycle design for BFN. This design uses the ATRIUM 11 fuel assembly and the currently approved operating domains. This analysis has been performed with the approved Framatome neutronic modeling methodology (Reference 15). This analysis also used the Reference 16 critical power methodology. The CASMO-4 lattice depletion code was used to generate nuclear

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data including cross sections and local power peaking factors. The MICROBURN-B2 three-dimensional core simulator code, combined with the ACE critical power correlation, was used to model the core. The MICROBURN-B2 pin power reconstruction (PPR) model was used to determine the thermal margins presented in the report. Design results including projected control rod patterns and evaluations of thermal and reactivity margins are presented.

Attachment 7a: ANP-3850P, Revision 0, Browns Ferry ATRIUM 11 Equilibrium Cycle Nuclear Fuel Design Report

ANP-3850P Revision 0 provides results of the neutronic design analyses performed by Framatome for the ATRIUM 11 equilibrium cycle fuel assemblies (used in Attachment 6a). NRC-approved neutronic design criteria are provided in Reference 17, and the NRC-approved neutronic design analysis methodology (Reference 15) was used to determine conformance to design criteria.

Attachment 8a: ANP-3860P, Revision 0, Mechanical Design Report for Browns Ferry ATRIUM 11 Fuel Assemblies

ANP-3860P Revision 0 documents the completion of the licensing analyses and related testing necessary to verify that the mechanical design criteria are met for the ATRIUM 11 fuel assemblies supplied by Framatome for insertion into BFN. This report also provides a description of the mechanical design and licensing methods for ATRIUM 11. The scope of this report is limited to an evaluation of the mechanical design of the fuel assembly and fuel channel. The fuel assembly design was evaluated according to the Framatome Boiling Water Reactor (BWR) generic mechanical design criteria (Reference 17). The fuel channel design was evaluated to the criteria given in the fuel channel TRs (References 18 and 19). The generic design criteria have been approved by the NRC and the criteria are applicable to the subject fuel assembly and channel design. Mechanical analyses for ATRIUM 11 have been performed using an NRC-approved design analysis methodology.

Attachment 9a: ANP-3866P, Revision 0, ATRIUM 11 Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry LAR

ANP-3866P Revision 0 reports the results of fuel rod thermal-mechanical analyses for the performance of ATRIUM 11 fuel assemblies inserted into to an equilibrium cycle for the BFN units and demonstrates that the design criteria relevant to the thermal-mechanical limits are satisfied. These analyses assume the use of chromia additive in enriched urania portions of the fuel and assume operation in the currently approved operating domains. Both the design criteria and the analysis methodology used in this report have been approved by the NRC. The analysis results are evaluated according to the generic fuel rod thermal and mechanical design criteria contained in Reference 17 along with design criteria provided in Reference 20. In addition, the approved methodology for the inclusion of chromia additive in the fuel pellets (Reference 21) is also used.

Attachment 10a: ANP-3859P, Revision 0, Browns Ferry Thermal-Hydraulic Design Report for ATRIUM 11 Fuel Assemblies

ANP-3859P Revision 0 presents the results of BFN thermal-hydraulic analyses, which demonstrate that Framatome ATRIUM 11 fuel is hydraulically compatible with the previously loaded ATRIUM 10XM fuel design. These reports also provide the hydraulic characterization of the ATRIUM 11 and the coresident ATRIUM 10XM design. The generic

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thermal-hydraulic design criteria applicable to the design have been reviewed and approved by the NRC in Reference 17. In addition, thermal-hydraulic criteria applicable to the design have also been reviewed and approved by the NRC in Reference 22.

Attachment 11a: ANP-3908P, Revision 3, Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel

ANP-2637P, "Boiling Water Reactor Licensing Methodology Compendium" is a compendium of Framatome methodologies and design criteria, which are described in TRs that the NRC has found acceptable for referencing in BWR licensing applications. Framatome provided this document to the NRC for information in Reference 23. This compendium provides a concise, organized source for BWR TRs. It presents information about the application of each TR, the associated Safety Evaluation Report (SER) and its conclusions and restrictions/limitations for each TR, the relationships among the TRs, and for certain methodologies, descriptions of their unique characteristics, or applications. Compliance with the SER restrictions/limitations is assured by implementing them within the engineering guidelines or by incorporating them into the computer codes.

ANP-3908P Revision 3 demonstrates that the Framatome licensing methodologies presented in Framatome document ANP-2637P are applicable to the ATRIUM 11 fuel type and operation of BFN in the currently approved operating domains. As noted earlier, ANP-3908P also discusses two plant-specific methodologies associated with the control rod drop accident analysis.

The report also addresses miscellaneous topics such as anticipated transients without scram (ATWS) containment response and vessel fluence, which were the subject of requests for additional information (RAIs) in the NRC-approved precedent LARs (References 8 and 12).

Attachment 12a: ANP-3905P, Revision 1, Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel

ANP-3905P Revision 1 presents the results of a loss-of-coolant accident (LOCA) break spectrum and emergency core cooling system (ECCS) analyses for BFN. The analyses documented in this report are performed with NRC-approved Framatome LOCA Evaluation Models for reactor licensing analyses (Reference 24). The purpose of the break spectrum analysis is to identify the break characteristics that result in the highest calculated peak cladding temperature (PCT) during a postulated LOCA. The results provide the maximum average planar linear heat generation rate (MAPLHGR) limit for ATRIUM 11 fuel as a function of exposure. The calculations described in this report are performed in conformance with 10 CFR 50 Appendix K requirements and satisfy the event acceptance criteria identified in 10 CFR 50.46.

Attachment 13a: ANP-3907P, Revision 0, Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry

ANP-3907P Revision 0 provides a demonstration of applying the Framatome BEO-III stability methodology described in Reference 6 to the equilibrium ATRIUM 11 cycle design in Attachment 6a. The BFN stability approach combines the RAMONA5-FA methodology with the Confirmation Density Algorithm (CDA) used within the DSS-CD hardware installed at BFN. The report refers to the BEO-III TR (Reference 6) for the RAMONA5-FA methodology basis.

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The CDA is integrated into the overall Framatome stability method for BFN by incorporating a code developed by GEH, called CDAST. The report describes how CDAST was integrated into the overall calculation framework, confirms that the CDA algorithm in CDAST is consistent with the CDA incorporated within the DSS-CD hardware at BFN, and how CDAST was validated on the Framatome computational platforms.

The report notes that the calculational procedure used each reload for generating the manual Backup Stability Protection (BSP) regions, as well as the process for validating the Automated Backup Stability Protection (ABSP) hardware setpoints, is unchanged from the current process used to support MELLLA+.

Attachment 14a: ANP-3906P, Revision 0, BFN ATWS-I Evaluation for ATRIUM 11 Fuel

For ATWS-I evaluations, BFN will transition from the GEH TRACG04 method used to license MELLLA+ (Reference 9) to the NRC-approved Framatome RAMONA5-FA method described in Reference 25. ANP-3906P Revision 0 provides the results of applying the Reference 25 methodology to the ATRIUM 11 equilibrium cycle design in Attachment 6a. Consistent with the Reference 9 MELLLA+ submittal, the evaluation considers both the two recirculation pump trip and the turbine trip with bypass events. Key assumptions such as the rate of feedwater temperature reduction, and the timing of operator action to reduce water level, are either unchanged or conservatively increased from the Reference 9 evaluations. The evaluation demonstrates that the fuel related aspects of the ATWS-I event remain acceptable.

Attachment 15a: ANP-3874P, Revision 2, Browns Ferry ATRIUM 11 Control Rod Drop Accident Analysis with the AURORA-B CRDA Methodology

ANP-3874P Revision 2 provides a demonstration of applying the NRC-approved Reference 26 methodology to the ATRIUM 11 equilibrium cycle design in Attachment 6a. The methodology includes the use of a nodal three-dimensional kinetics solution with both thermal-hydraulic and fuel temperature feedback. These models provide more precise localized neutronic and thermal conditions than previous methods. The report demonstrates the determination of candidate control rods that could challenge fuel failure criteria and the subsequent evaluation of these candidate rods with a three-dimensional neutron kinetics and thermal-hydraulics code system.

The report provides an evaluation against the cladding failure criteria in RG 1.236, Pressurized-Water Reactor Control Rod Ejection and Boiling-Water Reactor Control Rod Drop Accidents (Reference 13). High temperature cladding failure, pellet clad mechanical interaction failure, and molten fuel cladding failure are considered.

A radiological consequence evaluation is provided to demonstrate that the current licensing basis dose evaluation bounds the release from the number of failed ATRIUM 11 fuel rods in the BFN demonstration analysis. The transient release fractions provided in Draft RG DG-1327 Revision 1, July 2019, (Reference 27) were assumed², along with the steady state release fractions provided in RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," Revision 0 (Reference 28).

² As noted in the Response to Public Comments for Draft RG DG-1327 (ML18302A107), the transient release fractions are included as an appendix to Reference 27.

Attachment 16a: ANP-3904P, Revision 4, Browns Ferry ATRIUM 11 Transient Demonstration

ANP-3904P Revision 4 summarizes the results of a subset of limiting transient analyses performed utilizing the Reference 16 and Reference 29 methodologies based on the ATRIUM 11 equilibrium cycle design in Attachment 6a. The AURORA-B AOO methodology (Reference 29) is used to calculate the change in the minimum critical power ratio (ΔMCPR) during the AOO. The AURORA-B AOO methodology is also used to calculate the maximum reactor vessel pressure and the maximum steam dome pressure during the ASME Boiler and Pressure Vessel Code and ATWS overpressure events. The ACE/ATRIUM 11 critical power correlation (Reference 16) is used to evaluate the CPR thermal margin of the ATRIUM 11 fuel.

To address RAIs received as part of the review of the Reference 8 and Reference 12 NRC-approved LARs, the BFN transient demonstration report was expanded in scope relative to these precedent submittals. In addition to providing transient results with all equipment in service, results at rated power with various equipment out of service options licensed for BFN are included. Also, a disposition of events table is provided to address the BFN UFSAR Chapter 14 events. The report also discusses the cycle exposure points, scram times, and power/flow analysis points that will appear in the Reload Safety Analysis Report for the implementation cycle.

TVA also desires to modify the manner in which the power dependent MCPR operating limits are implemented for power levels above P_{bypass} (the power level below which the direct scram on a turbine trip or load reject is bypassed). For power levels below P_{bypass} , two sets of power dependent MCPR operating limits are traditionally utilized. These are differentiated by the use of a flow flag. One set of power dependent limits applies for core flows greater than or equal to the flow flag value, while the other set applies for core flows less than the flow flag value. The report that originally supported the licensing of BFN for ARTS (Reference 30) only discusses the use of a high/low flow flag value in the below P_{bypass} power range. Therefore, NRC approval is needed to extend the concept of a high/low flow flag to power dependent MCPR limits in the above P_{bypass} power range. TVA requests that this topic be reviewed as part of this LAR.

The report also addresses various miscellaneous topics such as decay heat, station blackout (SBO), and mass/energy release that were the subject of RAIs in the precedent LARs.

TVA has reviewed the RAIs associated with the review of the Reference 8 and Reference 12 NRC-approved LARs. Some of the precedent RAIs resulted in L&Cs in the advanced methodology TRs, and were accounted for in BFN analyses by application of the approved TRs. Others are addressed in the various demonstration reports attached to the LAR.

ATRIUM 11 Fuel Design and Cycle Specific Reports

The NRC-approved the use of Framatome fuel and core design methodologies to determine BFN core operating limits with the issuance of License Amendment 281 for Unit 1, and License Amendments 287 and 245 for Units 2 and 3, respectively. Framatome licensing TR ANF-89-98(P)(A) Revision 1 and Supplement 1 is one of these NRC-approved methodologies. ANF-89-98(P)(A) Revision 1 and Supplement 1, as clarified by a Siemens Power Corporation letter dated October 12, 1999, (Reference 31) and an NRC letter dated May 31, 2000, (Reference 32) requires that a summary of the evaluation of the ATRIUM 11 design against the NRC-approved generic design criteria be provided to the NRC for information. Framatome

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provided this evaluation to the NRC for information by letter dated September 18, 2018, which transmitted Framatome document ANP-3653P Revision 0, "Fuel Design Evaluation for ATRIUM 11 BWR Reload Fuel" (Reference 33). In accordance with the process described in ANF-89-98(P)(A) Revision 1 and Supplement 1, new fuel designs or fuel design changes satisfying the ANF-89-98(P)(A) design criteria do not require explicit NRC review and approval (i.e., satisfaction of the design criteria is sufficient for approval by reference to the criteria).

ANP-3653P identifies fuel design criteria, specified in ANF-89-98(P)(A) Revision 1 and Supplement 1, which are evaluated on a cycle specific basis. Reports summarizing the results of analyses performed to demonstrate BFN compliance with the cycle specific criteria are provided by Framatome to TVA as part of the normal reload licensing document package. This type of information is not available until later in the reload licensing process. Consistent with the process described in ANF-89-98(P)(A) Revision 1 and Supplement 1 (as clarified by References 31 and 32), TVA will submit the BFN Unit 2 Cycle 23 reload reports outlined in the table below to the NRC for information only within 15 days following TVA approval. These supplemental reports provide a demonstration of applying the advanced methodologies to the first transition cycle mixed core containing one reload of fresh ATRIUM 11 fuel with co-resident ATRIUM 10XM legacy fuel. The reports will be provided in supplemental letters as documented in Attachment 4. The anticipated schedule is presented in the table below.

Report	Estimated Transmittal Date
Fuel Cycle Design Report	May 2022
Nuclear Fuel Bundle Design Report	May 2022
Fuel Rod Design Report	July 2022
Safety Limit MCPR Report	September 2022
Reload Safety Analysis Report	October 2022

BFN Units 1, 2, and 3 have the same core power, flow, vessel geometries, and bundle geometries. The three units operate on a 24-month fuel cycle resulting in minimal differences in fuel and core neutronic design.

Based on the minimal differences between the three units, the information that is included in this LAR, and the information in the table above that will be provided for Unit 2 Cycle 23, only limited information needs to be provided for Units 1 and 3. Therefore, TVA will submit, for information, the Unit 3 Cycle 22 Reload Safety Analysis Report with the transmittal of the COLR prior to startup from the Unit 3 Cycle 21 refueling outage (spring 2024 timeframe) which will load the first reload batch of ATRIUM 11 fuel into the Unit 3 reactor core. Similarly, the Unit 1 Cycle 16 Reload Safety Analysis Report will be submitted for information along with the COLR prior to startup from the Unit 1 Cycle 15 refueling outage (fall 2024 timeframe), which will load the first reload batch of ATRIUM 11 fuel into the Unit 1 reactor core.

Attachment 4 of this Enclosure documents the regulatory commitments to provide these reports.

4.0 REGULATORY EVALUATION

4.1 Applicable Regulatory Requirements/Criteria

The following NRC requirements and guidance documents are applicable to the proposed change.

10 CFR 50.36(c)(5), "Technical specifications," states that the TSs will include administrative

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controls that address the provisions relating to organization and management, procedures, record keeping, review and audit, and reporting necessary to assure operation of the facility in a safe manner. The COLR is required as a part of the reporting requirements specified in the BFN TS Administrative Controls section. The TSs require the core operating limits to be established prior to each reload cycle, or prior to any remaining portion of a reload cycle, and to be documented in the COLR. In addition, it requires the analytical methods used to determine the core operating limits to be those that have been previously reviewed and approved by the NRC, and specifically to be those described in TS 5.6.5.b. The proposed amendments ensure that these requirements are met.

10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water power reactors," establishes the acceptance criteria for the design basis LOCA. Paragraph (b)(1) requires the calculated maximum fuel element cladding temperature (i.e., PCT) to not exceed 2200°F. 10 CFR Part 50, Appendix K, establishes required and acceptable features of evaluation models for heat removal by the ECCS after the blowdown phase of a LOCA. The use of the proposed analytical methods to determine core operating limits will continue to ensure that fuel performance during normal, transient, and accident conditions complies with these requirements. Specific Average Planar Linear Heat Generation Rate (APLHGR) limits will be determined in conformance with 10 CFR 50 Appendix K requirements and documented in the COLR to ensure compliance with 10 CFR 50.46(b)(1).

10 CFR 50.62, "Requirements for reduction of risk from anticipated transients without scram (ATWS) events for light-water-cooled nuclear power plants," defines an ATWS as an AOO followed by the failure of the reactor trip portion of the protection system specified in GDC 20. During an ATWS the potential exists for thermal-hydraulic instability to develop. The analyses presented in this LAR demonstrate ATWS regulatory criteria are satisfied for BFN, including those specifically applicable to ATWS-I (i.e., demonstrating core coolability is maintained).

The BFN units were designed and constructed based on the proposed General Design Criteria (GDC) published by the Atomic Energy Commission (AEC) in the Federal Register (32 FR 10213) on July 11, 1967 (hereafter called "draft GDC"). The AEC published the final rule that added Appendix A to 10 CFR Part 50, GDC for Nuclear Power Plants, in the Federal Register (36 FR 3255) on February 20, 1971 (hereafter called "final GDC"). As discussed in Appendix A of the Final Safety Analysis Report (FSAR), the licensee has made changes to the facility over the life of the plant that may have invoked the final GDC. The extent to which the final GDC have been invoked can be found in specific sections of the FSAR and in other design and licensing basis documentation. GDC 10, 12, and 28 are applicable to this LAR review.

Criterion 10-Reactor design. The reactor core and associated coolant, control, and protection systems be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

TVA will use the proposed analytical methods to perform plant-specific analyses for MCPR and LHGR. Application of the MCPR_{99.9%} and MCPR_{95/95} safety limit CPR values per TSTF-564 will ensure that sufficient conservatism exists in the operating limit MCPR such that, in the event of an AOO, adequate protection against the onset of boiling transition is assured. Limits on the LHGR are specified to ensure that fuel thermal mechanical design limits are not exceeded anywhere in the core during normal operation, including AOOs. Therefore, compliance with GDC 10 of 10 CFR 50, Appendix A is maintained.

Criterion 12-Suppression of reactor power oscillations. The reactor core and associated

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coolant, control, and protection systems be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed.

As part of the methodology changes outlined above, BFN will transition from DSS-CD to a BEO-III w/CDA stability methodology. With BEO-III w/CDA, the CDA will continue to provide the licensing basis trip function, and the automated and manual BSP functions will be maintained. The CDA provides reliable, automatic detection and suppression of stability related power oscillations. The automated and manual BSP functions assure that power oscillations, which can result in conditions exceeding specified acceptable fuel design limits, are not possible. Therefore, compliance with GDC 12 of 10 CFR 50, Appendix A is maintained.

Criterion 28-Reactivity limits. The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor coolant pressure boundary greater than limited local yielding nor (2) sufficiently disturb the core, its support structures or other reactor pressure vessel internals to impair significantly the capability to cool the core. These postulated reactivity accidents include consideration of rod ejection (i.e., unless prevented by positive means), rod dropout, steam line rupture, changes in reactor coolant temperature and pressure, and cold-water addition.

The use of the proposed analytical methods for the CRDA calculations will continue to demonstrate compliance with GDC 28.

TVA has determined that the proposed change does not require any exemptions or relief from regulatory requirements, other than the TSs, and does not affect conformance with the intent of any GDC differently than described in the FSAR.

4.2 Precedent

Two NRC-approved LARs were identified that serve as precedents for the BFN LAR, relative to the addition of the advanced Framatome methodologies to the Technical Specifications. An additional precedent was identified relative to the adoption of TSTF-564 for BFN.

Brunswick (Advanced Framatome Methodologies)

The NRC has previously approved the application of the Framatome advanced methodologies at BSEP in Reference 8. In the case of BSEP, some of the methodologies were not yet generically approved, which required a plant specific report for each of those methodologies. For BFN, each of the advanced methodologies is now generically approved, and the generic TR for each method will be added to TS 5.6.5.b. Because BSEP and BFN are both MELLLA+ plants, all of the advanced methodologies added to the TSs for BSEP are also appropriately added to the BFN TSs.

As in the case of BSEP, the BEO-III w/CDA hybrid stability solution will be used. Some differences from the application approach BSEP used are noted. While BSEP performs the CDA response and MCPR response analyses with an in-house code, BFN procured a CDA code from GEH, which TVA provided to Framatome for integration into their stability analysis framework. Because the CDA code is fully integrated into the Framatome analysis framework, no screening out of cases for CDA and MCPR analysis is performed, as BSEP elected to do.

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The BFN stability cases analyzed with RAMONA5-FA are fully evaluated for CDA and MCPR response.

With the exception of these noted differences, the BSEP LAR serves as an applicable precedent for this BFN LAR.

Susquehanna (Advanced Framatome Methodologies)

The NRC approved the application of the Framatome advanced methodologies to SSES in Reference 12. However, given that SSES is not a MELLLA+ plant, their LAR did not add the BEO-III stability method to their TS, as they retained their existing Option III stability solution. The SSES LAR did not address use of the RAMONA5-FA based ATWS-I method, as it is not required, given they are a non MELLLA+ plant. Also, the SSES LAR requested the addition of the SAFLIM3D and RODEX4 methods to their TS; the BFN TS already contain these two methodologies.

The SSES LAR also included the TS changes related to TSTF-535, "Revise Shutdown Margin Definition to Address Advanced Fuel Designs." This part of the SSES LAR is not relevant to the BFN LAR as precedent, as BFN has already implemented the TSTF-535 related changes to the TS.

With the exception of these noted differences, the SSES LAR serves as an applicable precedent for this BFN LAR.

Brunswick (TSTF-564)

The NRC has previously reviewed and approved the adoption of TSTF-564 for Framatome methodologies at BSEP in Reference 34. The precedent is directly applicable because BSEP transitioned to ATRIUM 11 fuel, with ATRIUM 10XM legacy fuel. BSEP and BFN both utilize the ACE critical power correlations for these two fuel types. The MCPR_{95/95} value being incorporated into the BFN TS is identical to the one in the BSEP TS.

4.3 No Significant Hazards Consideration

Pursuant to 10 CFR 50.90, Tennessee Valley Authority (TVA), is submitting a request for an amendment to the Technical Specifications (TS) for the Browns Ferry Nuclear Plant (BFN), Units 1, 2, and 3, Renewed Facility Operating Licenses numbers DPR-33, DPR-52, and DPR-68. The proposed change revises the BFN TS to allow application of Advanced Framatome Methodologies for determining core operating limits in support of loading Framatome fuel type ATRIUM 11.

Additionally, TVA requests adoption of Technical Specification Task Force (TSTF)-564, "Safety Limit MCPR," which is an approved change to the Improved Standard Technical Specifications (ISTS), into the BFN, Units 1, 2, and 3 TS. The proposed change revises the TS safety limit on minimum critical power ratio (SLMCPR). The revised limit calculation method is based on using the Critical Power Ratio (CPR) data statistics and is revised from ensuring that 99.9% of the rods would not be susceptible to boiling transition to ensuring that there is a 95% probability at a 95% confidence level that no rods will be susceptible to transition boiling. A single SLMCPR value will be used instead of two values applicable when one or two recirculation loops are in operation. TS 5.6.5, "Core Operating Limits Report (COLR)," is revised to require the current SLMCPR value to be included in the COLR.

Enclosure

TVA has evaluated whether or not a significant hazards consideration is involved with the proposed amendment(s) by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of amendment," as discussed below:

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

Response: No

Advanced Framatome Methodologies

The probability of an evaluated accident is derived from the probabilities of the individual precursors to that accident. The proposed amendments revise the list of Nuclear Regulatory Commission (NRC)-approved analytical methods used to establish core operating limits. These changes do not require any physical plant modifications, physically affect any plant components, or entail changes in plant operation. Because no individual precursors of an accident are affected, the proposed amendment does not increase the probability of a previously analyzed event.

The consequences of an evaluated accident are determined by the operability of plant systems designed to mitigate those consequences. The proposed amendment revises the list of NRC-approved analytical methods used to establish core operating limits. These changes do not alter the assumptions of accident analyses. Based on the above, the proposed amendment does not increase the consequences of a previously analyzed accident.

TSTF-564

The proposed amendment revises the TS SLMCPR and the list of core operating limits to be included in the COLR. The SLMCPR is not an initiator of any accident previously evaluated. The revised safety limit values continue to ensure for all accidents previously evaluated that the fuel cladding will be protected from failure due to transition boiling. The proposed change does not affect plant operation or any procedural or administrative controls on plant operation that affect the functions of preventing or mitigating any accidents previously evaluated.

Therefore, the proposed amendment does not involve a significant increase in the probability or consequences of an accident previously evaluated.

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

Response: No

Advanced Framatome Methodologies

Creation of the possibility of a new or different kind of accident requires creating one or more new accident precursors. New accident precursors may be created by modifications of plant configuration, including changes in allowable modes of operation. The proposed amendment revises the list of NRC-approved analytical methods used to establish core operating limits. The proposed amendments do not involve any plant configuration modifications or changes to allowable modes of operation thereby ensuring no new or different kind of accident precursors are created.

TSTF-564

The proposed amendment revises the TS SLMCPR and the list of core operating limits to be included in the COLR. The proposed change will not affect the design function or operation of any structures, systems, or components (SSCs). No new equipment will be installed. As a result, the proposed change will not create any credible new failure mechanisms, malfunctions, or accident initiators not considered in the design and licensing bases.

Therefore, the proposed amendment does not create the possibility of a new or different kind of accident from any accident previously evaluated.

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

Response: No

Advanced Framatome Methodologies

The proposed amendment revises the list of NRC-approved analytical methods used to establish core operating limits. The proposed amendment will ensure that the current level of fuel protection is maintained by continuing to ensure that the fuel design safety criteria are met. Therefore, the proposed amendment does not involve a significant reduction in a margin of safety.

TSTF-564

The proposed amendment revises the TS SLMCPR and the list of core operating limits to be included in the COLR. This will result in a change to a safety limit, but will not result in a significant reduction in the margin of safety provided by the safety limit. As discussed in the application, changing the SLMCPR methodology to one based on a 95% probability with 95% confidence that no fuel rods experience transition boiling during an anticipated transient instead of the current limit based on ensuring that 99.9% of the fuel rods are not susceptible to boiling transition does not have a significant effect on plant response to any analyzed accident. The SLMCPR and the TS Limiting Condition for Operation (LCO) on MCPR continue to provide the same level of assurance as the current limits and do not reduce a margin of safety.

Therefore, the proposed amendment does not involve a significant reduction in a margin of safety.

Based on the above, TVA concludes the proposed amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92 (c), and, accordingly, a finding of "no significant hazards consideration" is justified.

4.4 Conclusion

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

5.0 ENVIRONMENTAL CONSIDERATION

A review has determined the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or would change an inspection or surveillance requirement. However, the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluents 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 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.

6.0 REFERENCES

1. NRC letter to TSTF, "Revised Final Safety Evaluation of Technical Specifications Task Force Traveler TSTF-564, Revision 2, 'Safety Limit MCPR,' Using the Consolidated Line Item Improvement Process," dated May 13, 2020 (ML20132A260)
2. ANP-10298PA Revision 0, "ACE/ATRIUM 10XM Critical Power Correlation," AREVA NP Inc., March 2010
3. ANP-3140(P) Revision 0, "Browns Ferry Units 1, 2, and 3 Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation," AREVA NP Inc., August 2012
4. NRC letter to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Issuance of Amendments Regarding Technical Specification (TS) Change TS-478 Addition of Analytical Methodologies to TS 5.6.5 and Revision of TS 2.1.1.2 for Unit 2 (TAC Nos. MF0877, MF0878, and MF0879)," dated July 31, 2014 (ML14108A334)
5. ANP-10298P-A, Revision 1, "ACE/ATRIUM 10XM Critical Power Correlation," AREVA Inc., March 2014
6. ANP-10344P-A Revision 0, "Framatome Best-Estimate Enhanced Option III Methodology," Framatome Inc., March 2021
7. NEDC-33075P-A, "GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density," GE-Hitachi Nuclear Energy Americas LLC, Revision 8, November 2013
8. NRC letter to Duke Energy, "Brunswick Steam Electric Plant, Units 1 and 2 – Issuance of Amendment Nos. 299 and 327 to Revise Technical Specification 5.6.5.b To Allow Application of Advanced Framatome ATRIUM 11 Fuel Methodologies (EPID L-2018-LLA-0273)," dated March 6, 2020 (ML20073F186)
9. NRC letter to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 – Issuance of Amendment Nos. 310, 333, and 293 Regarding Maximum Extended Load Line Limit Analysis Plus (EPID L-2018-LLA-0048)," dated December 26, 2019 (ML19210C308)
10. NRC letter to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Issuance of Amendments Regarding Extended Power Uprate (CAC Nos. MF6741, MF6742, and MF6743)," dated August 14, 2017 (ML17032A120)

Enclosure

11. NRC letter to TVA, "Summary of June 8, 2020, Partially Closed Meeting with Tennessee Valley Authority to Discuss a Planned License Amendment (EPID L-2020-LRM-0023)" dated June 25, 2020 (ML20162A153)
12. NRC letter to Susquehanna Nuclear, LLC, "Susquehanna Steam Electric Station, Units 1 and 2 – Issuance of Amendment Nos. 278 and 260 to Allow Application of Advanced Framatome ATRIUM 11 Fuel Methodologies (EPID L-2019-LLA-0153)," dated January 1, 2021 (ML20168B004)
13. Regulatory Guide (RG) 1.236, "Pressurized-Water Reactor Control Rod Ejection and Boiling-Water Reactor Control Rod Drop Accidents," June 2020
14. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)," Framatome Inc., March 2018
15. EMF-2158(P)(A) Revision 0, "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," Siemens Power Corporation, October 1999
16. ANP-10335P-A, Revision 0, "ACE/ATRIUM 11 Critical Power Correlation," Framatome Inc., May 2018
17. ANF-89-98(P)(A) Revision 1 and Supplement 1, "Generic Mechanical Design Criteria for BWR Designs," Advanced Nuclear Fuels Corporation, dated May 1995
18. EMF-93-177(P)(A) Revision 1, "Mechanical Design for BWR Fuel Channels," Framatome ANP Inc., August 2005
19. EMF-93-177P-A Revision 1, Supplement 1P-A, Revision 0, "Mechanical Design for BWR Fuel Channels Supplement 1: Advanced Methods for New Channel Designs," AREVA NP Inc., September 2013
20. BAW-10247PA, Revision 0, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors," AREVA NP Inc., February 2008
21. ANP-10340P-A Revision 0, "Incorporation of Chromia-Doped Fuel Properties in AREVA Approved Methods", Framatome Inc., May 2018
22. XN-NF-80-19(P)(A) Volume 4 Revision 1, "Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads," Exxon Nuclear Company, April 1986
23. Framatome Letter to NRC, "Informational Transmittal of ANP-2637P, Revision 9, 'Boiling Water Reactor Licensing Compendium'," dated April 30, 2021 (ML21132A051)
24. ANP-10332P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios," Framatome Inc., March 2019
25. ANP-10346P-A Revision 0, "ATWS-I Analysis Methodology for BWRs Using RAMONA5-FA," Framatome Inc., October 2019

Enclosure

26. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)," Framatome Inc., March 2018
27. Draft Regulatory Guide DG-1327, "Pressurized-Water Reactor Control Rod Ejection and Boiling-Water Reactor Control Rod Drop Accidents," July 2019
28. Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," July 2000
29. ANP-10300P-A Revision 1, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios," Framatome Inc., January 2018
30. NEDC-32433P, "Maximum Extended Load Line Limit and ARTS Improvement Program Analyses for Browns Ferry Nuclear Plant Unit 1, 2, and 3," GE Nuclear Energy, April 1995
31. Siemens Power Corporation letter to the NRC Document Control Desk, "Revision to Attachment 1 of Letter NRC:99:030, 'Request for Concurrence on SER Clarifications'," dated October 12, 1999 (ML20217E246)
32. NRC letter to Siemens Power Corporation, "Siemens Power Corporation Re: Request for Concurrence on Safety Evaluation Report Clarifications (TAC No. MA6160)," dated May 31, 2000, (ML003719373)
33. Framatome letter to NRC, "Informational Transmittal of ANP-3653P Revision 0, 'Fuel Design Evaluation for ATRIUM 11 BWR Reload Fuel' and ANP-2637P Revision 7, 'Boiling Water Reactor Licensing Methodology Compendium'," dated September 18, 2018 (ML18264A015)
34. NRC letter to Duke Energy Progress, LLC, "Brunswick Steam Electric Plant, Units 1 and 2 - Issuance of Amendment Nos. 301 and 329 to Revise Technical Specification to Adopt TSTF-564 (EPID L-2020-LLA-0043)," dated September 29, 2020 (ML20269A305)

ATTACHMENT 1

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

Proposed Technical Specifications Changes (Markup)

2.0 SAFETY LIMITS (SLs)

2.1 SLs

2.1.1 Reactor Core SLs

2.1.1.1 With the reactor steam dome pressure < 585 psig or core flow < 10% rated core flow:

THERMAL POWER shall be $\leq 23\%$ RTP.

2.1.1.2 With the reactor steam dome pressure ≥ 585 psig and core flow $\geq 10\%$ rated core flow:

1.05

MCPR shall be ≥ 1.06 for two recirculation loop operation or ≥ 1.08 for single loop operation.

2.1.1.3 Reactor vessel water level shall be greater than the top of active irradiated fuel.

2.1.2 Reactor Coolant System Pressure SL

Reactor steam dome pressure shall be ≤ 1325 psig.

2.2 SL Violations

With any SL violation, the following actions shall be completed within 2 hours:

2.2.1 Restore compliance with all SLs; and

2.2.2 Insert all insertable control rods.

RPS Instrumentation
3.3.1.1

Table 3.3.1.1-1 (page 2 of 3)
Reactor Protection System Instrumentation

FUNCTION	APPLICABLE MODES OR OTHER SPECIFIED CONDITIONS	REQUIRED CHANNELS PER TRIP SYSTEM	CONDITIONS REFERENCED FROM REQUIRED ACTION D.1	SURVEILLANCE REQUIREMENTS	ALLOWABLE VALUE
2. Average Power Range Monitors (continued)					
d. Inop	1,2	3(b)	G	SR 3.3.1.1.16	NA
e. 2-Out-Of-4 Voter	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.14 SR 3.3.1.1.16	NA
f. OPRM Upscale	≥18% ~~(f)~~	3(b)	I	SR 3.3.1.1.1 SR 3.3.1.1.7 SR 3.3.1.1.13 SR 3.3.1.1.16	NA
3. Reactor Vessel Steam Dome Pressure - High ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.10 SR 3.3.1.1.14	≤ 1090 psig
4. Reactor Vessel Water Level - Low, Level 3 ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≥ 528 inches above vessel zero
5. Main Steam Isolation Valve - Closure	1	8	F	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 10% closed
6. High Drywell Pressure	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 2.5 psig
7. Scram Discharge Volume Water Level - High					
a. Resistance Temperature Detector	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons
	5(a)	2	H	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons

(continued)

(a) With any control rod withdrawn from a core cell containing one or more fuel assemblies.

(b) Each APRM channel provides inputs to both trip systems.

(d) During instrument calibrations, if the As Found channel setpoint is conservative with respect to the Allowable Value but outside its acceptable As Found band as defined by its associated Surveillance Requirement procedure, then there shall be an initial determination to ensure confidence that the channel can perform as required before returning the channel to service in accordance with the Surveillance. If the As Found instrument channel setpoint is not conservative with respect to the Allowable Value, the channel shall be declared inoperable. Prior to returning a channel to service, the instrument channel setpoint shall be calibrated to a value that is within the acceptable As Left tolerance of the setpoint; otherwise, the channel shall be declared inoperable.

The nominal Trip Setpoint shall be specified on design output documentation which is incorporated by reference in the Updated Final Safety Analysis Report. The methodology used to determine the nominal Trip Setpoint, the predefined As Found Tolerance, and the As Left Tolerance band, and a listing of the setpoint design output documentation shall be specified in Chapter 7 of the Updated Final Safety Analysis Report.

~~(f) Following Detect and Suppress Solution - Confirmation Density (DSS-CD) implementation, DSS-CD is not required to be armed while in the DSS-CD Armed Region during the first reactor startup and during the first controlled shutdown that passes completely through the DSS-CD Armed Region. However, DSS-CD is considered OPERABLE and shall be maintained OPERABLE and capable of automatically arming for operation at recirculation drive flow rates above the DSS-CD Armed Region.~~

5.6 Reporting Requirements (continued)

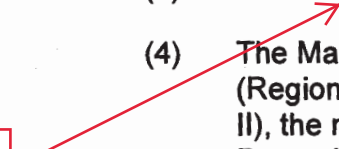
5.6.4 (Deleted).

5.6.5 CORE OPERATING LIMITS REPORT (COLR)

a. Core operating limits shall be established prior to each reload cycle, or prior to any remaining portion of a reload cycle, and shall be documented in the COLR for the following:

- (1) The APLHGRs for Specification 3.2.1;
- (2) The LHGR for Specification 3.2.3;
- (3) ~~The MCPR Operating Limits~~ for Specification 3.2.2;
- (4) The Manual Backup Stability Protection (BSP) Scram Region (Region I), the Manual BSP Controlled Entry Region (Region II), the modified APRM Flow Biased Simulated Thermal Power-High Scram setpoints used in the Automated BSP Scram Region, and the BSP Boundary for Specification 3.3.1.1; and
- (5) The RBM setpoints and applicable reactor thermal power ranges for each of the setpoints for Specification 3.3.2.1, Table 3.3.2.1-1.

MINIMUM
CRITICAL POWER
RATIO (MCPR)
and MCPR_{99.9%}



b. The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC, specifically those described in the following documents:

1. ~~NEDE-24011-P-A, Revision 16, General Electric Standard Application for Reactor Fuel, October 2007.~~  Deleted.
2. XN-NF-81-58(P)(A) Revision 2 and Supplements 1 and 2, RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model, Exxon Nuclear Company, March 1984.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

10. ~~XN-NF-84-105(P)(A) Volume 1 and Volume 1 Supplements 1 and 2, XCOBRA T: A Computer Code for BWR Transient Thermal-Hydraulic Core Analysis, Exxon Nuclear Company, February 1987.~~ Deleted.
11. ANF-10307PA Revision 0, AREVA MCPR Safety Limit Methodology for Boiling Water Reactors, AREVA NP, June 2011.
12. ~~ANF-913(P)(A) Volume 1 Revision 1 and Volume 1 Supplements 2, 3 and 4, COTRANSA2: A Computer Program for Boiling Water Reactor Transient Analyses, Advanced Nuclear Fuels Corporation, August 1990.~~ Deleted.
13. ANF-1358(P)(A) Revision 3, The Loss of Feedwater Heating Transient in Boiling Water Reactors, Framatome ANP, September 2005.
14. EMF-2209(P)(A) Revision 3, SPCB Critical Power Correlation, AREVA NP, September 2009.
15. EMF-2245(P)(A) Revision 0, Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel, Siemens Power Corporation, August 2000.
16. EMF-2361(P)(A) Revision 0, EXEM BWR-2000 ECCS Evaluation Model, Framatome ANP Inc., May 2001 as supplemented by the site-specific approval in NRC safety evaluations dated April 27, 2012, and July 31, 2014.
17. EMF-2292(P)(A) Revision 0, ATRIUM™-10: Appendix K Spray Heat Transfer Coefficients, Siemens Power Corporation, September 2000.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

18. EMF-CC-074(P)(A), Volume 4, Revision 0, BWR Stability Analysis: Assessment of STAIF with Input from MICROBURN-B2, Siemens Power Corporation, August 2000.
19. ~~BAW-10255(P)(A), Revision 2, Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code, AREVA NP, May 2008.~~ ← Deleted.
20. BAW-10247PA Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors, AREVA NP, February 2008. Revision 1
21. ANP-10298PA Revision 0, ACE/ATRIUM 10XM Critical Power Correlation, AREVA NP, March 2010. ← 2014
Inc.
22. ~~ANP-3140(P) Revision 0, Browns Ferry Units 1, 2, and 3 Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation, AREVA NP, August 2012.~~ ← Deleted.
23. NEDC-33075P-A, GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density, Revision 8, November 2013.

Insert A →

(continued)

Insert A

24. BAW-10247P-A Supplement 2P-A Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods, Framatome Inc., August 2018.
25. ANP-10300P-A Revision 1, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios, Framatome Inc., January 2018.
26. ANP-10332P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios, Framatome Inc., March 2019.
27. ANP-10333P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA), Framatome Inc., March 2018 (as supplemented by Section 6.4 of ANP-3908P Revision 3, Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel, Framatome Inc., July 2021).
28. ANP-10335P-A Revision 0, ACE/ATRIUM 11 Critical Power Correlation, Framatome Inc., May 2018.
29. ANP-10340P-A Revision 0, Incorporation of Chromia-Doped Fuel Properties in AREVA Approved Methods, Framatome Inc., May 2018.
30. ANP-3907P Revision 0, Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry, Framatome Inc., April 2021.

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2.1 SLs

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2.1.2 Reactor Coolant System Pressure SL

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(continued)

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5.6 Reporting Requirements (continued)

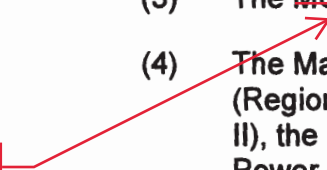
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- (2) The LHGR for Specification 3.2.3;
- (3) ~~The MCPR Operating Limits for Specification 3.2.2;~~
- (4) The Manual Backup Stability Protection (BSP) Scram Region (Region I), the Manual BSP Controlled Entry Region (Region II), the modified APRM Flow Biased Simulated Thermal Power-High Scram setpoints used in the Automated BSP Scram Region, and the BSP Boundary for Specification 3.3.1.1; and
- (5) The RBM setpoints and applicable reactor thermal power ranges for each of the setpoints for Specification 3.3.2.1, Table 3.3.2.1-1.

MINIMUM
CRITICAL POWER
RATIO (MCPR)
and MCPR_{99.9%}



b. The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC, specifically those described in the following documents:

1. XN-NF-81-58(P)(A) Revision 2 and Supplements 1 and 2, RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model, Exxon Nuclear Company, March 1984.
2. XN-NF-85-67(P)(A) Revision 1, Generic Mechanical Design for Exxon Nuclear Jet Pump BWR Reload Fuel, Exxon Nuclear Company, September 1986.
3. EMF-85-74(P) Revision 0 Supplement 1(P)(A) and Supplement 2 (P)(A), RODEX2A (BWR) Fuel Rod Thermal-Mechanical Evaluation Model, Siemens Power Corporation, February 1998.

(continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

5.6 Reporting Requirements (continued)

4. ANF-89-98(P)(A) Revision 1 and Supplement 1, Generic Mechanical Design Criteria for BWR Fuel Designs, Advanced Nuclear Fuels Corporation, May 1995.
5. XN-NF-80-19(P)(A) Volume 1 and Supplements 1 and 2, Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis, Exxon Nuclear Company, March 1983.
6. XN-NF-80-19(P)(A) Volume 4 Revision 1, Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads, Exxon Nuclear Company, June 1986.
7. EMF-2158(P)(A) Revision 0, Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURNB2, Siemens Power Corporation, October 1999.
8. XN-NF-80-19(P)(A) Volume 3 Revision 2, Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description, Exxon Nuclear Company, January 1987.
9. ~~XN-NF-84-105(P)(A) Volume 1 and Volume 1 Supplements 1 and 2, XCOBRA T: A Computer Code for BWR Transient Thermal Hydraulic Core Analysis, Exxon Nuclear Company, February 1987.~~ Deleted.
10. ANP-10307PA Revision 0, AREVA MCPR Safety Limit Methodology for Boiling Water Reactors, AREVA NP, June 2011.
11. ~~ANF-913(P)(A) Volume 1 Revision 1 and Volume 1 Supplements 2, 3 and 4, COTRANSA2: A Computer Program for Boiling Water Reactor Transient Analyses, Advanced Nuclear Fuels Corporation, August 1990.~~ Deleted.
12. ANF-1358(P)(A) Revision 3, The Loss of Feedwater Heating Transient in Boiling Water Reactors, Framatome ANP, September 2005.
13. EMF-2209(P)(A) Revision 3, SPCB Critical Power Correlation, AREVA NP, September 2009.

(continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

5.6 Reporting Requirements (continued)

14. EMF-2245(P)(A) Revision 0, Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel, Siemens Power Corporation, August 2000.
15. EMF-2361(P)(A) Revision 0, EXEM BWR-2000 ECCS Evaluation Model, Framatome ANP Inc., May 2001 as supplemented by the site-specific approval in NRC safety evaluation dated February 15, 2013, and July 31, 2014.
16. EMF-2292(P)(A) Revision 0, ATRIUM™-10: Appendix K Spray Heat Transfer Coefficients, Siemens Power Corporation, September 2000.
17. EMF-CC-074(P)(A), Volume 4, Revision 0, BWR Stability Analysis: Assessment of STAIF with Input from MICROBURN-B2, Siemens Power Corporation, August 2000.
18. ~~BAW-10255(P)(A), Revision 2, Cycle Specific DIVOM Methodology Using the RAMONA5-FA Code, AREVA NP, May 2008.~~ Deleted.
19. BAW-10247PA Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors, AREVA NP, February 2008.
20. ANP-10298PA Revision 0, ACE/ATRIUM 10XM Critical Power Correlation, AREVA NP, March 2010. 2014
21. ~~ANP-3140(P) Revision 0, Browns Ferry Units 1, 2, and 3 Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation, AREVA NP, August 2012.~~ Deleted.
22. NEDC-33075P-A, GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density, Revision 8, November 2013.

INSERT A

(continued)

Insert A

23. BAW-10247P-A Supplement 2P-A Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods, Framatome Inc., August 2018.
24. ANP-10300P-A Revision 1, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios, Framatome Inc., January 2018.
25. ANP-10332P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios, Framatome Inc., March 2019.
26. ANP-10333P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA), Framatome Inc., March 2018 (as supplemented by Section 6.4 of ANP-3908P Revision 3, Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel, Framatome Inc., July 2021).
27. ANP-10335P-A Revision 0, ACE/ATRIUM 11 Critical Power Correlation, Framatome Inc., May 2018.
28. ANP-10340P-A Revision 0, Incorporation of Chromia-Doped Fuel Properties in AREVA Approved Methods, Framatome Inc., May 2018.
29. ANP-3907P Revision 0, Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry, Framatome Inc., April 2021.

2.0 SAFETY LIMITS (SLs)

2.1 SLs

2.1.1 Reactor Core SLs

- 2.1.1.1 With the reactor steam dome pressure < 585 psig or core flow < 10% rated core flow:

THERMAL POWER shall be $\leq 23\%$ RTP.

- 2.1.1.2 With the reactor steam dome pressure ≥ 585 psig and core flow $\geq 10\%$ rated core flow:

MCPR shall be ≥ 1.05 for two recirculation loop operation or ≥ 1.08 for single loop operation.

- 2.1.1.3 Reactor vessel water level shall be greater than the top of active irradiated fuel.

2.1.2 Reactor Coolant System Pressure SL

Reactor steam dome pressure shall be ≤ 1325 psig.

2.2 SL Violations

With any SL violation, the following actions shall be completed within 2 hours:

- 2.2.1 Restore compliance with all SLs; and
2.2.2 Insert all insertable control rods.
-

Table 3.3.1.1-1 (page 2 of 3)
Reactor Protection System Instrumentation

FUNCTION	APPLICABLE MODES OR OTHER SPECIFIED CONDITIONS	REQUIRED CHANNELS PER TRIP SYSTEM	CONDITIONS REFERENCED FROM REQUIRED ACTION D.1.	SURVEILLANCE REQUIREMENTS	ALLOWABLE VALUE
2. Average Power Range Monitors (continued)					
d. Inop	1,2	3(b)	G	SR 3.3.1.1.16	NA
e. 2-Out-Of-4 Voter	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.14 SR 3.3.1.1.16	NA
f. OPRM Upscale	≥18% ^(f)	3(b)	I	SR 3.3.1.1.1 SR 3.3.1.1.7 SR 3.3.1.1.13 SR 3.3.1.1.16	NA
3. Reactor Vessel Steam Dome Pressure - High ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.10 SR 3.3.1.1.14	≤ 1090 psig
4. Reactor Vessel Water Level - Low, Level 3 ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≥ 528 inches above vessel zero
5. Main Steam Isolation Valve - Closure	1	8	F	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 10% closed
6. Drywell Pressure - High	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 2.5 psig
7. Scram Discharge Volume Water Level - High					
a. Resistance Temperature Detector	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons
	5(a)	2	H	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons

(continued)

(a) With any control rod withdrawn from a core cell containing one or more fuel assemblies.

(b) Each APRM channel provides inputs to both trip systems.

(d) During instrument calibrations, if the As Found channel setpoint is conservative with respect to the Allowable Value but outside its acceptable As Found band as defined by its associated Surveillance Requirement procedure, then there shall be an initial determination to ensure confidence that the channel can perform as required before returning the channel to service in accordance with the Surveillance. If the As Found instrument channel setpoint is not conservative with respect to the Allowable Value, the channel shall be declared inoperable. Prior to returning a channel to service, the instrument channel setpoint shall be calibrated to a value that is within the acceptable As Left tolerance of the setpoint; otherwise, the channel shall be declared inoperable. The nominal Trip Setpoint shall be specified on design output documentation which is incorporated by reference in the Updated Final Safety Analysis Report. The methodology used to determine the nominal Trip Setpoint, the predefined As Found Tolerance, and the As Left Tolerance band, and a listing of the setpoint design output documentation shall be specified in Chapter 7 of the Updated Final Safety Analysis Report.

~~(f) Following Detect and Suppress Solution - Confirmation Density (DSS-CD) implementation, DSS-CD is not required to be armed while in the DSS-CD Armed Region during the first reactor startup and during the first controlled shutdown that passes completely through the DSS-CD Armed Region. However, DSS-CD is considered OPERABLE and shall be maintained OPERABLE and capable of automatically arming for operation at recirculation drive flow rates above the DSS-CD Armed Region.~~

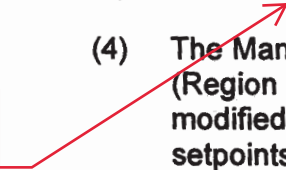
5.6 Reporting Requirements (continued)

5.6.4 (Deleted).

5.6.5 CORE OPERATING LIMITS REPORT (COLR)

- a. Core operating limits shall be established prior to each reload cycle, or prior to any remaining portion of a reload cycle, and shall be documented in the COLR for the following:
- (1) The APLHGRs for Specification 3.2.1;
 - (2) The LHGR for Specification 3.2.3;
 - (3) ~~The MCPR Operating Limits~~ for Specification 3.2.2;
 - (4) The Manual Backup Stability Protection (BSP) Scram Region (Region I), the Manual BSP Controlled Entry Region (Region II), the modified APRM Flow Biased Simulated Thermal Power-High Scram setpoints used in the Automated BSP Scram Region, and the BSP Boundary for Specification 3.3.1.1; and
 - (5) The RBM setpoints and applicable reactor thermal power ranges for each of the setpoints for Specification 3.3.2.1, Table 3.3.2.1-1.
- b. The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC, specifically those described in the following documents:
1. XN-NF-81-58(P)(A) Revision 2 and Supplements 1 and 2, RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model, Exxon Nuclear Company, March 1984.
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 3. EMF-85-74(P) Revision 0 Supplement 1(P)(A) and Supplement 2 (P)(A), RODEX2A (BWR) Fuel Rod Thermal-Mechanical Evaluation Model, Siemens Power Corporation, February 1998.

MINIMUM
CRITICAL POWER
RATIO (MCPR)
and MCPR_{99.9%}



(continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

5.6 Reporting Requirements (continued)

4. ANF-89-98(P)(A) Revision 1 and Supplement 1, Generic Mechanical Design Criteria for BWR Fuel Designs, Advanced Nuclear Fuels Corporation, May 1995.
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7. EMF-2158(P)(A) Revision 0, Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURNB2, Siemens Power Corporation, October 1999.
8. XN-NF-80-19(P)(A) Volume 3 Revision 2, Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description, Exxon Nuclear Company, January 1987.
9. ~~XN-NF-84-105(P)(A) Volume 1 and Volume 1 Supplements 1 and 2, XCOBRA T: A Computer Code for BWR Transient Thermal-Hydraulic Core Analysis, Exxon Nuclear Company, February 1987.~~
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(continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

5.6 Reporting Requirements (continued)

12. ANF-1358(P)(A) Revision 3, The Loss of Feedwater Heating Transient in Boiling Water Reactors, Framatome ANP, September 2005.
13. EMF-2209(P)(A) Revision 3, SPCB Critical Power Correlation, AREVA NP, September 2009.
14. EMF-2245(P)(A) Revision 0, Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel, Siemens Power Corporation, August 2000.
15. EMF-2361(P)(A) Revision 0, EXEM BWR-2000 ECCS Evaluation Model, Framatome ANP Inc., May 2001 as supplemented by the site-specific approval in NRC safety evaluations dated February 15, 2013, and July 31, 2014.
16. EMF-2292(P)(A) Revision 0, ATRIUM™-10: Appendix K Spray Heat Transfer Coefficients, Siemens Power Corporation, September 2000.
17. EMF-CC-074(P)(A), Volume 4, Revision 0, BWR Stability Analysis: Assessment of STAIF with Input from MICROBURN-B2, Siemens Power Corporation, August 2000.
18. ~~BAW-10255(P)(A), Revision 2, Cycle Specific DIVOM Methodology Using the RAMONA5-FA Code, AREVA NP, May 2008.~~ Deleted.
19. BAW-10247PA Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors, AREVA NP, February 2008.
20. ANP-10298PA Revision 0, ACE/ATRIUM 10XM Critical Power Correlation, AREVA NP, March 2010. Inc. Revision 1 2014
21. ~~ANP-3140(P) Revision 0, Browns Ferry Units 1, 2, and 3 Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation, AREVA NP, August 2012.~~ Deleted.
22. NEDC-33075P-A, GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density, Revision 8, November 2013.

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23. BAW-10247P-A Supplement 2P-A Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods, Framatome Inc., August 2018.
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27. ANP-10335P-A Revision 0, ACE/ATRIUM 11 Critical Power Correlation, Framatome Inc., May 2018.
28. ANP-10340P-A Revision 0, Incorporation of Chromia-Doped Fuel Properties in AREVA Approved Methods, Framatome Inc., May 2018.
29. ANP-3907P Revision 0, Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry, Framatome Inc., April 2021.

5.6 Reporting Requirements (continued)

~~21. ANP 3140(P) Revision 0, Browns Ferry Units 1, 2, and 3 Improved
K factor Model for ACE/ATRIUM 10XM Critical Power Correlation,
AREVA NP, August 2012.~~

(continued)

BFN-UNIT 3

5.0-24c

Amendment No. 212, 226,
245, 250, 268, 270

ATTACHMENT 2

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

Retyped Proposed Technical Specifications Pages

2.0 SAFETY LIMITS (SLs)

2.1 SLs

2.1.1 Reactor Core SLs

2.1.1.1 With the reactor steam dome pressure < 585 psig or core flow < 10% rated core flow:

THERMAL POWER shall be $\leq$ 23% RTP.

2.1.1.2 With the reactor steam dome pressure $\geq$ 585 psig and core flow $\geq$ 10% rated core flow:

MCPR shall be $\geq$ 1.05.

2.1.1.3 Reactor vessel water level shall be greater than the top of active irradiated fuel.

2.1.2 Reactor Coolant System Pressure SL

Reactor steam dome pressure shall be $\leq$ 1325 psig.

2.2 SL Violations

With any SL violation, the following actions shall be completed within 2 hours:

2.2.1 Restore compliance with all SLs; and

2.2.2 Insert all insertable control rods.

Table 3.3.1.1-1 (page 2 of 3)
Reactor Protection System Instrumentation

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2. Average Power Range Monitors (continued)					
d. Inop	1,2	3(b)	G	SR 3.3.1.1.16	NA
e. 2-Out-Of-4 Voter	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.14 SR 3.3.1.1.16	NA
f. OPRM Upscale	≥ 18%	3(b)	I	SR 3.3.1.1.1 SR 3.3.1.1.7 SR 3.3.1.1.13 SR 3.3.1.1.16	NA
3. Reactor Vessel Steam Dome Pressure - High ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.10 SR 3.3.1.1.14	≤ 1090 psig
4. Reactor Vessel Water Level - Low, Level 3 ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≥ 528 inches above vessel zero
5. Main Steam Isolation Valve - Closure	1	8	F	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 10% closed
6. High Drywell Pressure	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 2.5 psig
7. Scram Discharge Volume Water Level - High					
a. Resistance Temperature Detector	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons
	5(a)	2	H	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons

(continued)

(a) With any control rod withdrawn from a core cell containing one or more fuel assemblies.

(b) Each APRM channel provides inputs to both trip systems.

(d) During instrument calibrations, if the As Found channel setpoint is conservative with respect to the Allowable Value but outside its acceptable As Found band as defined by its associated Surveillance Requirement procedure, then there shall be an initial determination to ensure confidence that the channel can perform as required before returning the channel to service in accordance with the Surveillance. If the As Found instrument channel setpoint is not conservative with respect to the Allowable Value, the channel shall be declared inoperable.

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The nominal Trip Setpoint shall be specified on design output documentation which is incorporated by reference in the Updated Final Safety Analysis Report. The methodology used to determine the nominal Trip Setpoint, the predefined As Found Tolerance, and the As Left Tolerance band, and a listing of the setpoint design output documentation shall be specified in Chapter 7 of the Updated Final Safety Analysis Report.

5.6 Reporting Requirements (continued)

5.6.4 (Deleted).

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- a. Core operating limits shall be established prior to each reload cycle, or prior to any remaining portion of a reload cycle, and shall be documented in the COLR for the following:
 - (1) The APLHGRs for Specification 3.2.1;
 - (2) The LHGR for Specification 3.2.3;
 - (3) The MINIMUM CRITICAL POWER RATIO (MCPR) and MCPR_{99.9%} for Specification 3.2.2;
 - (4) The Manual Backup Stability Protection (BSP) Scram Region (Region I), the Manual BSP Controlled Entry Region (Region II), the modified APRM Flow Biased Simulated Thermal Power-High Scram setpoints used in the Automated BSP Scram Region, and the BSP Boundary for Specification 3.3.1.1; and
 - (5) The RBM setpoints and applicable reactor thermal power ranges for each of the setpoints for Specification 3.3.2.1, Table 3.3.2.1-1.
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(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

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10. (Deleted).

(continued)

5.6 Reporting Requirements (continued)

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11. ANP-10307PA Revision 0, AREVA MCPR Safety Limit Methodology for Boiling Water Reactors, AREVA NP, June 2011.
12. (Deleted).
13. ANF-1358(P)(A) Revision 3, The Loss of Feedwater Heating Transient in Boiling Water Reactors, Framatome ANP, September 2005.
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20. BAW-10247PA Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors, AREVA NP, February 2008.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

21. ANP-10298P-A Revision 1, ACE/ATRIUM 10XM Critical Power Correlation, AREVA Inc., March 2014.
22. (Deleted).
23. NEDC-33075P-A, GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density, Revision 8, November 2013.
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THERMAL POWER shall be $\leq$ 23% RTP.

2.1.1.2 With the reactor steam dome pressure $\geq$ 585 psig and core flow $\geq$ 10% rated core flow:

MCPR shall be $\geq$ 1.05.

2.1.1.3 Reactor vessel water level shall be greater than the top of active irradiated fuel.

2.1.2 Reactor Coolant System Pressure SL

Reactor steam dome pressure shall be $\leq$ 1325 psig.

2.2 SL Violations

With any SL violation, the following actions shall be completed within 2 hours:

2.2.1 Restore compliance with all SLs; and

2.2.2 Insert all insertable control rods.

Table 3.3.1.1-1 (page 2 of 3)
Reactor Protection System Instrumentation

FUNCTION	APPLICABLE MODES OR OTHER SPECIFIED CONDITIONS	REQUIRED CHANNELS PER TRIP SYSTEM	CONDITIONS REFERENCED FROM REQUIRED ACTION D.1	SURVEILLANCE REQUIREMENTS	ALLOWABLE VALUE
2. Average Power Range Monitors (continued)					
d. Inop	1,2	3(b)	G	SR 3.3.1.1.16	NA
e. 2-Out-Of-4 Voter	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.14 SR 3.3.1.1.16	NA
f. OPRM Upscale	≥ 18%	3(b)	I	SR 3.3.1.1.1 SR 3.3.1.1.7 SR 3.3.1.1.13 SR 3.3.1.1.16	NA
3. Reactor Vessel Steam Dome Pressure - High ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.10 SR 3.3.1.1.14	≤ 1090 psig
4. Reactor Vessel Water Level - Low, Level 3 ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≥ 528 inches above vessel zero
5. Main Steam Isolation Valve - Closure	1	8	F	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 10% closed
6. Drywell Pressure - High	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 2.5 psig
7. Scram Discharge Volume Water Level - High					
a. Resistance Temperature Detector	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons
	5(a)	2	H	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons

(continued)

(a) With any control rod withdrawn from a core cell containing one or more fuel assemblies.

(b) Each APRM channel provides inputs to both trip systems.

(d) During instrument calibrations, if the As Found channel setpoint is conservative with respect to the Allowable Value but outside its acceptable As Found band as defined by its associated Surveillance Requirement procedure, then there shall be an initial determination to ensure confidence that the channel can perform as required before returning the channel to service in accordance with the Surveillance. If the As Found instrument channel setpoint is not conservative with respect to the Allowable Value, the channel shall be declared inoperable.

Prior to returning a channel to service, the instrument channel setpoint shall be calibrated to a value that is within the acceptable As Left tolerance of the setpoint; otherwise, the channel shall be declared inoperable.

The nominal Trip Setpoint shall be specified on design output documentation which is incorporated by reference in the Updated Final Safety Analysis Report. The methodology used to determine the nominal Trip Setpoint, the predefined As Found Tolerance, and the As Left Tolerance band, and a listing of the setpoint design output documentation shall be specified in Chapter 7 of the Updated Final Safety Analysis Report.

5.6 Reporting Requirements (continued)

5.6.4 (Deleted).

5.6.5 CORE OPERATING LIMITS REPORT (COLR)

- a. Core operating limits shall be established prior to each reload cycle, or prior to any remaining portion of a reload cycle, and shall be documented in the COLR for the following:
 - (1) The APLHGRs for Specification 3.2.1;
 - (2) The LHGR for Specification 3.2.3;
 - (3) The MINIMUM CRITICAL POWER RATIO (MCPR) and MCPR_{99.9%} for Specification 3.2.2;
 - (4) The Manual Backup Stability Protection (BSP) Scram Region (Region I), the Manual BSP Controlled Entry Region (Region II), the modified APRM Flow Biased Simulated Thermal Power-High Scram setpoints used in the Automated BSP Scram Region, and the BSP Boundary for Specification 3.3.1.1; and
 - (5) The RBM setpoints and applicable reactor thermal power ranges for each of the setpoints for Specification 3.3.2.1, Table 3.3.2.1-1.
- b. The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC, specifically those described in the following documents:
 - 1. XN-NF-81-58(P)(A) Revision 2 and Supplements 1 and 2, RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model, Exxon Nuclear Company, March 1984.
 - 2. XN-NF-85-67(P)(A) Revision 1, Generic Mechanical Design for Exxon Nuclear Jet Pump BWR Reload Fuel, Exxon Nuclear Company, September 1986.
 - 3. EMF-85-74(P) Revision 0 Supplement 1(P)(A) and Supplement 2 (P)(A), RODEX2A (BWR) Fuel Rod Thermal-Mechanical Evaluation Model, Siemens Power Corporation, February 1998.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

4. ANF-89-98(P)(A) Revision 1 and Supplement 1, Generic Mechanical Design Criteria for BWR Fuel Designs, Advanced Nuclear Fuels Corporation, May 1995.
5. XN-NF-80-19(P)(A) Volume 1 and Supplements 1 and 2, Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis, Exxon Nuclear Company, March 1983.
6. XN-NF-80-19(P)(A) Volume 4 Revision 1, Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads, Exxon Nuclear Company, June 1986.
7. EMF-2158(P)(A) Revision 0, Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2, Siemens Power Corporation, October 1999.
8. XN-NF-80-19(P)(A) Volume 3 Revision 2, Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description, Exxon Nuclear Company, January 1987.
9. (Deleted.)
10. ANP-10307PA Revision 0, AREVA MCPR Safety Limit Methodology for Boiling Water Reactors, AREVA NP, June 2011.
11. (Deleted).
12. ANF-1358(P)(A) Revision 3, The Loss of Feedwater Heating Transient in Boiling Water Reactors, Framatome ANP, September 2005.
13. EMF-2209(P)(A) Revision 3, SPCB Critical Power Correlation, AREVA NP, September 2009.
14. EMF-2245(P)(A) Revision 0, Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel, Siemens Power Corporation, August 2000.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

15. EMF-2361(P)(A) Revision 0, EXEM BWR-2000 ECCS Evaluation Model, Framatome ANP Inc., May 2001 as supplemented by the site-specific approval in NRC safety evaluation dated February 15, 2013 and July 31, 2014.
16. EMF-2292(P)(A) Revision 0, ATRIUM™-10: Appendix K Spray Heat Transfer Coefficients, Siemens Power Corporation, September 2000.
17. EMF-CC-074(P)(A), Volume 4, Revision 0, BWR Stability Analysis: Assessment of STAIF with Input from MICROBURN-B2, Siemens Power Corporation, August 2000.
18. (Deleted.)
19. BAW-10247PA Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors, AREVA NP, February 2008.
20. ANP-10298P-A Revision 1, ACE/ATRIUM 10XM Critical Power Correlation, AREVA Inc., March 2014.
21. (Deleted.)
22. NEDC-33075P-A, GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density, Revision 8, November 2013.
23. BAW-10247P-A Supplement 2P-A Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods, Framatome Inc., August 2018.
24. ANP-10300P-A Revision 1, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios, Framatome Inc., January, 2018.
25. ANP-10332P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios, Framatome Inc., March 2019.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

26. ANP-10333P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA), Framatome Inc., March 2018 (as supplemented by Section 6.4 of ANP-3908P Revision 3, Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel, Framatome Inc., July 2021).
27. ANP-10335P-A Revision 0, ACE/ATRIUM 11 Critical Power Correlation, Framatome Inc., May 2018.
28. ANP-10340P-A Revision 0, Incorporation of Chromia Doped Fuel Properties in AREVA Approved Methods, Framatome Inc., May 2018.
29. ANP-3907P Revision 0, Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry, Framatome Inc., April 2021.

2.0 SAFETY LIMITS (SLs)

2.1 SLs

2.1.1 Reactor Core SLs

2.1.1.1 With the reactor steam dome pressure < 585 psig or core flow < 10% rated core flow:

THERMAL POWER shall be $\leq$ 23% RTP.

2.1.1.2 With the reactor steam dome pressure $\geq$ 585 psig and core flow $\geq$ 10% rated core flow:

MCPR shall be $\geq$ 1.05.

2.1.1.3 Reactor vessel water level shall be greater than the top of active irradiated fuel.

2.1.2 Reactor Coolant System Pressure SL

Reactor steam dome pressure shall be $\leq$ 1325 psig.

2.2 SL Violations

With any SL violation, the following actions shall be completed within 2 hours:

2.2.1 Restore compliance with all SLs; and

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Table 3.3.1.1-1 (page 2 of 3)
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2. Average Power Range Monitors (continued)					
d. Inop	1,2	3(b)	G	SR 3.3.1.1.16	NA
e. 2-Out-Of-4 Voter	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.14 SR 3.3.1.1.16	NA
f. OPRM Upscale	≥ 18%	3(b)	I	SR 3.3.1.1.1 SR 3.3.1.1.7 SR 3.3.1.1.13 SR 3.3.1.1.16	NA ^(e)
3. Reactor Vessel Steam Dome Pressure - High ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.10 SR 3.3.1.1.14	≤ 1090 psig
4. Reactor Vessel Water Level - Low, Level 3 ^(d)	1,2	2	G	SR 3.3.1.1.1 SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≥ 528 inches above vessel zero
5. Main Steam Isolation Valve - Closure	1	8	F	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 10% closed
6. Drywell Pressure - High	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 2.5 psig
7. Scram Discharge Volume Water Level - High					
a. Resistance Temperature Detector	1,2	2	G	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons
	5(a)	2	H	SR 3.3.1.1.4 SR 3.3.1.1.13 SR 3.3.1.1.14	≤ 50 gallons

(continued)

(a) With any control rod withdrawn from a core cell containing one or more fuel assemblies.

(b) Each APRM channel provides inputs to both trip systems.

(d) During instrument calibrations, if the As Found channel setpoint is conservative with respect to the Allowable Value but outside its acceptable As Found band as defined by its associated Surveillance Requirement procedure, then there shall be an initial determination to ensure confidence that the channel can perform as required before returning the channel to service in accordance with the Surveillance. If the As Found instrument channel setpoint is not conservative with respect to the Allowable Value, the channel shall be declared inoperable.

Prior to returning a channel to service, the instrument channel setpoint shall be calibrated to a value that is within the acceptable As Left tolerance of the setpoint; otherwise, the channel shall be declared inoperable.

The nominal Trip Setpoint shall be specified on design output documentation which is incorporated by reference in the Updated Final Safety Analysis Report. The methodology used to determine the nominal Trip Setpoint, the predefined As Found Tolerance, and the As Left Tolerance band, and a listing of the setpoint design output documentation shall be specified in Chapter 7 of the Updated Final Safety Analysis Report.

5.6 Reporting Requirements (continued)

5.6.4 (Deleted).

5.6.5 CORE OPERATING LIMITS REPORT (COLR)

- a. Core operating limits shall be established prior to each reload cycle, or prior to any remaining portion of a reload cycle, and shall be documented in the COLR for the following:
 - (1) The APLHGRs for Specification 3.2.1;
 - (2) The LHGR for Specification 3.2.3;
 - (3) The MINIMUM CRITICAL POWER RATIO (MCPR) and MCPR_{99.9%} for Specification 3.2.2;
 - (4) The Manual Backup Stability Protection (BSP) Scram Region (Region I), the Manual BSP Controlled Entry Region (Region II), the modified APRM Flow Biased Simulated Thermal Power-High Scram setpoints used in the Automated BSP Scram Region, and the BSP Boundary for Specification 3.3.1.1; and
 - (5) The RBM setpoints and applicable reactor thermal power ranges for each of the setpoints for Specification 3.3.2.1, Table 3.3.2.1-1.
- b. The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC, specifically those described in the following documents:
 1. XN-NF-81-58(P)(A) Revision 2 and Supplements 1 and 2, RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model, Exxon Nuclear Company, March 1984.
 2. XN-NF-85-67(P)(A) Revision 1, Generic Mechanical Design for Exxon Nuclear Jet Pump BWR Reload Fuel, Exxon Nuclear Company, September 1986.
 3. EMF-85-74(P) Revision 0 Supplement 1(P)(A) and Supplement 2 (P)(A), RODEX2A (BWR) Fuel Rod Thermal-Mechanical Evaluation Model, Siemens Power Corporation, February 1998.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

4. ANF-89-98(P)(A) Revision 1 and Supplement 1, Generic Mechanical Design Criteria for BWR Fuel Designs, Advanced Nuclear Fuels Corporation, May 1995.
5. XN-NF-80-19(P)(A) Volume 1 and Supplements 1 and 2, Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis, Exxon Nuclear Company, March 1983.
6. XN-NF-80-19(P)(A) Volume 4 Revision 1, Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads, Exxon Nuclear Company, June 1986.
7. EMF-2158(P)(A) Revision 0, Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2, Siemens Power Corporation, October 1999.
8. XN-NF-80-19(P)(A) Volume 3 Revision 2, Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description, Exxon Nuclear Company, January 1987.
9. (Deleted).
10. ANP-10307PA Revision 0, AREVA MCPR Safety Limit Methodology for Boiling Water Reactors, AREVA NP, June 2011.
11. (Deleted).
12. ANF-1358(P)(A) Revision 3, The Loss of Feedwater Heating Transient in Boiling Water Reactors, Framatome ANP, September 2005.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

13. EMF-2209(P)(A) Revision 3, SPCB Critical Power Correlation, AREVA NP, September 2009.
14. EMF-2245(P)(A) Revision 0, Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel, Siemens Power Corporation, August 2000.
15. EMF-2361(P)(A) Revision 0, EXEM BWR-2000 ECCS Evaluation Model, Framatome ANP Inc., May 2001 as supplemented by the site-specific approval in NRC safety evaluations dated February 15, 2013, and July 31, 2014.
16. EMF-2292(P)(A) Revision 0, ATRIUM™-10: Appendix K Spray Heat Transfer Coefficients, Siemens Power Corporation, September 2000.
17. EMF-CC-074(P)(A), Volume 4, Revision 0, BWR Stability Analysis: Assessment of STAIF with Input from MICROBURN-B2, Siemens Power Corporation, August 2000.
18. (Deleted).
19. BAW-10247PA Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors, AREVA NP, February 2008.
20. ANP-10298P-A Revision 1, ACE/ATRIUM 10XM Critical Power Correlation, AREVA Inc., March 2014.
21. (Deleted).
22. NEDC-33075P-A, GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density, Revision 8, November 2013.
23. BAW-10247P-A Supplement 2P-A Revision 0, Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods, Framatome Inc., August 2018.

(continued)

5.6 Reporting Requirements (continued)

5.6.5 CORE OPERATING LIMITS REPORT (COLR) (continued)

24. ANP-10300P-A Revision 1, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios, Framatome Inc., January, 2018.
25. ANP-10332P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios, Framatome Inc., March 2019.
26. ANP-10333P-A Revision 0, AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA), Framatome Inc., March 2018 (as supplemented by Section 6.4 of ANP-3908P Revision 3, Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel, Framatome Inc., July 2021).
27. ANP-10335P-A Revision 0, ACE/ATRIUM 11 Critical Power Correlation, Framatome Inc., May 2018.
28. ANP-10340P-A Revision 0, Incorporation of Chromia Doped Fuel Properties in AREVA Approved Methods, Framatome Inc., May 2018.
29. ANP-3907P Revision 0, Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry, Framatome Inc., April 2021.

(continued)

ATTACHMENT 3

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

Proposed Technical Specification Bases Changes (Markup)

BASES

BACKGROUND (continued)

incremental, cladding deterioration. Therefore, the fuel cladding SL is defined with a margin to the conditions that would produce onset of transition boiling (i.e., MCPR = 1.00). These conditions represent a significant departure from the condition intended by design for planned operation. ~~The MCPR fuel-cladding integrity SL ensures that during normal operation and during abnormal operational transients, at least 99.9% of the fuel rods in the core do not experience transition boiling. This is accomplished by having a Safety Limit Minimum Critical Power Ratio (SLMCPR) design basis, referred to as the SLMCPR_{95/95}, which corresponds to a 95% probability of a 95% confidence level (the 95/95 MCPR criterion) that transition boiling will not occur.~~

Operation above the boundary of the nucleate boiling regime could result in excessive cladding temperature because of the onset of transition boiling and the resultant sharp reduction in heat transfer coefficient. Inside the steam film, high cladding temperatures are reached, and a cladding-water (zirconium-water) reaction may take place. This chemical reaction results in oxidation of the fuel cladding to a structurally weaker form. This weaker form may lose its integrity, resulting in an uncontrolled release of activity to the reactor coolant.

APPLICABLE SAFETY ANALYSES

The fuel cladding must not sustain damage as a result of normal operation and abnormal operational transients. ~~The reactor core SLs are established to preclude violation of the fuel design criterion that an MCPR limit is to be established, such that at least 99.9% of the fuel rods in the core would not be expected to experience the onset of transition boiling. The Technical Specification SL is set generically on a fuel product MCPR correlation basis as the MCPR which corresponds to a 95% probability at a 95% confidence level that transition boiling will not occur, referred to as SLMCPR_{95/95}.~~

The Reactor Protection System setpoints (LCO 3.3.1.1, "Reactor Protection System (RPS) Instrumentation"), in combination with other LCOs, are designed to prevent any anticipated combination of transient conditions for Reactor Coolant System water level, pressure, and THERMAL POWER level that would result in reaching the MCPR limit.

(continued)

BASES

APPLICABLE SAFETY ANALYSES (continued)

2.1.1.1 Fuel Cladding Integrity

Critical power correlations are valid over a wide range of conditions per References 2, 5, and 59, extending to expected conditions below 23% THERMAL POWER. For core thermal power levels at, or above 23% rated, the hot channel flow rate is expected to be >28,000 lbm/hr, (core flow not less than natural circulation i.e., ~25%-30% core flow for 23% power); therefore, the fuel cladding integrity SL is conservative relative to the applicable range of the critical power correlations. For operation at low pressure/flow conditions, consistent with the low power region of the Power/Flow operating map, another basis is used as follows:

The static head across the fuel bundles is due to elevation effects from water solid channel, core bypass, and annulus regions, is approximately 4.5 psid. The pressure differential is maintained by the water solid bypass region of the core, along with the annulus region of the vessel. Elevation head provided by the bypass and annulus regions produces natural circulation flow conditions balancing pressure head with loss terms inside the core shroud.

Natural circulation principles maintain a core plenum to plenum pressure drop of approximately 4.5 to 5 psid along the natural circulation flow line of the Power/Flow operating map. When power levels approach 23% rated, pressure drop and density head terms are closely balanced as power changes, such that natural circulation flow is nearly independent of reactor power.

The flow characteristic is represented by the nearly vertical portion of the natural circulation line on the Power/Flow operating map. For a core pressure drop of approximately 4.5 to 5 psid, the hot channel flow rate is expected to be >28,000 lbm/hr in the region of operation when core power is < 23% with a corresponding core pressure drop of about 4.5 to 5 psid.

(continued)

BASES

APPLICABLE
SAFETY ANALYSES

2.1.1.1 Fuel Cladding Integrity (continued)

For example, References 5 and 9 test data, taken at low pressures and flow rates, indicate assembly critical power in excess of 4 MWt, for flow rates indicative of natural circulation conditions. At 23% rated power, assembly average power is < 1.2 MWt. When considering design peaking factors, hot channel power could be expected to be on the order of 2 MWt. Consequently, operation up to 23% rated core power, with normal natural circulation available, is conservative even if reactor pressure is less than the lower pressure limit of the critical power correlation.

When reactor power is significantly less than 23% of rated (e.g., below 10% of rated), hot channel flow supported by the available driving head may fall below 28,000 lbm/hr (along the lower portion of the natural circulation flow characteristic on the Power/Flow map). However, the critical power supported by the flow, remains above actual hot channel power conditions. The inherent characteristics of BWR natural circulation make core power/flow follow the natural circulation line as long as normal annulus water level is maintained.

Operation below 23% rated core thermal power is conservatively acceptable, even for reactor operations at natural circulation. Adequate fuel thermal margins are maintained for low power conditions present during core natural circulation, even though the flow may be less than the critical power correlation applicability range.

The low pressure safety limit value of 585 psig has been determined to adequately bound the minimum pressure that might occur while reactor power is at or above 23% of rated. This condition would most likely be created by a pressure regulator failure open transient (PRFO) that results in a rapid depressurization of the vessel and a subsequent scram. Reference 8 provides a detailed evaluation of this transient event, and provides the basis for the low pressure safety limit of 585 psig.

(continued)

BASES

APPLICABLE SAFETY ANALYSES (continued)

2.1.1.2 MCPR

The fuel cladding integrity SL is set such that no fuel damage is calculated to occur if the limit is not violated. Since the parameters that result in fuel damage are not directly observable during reactor operation, the thermal and hydraulic conditions that result in the onset of transition boiling have been used to mark the beginning of the region in which fuel damage could occur. Although it is recognized that the onset of transition boiling would not result in damage to BWR fuel rods, the critical power at which boiling transition is calculated to occur has been adopted as a convenient limit. The Technical Specification SL value is dependent on the fuel product line and the corresponding MCPR correlation, which is cycle-independent. The value is based on the Critical Power Ratio (CPR) data statistics and a 95% probability with 95% confidence that rods are not susceptible to boiling transition, referred to as $MCPR_{95/95}$. ~~However, the uncertainties in monitoring the core operating state and in the procedures used to calculate the critical power result in an uncertainty in the value of the critical power. Therefore, the fuel cladding integrity SL is defined as the critical power ratio in the limiting fuel assembly for which more than 99.9% of the fuel rods in the core are expected to avoid boiling transition, considering the power distribution within the core and all uncertainties.~~

~~The MCPR SL is determined using a statistical model combining all the uncertainties in operating parameters and the procedures used to calculate critical power. The probability of the occurrence of boiling transition is determined using the approved AREVA critical power correlations. One specific uncertainty included in the SL is the uncertainty inherent in the critical power correlation. References 2, 3, 4, 5, and 6 describe the uncertainties and methodologies used in determining the MCPR SL. The SL is based on ATRIUM 11 fuel. For cores with a single fuel product line, the $SLMCPR_{95/95}$ is the $MCPR_{95/95}$ for the fuel type. For cores loaded with a mix of applicable fuel types, the $SLMCPR_{95/95}$ is based on the largest (i.e., most limiting) of the MCPR values for the fuel product lines that are fresh or once-burned at the start of the cycle.~~

(continued)

BASES (continued)

SAFETY LIMIT
VIOLATIONS

Exceeding an SL may cause fuel damage and create a potential for radioactive releases in excess of 10 CFR 50.67, "Accident Source Term," limits (Ref. 7). Therefore, it is required to insert all insertable control rods and restore compliance with the SLs within 2 hours. The 2 hour Completion Time ensures that the operators take prompt remedial action and also ensures that the probability of an accident occurring during this period is minimal.

REFERENCES

1. 10 CFR 50, Appendix A, GDC 10.
2. EMF-2209(P)(A), SPCB Critical Power Correlation, (as identified in the COLR).
3. EMF-2245(P)(A), Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel, (as identified in the COLR).
4. ANP-10307PA Revision 0, AREVA MCPR Safety Limit Methodology for Boiling Water Reactors, AREVA NP, June 2011.
5. ~~ANP-10298PA Revision 0~~ANP-10298P-A Revision 1, ACE/ATRIUM 10XM Critical Power Correlation, AREVA ~~NP~~Inc., March ~~2010~~2014.
6. ~~ANP-3140(P) Revision 0, Browns Ferry Units 1, 2, and 3 Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation, AREVA NP, August 2012.~~Not used.
7. 10 CFR 50.67.
8. ANP-3245P Revision 1, Browns Ferry Evaluation of PRFO Low Pressure Technical Specification Value, AREVA Inc., February 2014.
9. ANP-10335P-A Revision 0, ACE/ATRIUM 11 Critical Power Correlation, Framatome Inc., May 2018.

B 3.1 REACTIVITY CONTROL SYSTEMS

B 3.1.1 SHUTDOWN MARGIN (SDM)

BASES

BACKGROUND

SDM requirements are specified to ensure:

- a. The reactor can be made subcritical from all operating conditions and transients and Design Basis Events;
- b. The reactivity transients associated with postulated accident conditions are controllable within acceptable limits; and
- c. The reactor will be maintained sufficiently subcritical to preclude inadvertent criticality in the shutdown condition.

These requirements are satisfied by the control rods, as described in GDC 26 (Ref. 1), which can compensate for the reactivity effects of the fuel and water temperature changes experienced during all operating conditions.

APPLICABLE
SAFETY ANALYSES

The control rod drop accident (CRDA) analysis (Refs. 2, ~~3, 9,~~ and ~~10~~11) assumes the core is subcritical with the highest worth control rod withdrawn. Typically, the first control rod withdrawn has a very high reactivity worth and, should the core be critical during the withdrawal of the first control rod, the consequences of a CRDA could exceed the fuel damage limits for a CRDA (see Bases for LCO 3.1.6, "Rod Pattern Control"). Also, SDM is assumed as an initial condition for the control rod removal error during refueling (Ref. 4) and fuel assembly insertion error during refueling (Ref. 5) accidents. The analysis of these reactivity insertion events assumes the refueling interlocks are OPERABLE when the reactor is in the refueling mode of operation. These interlocks prevent the withdrawal of more

(continued)

BASES

ACTIONS

E.1, E.2, E.3, E.4, and E.5 (continued)

or other reasons. It is not necessary to perform the SRs needed to demonstrate the OPERABILITY of the components. If, however, any required component is inoperable, then it must be restored to OPERABLE status. In this case, SRs may need to be performed to restore the component to OPERABLE status. Action must continue until all required components are OPERABLE.

SURVEILLANCE
REQUIREMENTSSR 3.1.1.1

Adequate SDM must be verified to ensure that the reactor can be made subcritical from any initial operating condition. This can be accomplished by a test, an evaluation, or a combination of the two. Adequate SDM is demonstrated before or during the first startup after fuel movement, or shuffling within the reactor pressure vessel, or control rod replacement. Control rod replacement refers to the decoupling and removal of a control rod from a core location, and subsequent replacement with a new control rod or a control rod from another core location. Since core reactivity will vary during the cycle as a function of fuel depletion and poison burnup, the beginning of cycle (BOC) test must also account for changes in core reactivity during the cycle. Therefore, to obtain the SDM, the initial measured value must be increased by an adder, "R", which is the difference between the calculated value of maximum core reactivity during the operating cycle and the calculated BOC core reactivity. If the value of R is negative (that is, BOC is the most reactive point in the cycle), no correction to the BOC measured value is required ~~(Ref. 7)~~.

(continued)

BASES (continued)

REFERENCES

1. 10 CFR 50, Appendix A, GDC 26.
2. FSAR, Section 14.6.2.
3. ~~NEDE-24011-P-A, Rev. 16, "General Electric Standard Application for Reactor Fuel," Section S.2.2.3.1, October 2007. Not used.~~
4. FSAR, Section 14.5.~~34~~.3.
5. FSAR, Section 14.5.~~34~~.4.
6. FSAR, Section 3.6.~~5-24~~.4.
7. ~~NEDE-24011-P-A, Rev. 16, "General Electric Standard Application for Reactor Fuel," Section 3.2.4.1, October 2007. Not used.~~
8. NRC 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
9. ~~XN-NF-80-19(P)(A), Volume 1, "Exxon Nuclear Methodology for Boiling Water Reactors – Neutronic Methods for Design and Analysis," (as identified in the COLR). Not used.~~
10. ~~EMF-2158(P)(A), "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," (as identified in the COLR). Not used.~~
11. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)," Framatome Inc., March 2018.

BASES (continued)

APPLICABLE
SAFETY ANALYSES

The analytical methods and assumptions used in evaluating the control rod scram function are presented in References 2, 3, and 4. The Design Basis Accident (DBA) and transient analyses assume that all of the control rods scram at a specified insertion rate. The resulting negative scram reactivity forms the basis for the determination of plant thermal limits (e.g., the MCPR). Other distributions of scram times (e.g., several control rods scrambling slower than the average time with several control rods scrambling faster than the average time) can also provide sufficient scram reactivity. Surveillance of each individual control rod's scram time ensures the scram reactivity assumed in the DBA and transient analyses can be met.

The scram function of the CRD System protects the MCPR Safety Limit (SL) (see Bases for SL 2.1.1, "Reactor Core SLs," and LCO 3.2.2, "MINIMUM CRITICAL POWER RATIO (MCPR)") and the 1% cladding plastic strain fuel design limit (see Bases for LCO 3.2.1, "AVERAGE PLANAR LINEAR HEAT GENERATION RATE (APLHGR)", and LCO 3.2.3, "LINEAR HEAT GENERATION RATE (LHGR)"), which ensure that no fuel damage will occur if these limits are not exceeded. Above 800 psig, the scram function is designed to insert negative reactivity at a rate fast enough to prevent the actual MCPR from becoming less than the MCPR SL, during the analyzed limiting power transient, using the methodology in Reference 11. Below 800 psig, the scram function is assumed to perform during the control rod drop accident (~~Refs. 5, 8, and 9~~Ref. 10) and, therefore, also provides protection against violating fuel damage limits during reactivity insertion accidents (see Bases for LCO 3.1.6, "Rod Pattern Control"). For the reactor vessel overpressure protection analysis, the scram function, along with the safety/relief valves, ensure that the peak vessel pressure is maintained within the applicable ASME Code limits.

Control rod scram times satisfy Criterion 3 of the NRC Policy Statement (Ref. 7).

(continued)

BASES (continued)

REFERENCES

1. 10 CFR 50, Appendix A, GDC 10.
 2. FSAR, Section 3.4.6.
 3. FSAR, Section 14.5.
 4. FSAR, Section 14.6.
 5. ~~NEDE-24011-P-A, Rev. 16, "General Electric Standard Application for Reactor Fuel," Section 3.2.4.1, October 2007. Not used.~~
 6. Letter from R. F. Janecek (BWROG) to R. W. Starostecki (NRC), "BWR Owners Group Revised Reactivity Control System Technical Specifications," BWROG-8754, September 17, 1987.
 7. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
 8. ~~XN-NF-80-19(P)(A), Volume 1, "Exxon Nuclear Methodology for Boiling Water Reactors—Neutronic Methods for Design and Analysis," (as identified in the COLR). Not used.~~
 9. ~~EMF-2158(P)(A), "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," (as identified in the COLR). Not used.~~
 10. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)," Framatome Inc., March 2018.
 11. ANP-10300P-A Revision 1, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios," Framatome Inc., January 2018.
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B 3.1 REACTIVITY CONTROL SYSTEMS

B 3.1.6 Rod Pattern Control

BASES

BACKGROUND

Control rod patterns during startup conditions are controlled by the operator and the rod worth minimizer (RWM) (LCO 3.3.2.1, "Control Rod Block Instrumentation"), so that only specified control rod sequences and relative positions are allowed over the operating range of all control rods inserted to 10% RTP. The sequences limit the potential amount of reactivity addition that could occur in the event of a Control Rod Drop Accident (CRDA).

This Specification assures that the control rod patterns are consistent with the assumptions of the CRDA analyses of ~~References 1, 2, 11, and 12~~Reference 13.

APPLICABLE SAFETY ANALYSES

The analytical methods and assumptions used in evaluating the CRDA are summarized in ~~References 1, 2, 11, and 12~~Reference 13. CRDA analyses assume that the reactor operator follows prescribed withdrawal sequences. These sequences define the potential initial conditions for the CRDA analysis. The RWM (LCO 3.3.2.1) provides backup to operator control of the withdrawal sequences to ensure that the initial conditions of the CRDA analysis are not violated.

Prevention or mitigation of positive reactivity insertion events is necessary to limit the energy deposition in the fuel, thereby preventing significant fuel damage which could result in the undue release of radioactivity. ~~Since the failure consequences for UO₂ have been shown to be insignificant below fuel energy~~The CRDA analysis ensures that the potential release of radioactivity does not exceed that assumed in the plants licensing basis dose evaluation. The criteria of Regulatory Guide (RG) 1.236 (Ref. 14) is utilized with the steady state release fractions of RG 1.183 (July 2000 version, Ref. 15) and using the DG-1327 (July 2019 version, Ref. 16) transient fission gas release correlations and fission gas multipliers in making this determination. Consequently, the calculated offsite dose will be well within the required limits (Ref. 5).

(continued)

BASES

APPLICABLE SAFETY ANALYSES (continued)

~~depositions of 300 cal/gm (Ref. 3), the fuel damage limit of 280 cal/gm provides a margin of safety from significant core damage which would result in release of radioactivity (Refs. 4 and 5). Generic evaluations (Refs. 1, 6, and 11) of a design basis CRDA (i.e., a CRDA resulting in a peak fuel energy deposition of 280 cal/gm) have shown that if the peak fuel enthalpy remains below 280 cal/gm, then the maximum reactor pressure will be less than the required ASME Code limits (Ref. 7) and the calculated offsite doses will be well within the required limits (Ref. 5). The potential for CRDA to exceed ASME code pressure limits was addressed in Reference 13. The most severe power pulse for the CRDA occurs at the cold conditions at atmospheric pressure. Therefore, a significant amount of energy is required to simply pressurize the core. Although local pressure increase occurs within a few assemblies, there is little change in the core system pressure in either the startup range or the power range. Therefore, the CRDA would not result in a reactor pressure which would cause increased stress to exceed the "Service Limit C" ASME Boiler and Pressure Vessel Code.~~

Control rod patterns analyzed in References 1, 11, and 12 Reference 13, follow the banked position withdrawal sequence (BPWS). The BPWS is applicable from the condition of all control rods fully inserted to 10% RTP (Ref. 2). For the BPWS, the control rods are required to be moved in groups, with all control rods assigned to a specific group required to be within specified banked positions (e.g., between notches 08 and 12). The banked positions are established to minimize the maximum incremental control rod worth without being overly restrictive during normal plant operation. Analyses are performed using the Reference 11-13 methodology demonstrating the 280 cal/gm fuel damage limit RG 1.236 (Ref. 14) criteria will not be violated during a CRDA while following the BPWS mode of operation. The evaluation provided by the generic BPWS analysis (Ref. 8) allows a limited number (i.e., eight) and corresponding distribution of fully inserted, inoperable control rods, that are not in compliance with the sequence.

When performing a shutdown of the plant, an optional BPWS control room sequence (Ref. 10) may be used provided that all withdrawn control rods have been confirmed to be coupled. The rods may be inserted without the need to stop at intermediate positions since the possibility of a CRDA is eliminated by the confirmation that withdrawn control rods are coupled. When using the Reference 10 control rod sequence for shutdown, the Rod Worth Minimizer may be reprogrammed.

(continued)

BASES (continued)

REFERENCES

1. ~~NEDE-24011-P-A, Rev. 16, "General Electric Standard Application for Reactor Fuel," Section 2.2.3.1, October 2007. Not used.~~
2. Letter from T. Pickens (BWROG) to G. C. Lainas (NRC), Amendment 17 to General Electric Licensing Topical Report, NEDE-24011-P-A, August 15, 1986.
3. NUREG-0979, Section 4.2.1.3.2, April 1983.
4. NUREG-0800, Section 15.0.1.
5. 10 CFR 50.67.
6. NEDO-21778-A, "Transient Pressure Rises Affected Fracture Toughness Requirements for Boiling Water Reactors," December 1978.
7. ASME, Boiler and Pressure Vessel Code.
8. NEDO-21231, "Banked Position Withdrawal Sequence," January 1977.
9. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
10. NEDO 33091-A, Revision 2, "Improved BPWS Control Rod Insertion Process," July 2004.
11. ~~XN-NF-80-19(P)(A), Volume 1, "Exxon Nuclear Methodology for Boiling Water Reactors—Neutronic Methods for Design and Analysis," (as identified in the COLR). Not used.~~
12. ~~EMF-2158(P)(A), "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," (as identified in the COLR). Not used.~~
13. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)," Framatome Inc., March 2018.
14. Regulatory Guide 1.236, "Pressurized-Water Reactor Control Rod Ejection and Boiling-Water Reactor Control Rod Drop Accidents," June 2020 (NRC ADAMS ML20055F490).
15. Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," July 2000 (NRC ADAMS ML003716792).
16. Draft Regulatory Guide 1327, "Pressurized-Water Reactor Control Rod Ejection and Boiling Water Reactor Control Rod Drop Accidents," July 2019 (NRC ADAMS ML18302A106).

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.1.7.11

SR 3.1.7.11 verifies that each valve in the system is in its correct position, but does not apply to the squib (i.e., explosive) valves. Verifying the correct alignment for manual, power operated, and automatic valves in the SLC System Flowpath provides assurance that the proper flow paths will exist for system operation. A valve is also allowed to be in the nonaccident position provided it can be aligned to the accident position from the control room, or locally by a dedicated operator at the valve control. This is acceptable since the SLC System is a manually initiated system. This surveillance also does not apply to valves that are locked, sealed, or otherwise secured in position since they are verified to be in the correct position prior to locking, sealing or securing. This verification of valve alignment does not require any testing or valve manipulation; rather, it involves verification that those valves capable of being mispositioned are in the correct position. This SR does not apply to valves that cannot be inadvertently misaligned, such as check valves. The 31 day Frequency is based on engineering judgment and is consistent with the procedural controls governing valve operation that ensures correct valve positions.

REFERENCES

1. 10 CFR 50.62.
 2. NEDC-33860P, "Safety Analysis Report for Browns Ferry Nuclear Plant Units 1, 2, and 3 Extended Power Uprate," [GE Hitachi Nuclear Energy, October 2016.](#) Section 2.8.
 3. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
 4. FSAR, Section 14.6.
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B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.1 AVERAGE PLANAR LINEAR HEAT GENERATION RATE (APLHGR)

BASES

BACKGROUND	The APLHGR is a measure of the average LHGR of all the fuel rods in a fuel assembly at any axial location. Limits on the APLHGR are specified to ensure that the fuel design limits are not exceeded during abnormal operational transients and that the peak cladding temperature (PCT) during the postulated design basis loss of coolant accident (LOCA) does not exceed the limits specified in 10 CFR 50.46.

APPLICABLE SAFETY ANALYSES	The analytical methods and assumptions used in evaluating the fuel design limits are presented in References 2 and 11. The analytical methods and assumptions used in evaluating Design Basis Accidents (DBAs), abnormal operational transients, and normal operation that determine the APLHGR limits are presented in References 11, 12, 13, 14, 15, ~~and 16, 17, 18, 19, and 20.~~ <u>for AREVA fuel.</u>

(continued)

BASES

APPLICABLE
SAFETY ANALYSES
(continued)

(Deleted by Tech Spec Bases Revision 104)

AREVA Fuel

~~For AREVA fuel, the~~ APLHGR limits are developed as a function of exposure and, along with the LHGR limits, ensure adherence to fuel design limits during abnormal operational transients. No power- or flow-dependent corrections are applied to the APLHGR (referred to as the maximum APLHGR or MAPLHGR). ~~AREVA~~ APLHGR limits are intended to be bound by the LHGR limits.

The calculational procedure used to establish ~~the AREVA fuel~~ MAPLHGR limits is based on LOCA analyses as defined in 10 CFR 50.46, Appendix K. MAPLHGR limits are created to assure that the peak cladding temperature ~~of AREVA fuel~~ following a postulated design basis LOCA will not exceed the PCT and maximum oxidation limits specified in 10 CFR 50.46, Appendix K. The calculational models and methodology are described in References 11, ~~and 12,~~ and 19.

~~The AREVA fuel~~ MAPLHGR limits for two-loop operation are specified in the COLR. For single-loop operation, a MAPLHGR multiplier is applied to the MAPLHGR limit (Ref. 11). The multiplier is documented in the COLR.

The APLHGR satisfies Criterion 2 of the NRC Policy Statement (Ref. 6).

(continued)

BASES

LCO

The APLHGR limits specified in the COLR are the result of the fuel design, DBA, and transient analyses. With only one recirculation loop in operation, in conformance with the requirements of LCO 3.4.1, "Recirculation Loops Operating," the limit is determined by multiplying the exposure dependent limit by an APLHGR correction factor ~~(Ref. 5 and Ref. 10)~~. Cycle specific APLHGR correction factors for single recirculation loop operation are documented in the COLR. APLHGR limits are selected such that no power or flow dependent corrections are required. Additional APLHGR operating limit adjustments may be provided in the COLR supporting other analyzed equipment out-of-service conditions.

APPLICABILITY

The APLHGR limits are primarily derived from fuel design evaluations and LOCA and transient analyses that are assumed to occur at high power levels. Design calculations (Ref. 4) and operating experience have shown that as power is reduced, the margin to the required APLHGR limits increases. This trend continues down to the power range of 5% to 15% RTP when entry into MODE 2 occurs. When in MODE 2, the intermediate range monitor scram function provides prompt scram initiation during any significant transient, thereby effectively removing any APLHGR limit compliance concern in MODE 2. Therefore, at THERMAL POWER levels $\leq 23\%$ RTP, the reactor is operating with substantial margin to the APLHGR limits; thus, this LCO is not required.

(continued)

BASES

REFERENCES

1. (Deleted by Tech Spec Revision 104).
2. FSAR, Chapter 3.
3. FSAR, Chapter 14.
4. FSAR, Appendix N.
5. ~~NEDC-32484P, "Browns Ferry Nuclear Plant Units 1, 2, and 3, SAFER/GESTR-LOCA Loss-of-Coolant Accident Analysis," Revision 2, December 1997. Not used.~~
6. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
7. ~~NEDC-32433P, "Maximum Extended Load Line Limit and ARTS Improvement Program Analyses for Browns Ferry Nuclear Plant Units 1, 2, and 3," April 1995. Not used.~~
8. ~~NEDO-30130-A, "Steady State Nuclear Methods," May 1985. Not used.~~
9. ~~NEDO-24154, "Qualification of the One-Dimensional Core-Transient Model for Boiling Water Reactors," October 1978. Not used.~~
10. ~~NEDO-24236, "Browns Ferry Nuclear Plant Units 1, 2, and 3, Single-Loop Operation," May 1981. Not used.~~

(continued)

BASES

REFERENCES (continued)

11. EMF-2361(P)(A), Rev. 0, "EXEM BWR-2000 ECCS Evaluation Model," Framatome ANP Inc., as supplemented by the site-specific approval in NRC safety evaluation dated April 27, 2012, and July 31, 2014.
12. EMF-2292(P)(A), "ATRIUM™-10: Appendix K Spray Heat Transfer Coefficients," (as identified in the COLR).
13. XN-NF-81-58(P)(A), "RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model," (as identified in the COLR).
14. XN-NF-80-19(P)(A), Volume 1, "Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis," (as identified in the COLR).
15. XN-NF-80-19(P)(A), Volume 4, "Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads," (as identified in the COLR).
16. BAW-10247PA Revision 0, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors," AREVA NP, February 2008.
17. ANF-89-98(P)(A) Revision 1 and Supplement 1, "Generic Mechanical Design Criteria for BWR Fuel Designs," Advanced Nuclear Fuels Corporation, May 1995.
18. BAW-10247P-A Supplement 2P-A Revision 0, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods," Framatome Inc., August 2018.
19. ANP-10332P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios," Framatome Inc., March 2019.
20. ANP-10340P-A Revision 0, "Incorporation of Chromia-Doped Fuel Properties in AREVA Approved Methods," Framatome Inc., May 2018.

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B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.2 MINIMUM CRITICAL POWER RATIO (MCPR)

BASES

BACKGROUND

MCPR is a ratio of the fuel assembly power that would result in the onset of boiling transition to the actual fuel assembly power. ~~The MCPR Safety Limit (SL) is set such that 99.9% of the fuel rods avoid boiling transition if the limit is not violated (refer to the Bases for SL 2.1.1.2).~~ The operating limit MCPR is established to ensure that no fuel damage results during abnormal operational transients and that 99.9% of the fuel rods are not susceptible to boiling transition if the limit is not violated. Although fuel damage does not necessarily occur if a fuel rod actually experienced boiling transition (Ref. 1), the critical power at which boiling transition is calculated to occur has been adopted as a fuel design criterion.

The onset of transition boiling is a phenomenon that is readily detected during the testing of various fuel bundle designs. Based on these experimental data, correlations have been developed to predict critical bundle power (i.e., the bundle power level at the onset of transition boiling) for a given set of plant parameters (e.g., reactor vessel pressure, flow, and subcooling). Because plant operating conditions and bundle power levels are monitored and determined relatively easily, monitoring the MCPR is a convenient way of ensuring that fuel failures due to inadequate cooling do not occur.

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BASES (continued)

APPLICABLE
SAFETY ANALYSES

The analytical methods and assumptions used in evaluating the abnormal operational transients to establish the operating limit MCPR are presented in References 11, 12, 13, ~~14, and 15~~ and 16. To ensure that the MCPR SL is not exceeded during any transient event that occurs with moderate frequency, limiting transients have been analyzed to determine the largest reduction in critical power ratio (CPR). The types of transients evaluated are loss of flow, increase in pressure and power, positive reactivity insertion, and coolant temperature decrease. The limiting transient yields the largest change in CPR (ΔCPR). When the largest ΔCPR is ~~added to~~ combined with the ~~MCPR-SL~~ MCPR_{99.9%}, the required operating limit MCPR is obtained.

The MCPR operating limits derived from the transient analysis are dependent on the operating core flow and power to ensure adherence to fuel design limits during the worst transient that occurs with moderate frequency (Ref. 8). Flow dependent MCPR (MCPR_f) limits are determined by steady state thermal hydraulic methods using the three dimensional BWR simulator code (Ref. 12) and the multichannel thermal hydraulics code (Ref. 13). The operating limit is dependent on the maximum core flow limiter setting in the Recirculation Flow Control System.

MCPR_{99.9%} is determined to ensure more than 99.9% of the fuel rods in the core are not susceptible to boiling transition using a statistical model that combines all the uncertainties in operating parameters and the procedures used to calculate critical power. The probability of the occurrence of boiling transition is determined using the approved Critical Power correlations. Details of the MCPR_{99.9%} calculation are given in Reference 11. The cycle-specific Reload Analysis report (as referenced in the COLR) includes tabulation of fuel- and plant-related uncertainties for the parameters used in the MCPR_{99.9%} statistical analysis.

Power dependent MCPR limits (MCPR_p) are derived from the MCPR_{99.9%} value and the transient analyses based on ~~determined by~~ the three-dimensional BWR simulator code (Ref. 12) and the ~~one-dimensional transient codes (Refs. 14 and 15)~~ multi-physics evaluation model (Ref. 16). Due to the sensitivity of the transient response to initial core flow levels at power levels below those at which the turbine stop valve closure and turbine control valve fast closure scrams are bypassed, high and low flow MCPR_p operating limits are provided for operating between 23% RTP and the previously mentioned bypass power level.

MCPR_p limits above the bypass power level may be implemented with a flow dependency as a margin improvement option. At a given power level, MCPR_p limits can be defined for specific ranges of core flow. The use of this approach expands the original basis for thermal limit administration under the ARTS methodology (Ref. 8), and can improve operating MCPR margin when operating at the lower core flows associated with the MELLLA+ operating domain.

The MCPR satisfies Criterion 2 of the NRC Policy Statement (Ref. 7).

(continued)

BASES (continued)

LCO

The MCPR operating limits specified in the COLR (MCPR_{99.9%} value, MCPR_f values, and MCPR_p values) are the result of the Design Basis Accident (DBA) and transient analysis. Additionally MCPR operating limits supporting analyzed equipment out-of-service conditions are provided in the COLR. The operating limit MCPR is determined by the larger of the MCPR_f and MCPR_p limits, which are based on the MCPR_{99.9%} limit specified in the COLR.

APPLICABILITY

The MCPR operating limits are primarily derived from transient analyses that are assumed to occur at high power levels. Below 23% RTP, the reactor is operating at a minimum recirculation pump speed and the moderator void ratio is small. Surveillance of thermal limits below 23% RTP is unnecessary due to the large inherent margin that ensures that the MCPR SL is not exceeded even if a limiting transient occurs. Statistical analyses indicate that the nominal value of the initial MCPR expected at 23% RTP is > 3.5. Studies of the variation of limiting transient behavior have been performed over the range of power and flow conditions. These studies encompass the range of key actual plant parameter values important to typically limiting transients. The results of these studies demonstrate that a margin is expected between performance and the MCPR requirements, and that margins increase as power is reduced to 23% RTP. This trend is expected to continue to the 5% to 15% power range when entry into MODE 2 occurs. When in MODE 2, the intermediate range monitor provides rapid scram initiation for any significant power increase transient, which effectively eliminates any MCPR compliance concern. Therefore, at THERMAL POWER levels < 23% RTP, the reactor is operating with substantial margin to the MCPR limits and this LCO is not required.

ACTIONS

A.1

If any MCPR is outside the required limits, an assumption regarding an initial condition of the design basis transient

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BASES

REFERENCES (continued)

8. NEDC-32433P, "Maximum Extended Load Line Limit and ARTS Improvement Program Analyses for Browns Ferry Nuclear Plant Units 1, 2, and 3," April 1995.
9. (Deleted by Tech Spec Revision 104).
10. NEDO-24236, "Browns Ferry Nuclear Plant Units 1, 2, and 3, Single-Loop Operation," May 1981.
11. ANP-10307PA Revision 0, "AREVA MCPR Safety Limit Methodology for Boiling Water Reactors," AREVA NP, June 2011.
12. EMF-2158(P)(A), "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," (as identified in the COLR).
13. XN-NF-80-19(P)(A) Volume 3, "Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description," (as identified in the COLR).
14. ~~ANF-913(P)(A) Volume 1, "COTRANSA2: A Computer Program for Boiling Water Reactor Transient Analyses," (as identified in the COLR). Not used.~~
15. ~~XN-NF-84-105(P)(A) Volume 1, "XCOBRA-T: A Computer Code for BWR Transient Thermal Hydraulic Core Analysis," (as identified in the COLR). Not used.~~
16. ANP-10300P-A Revision 1, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios," Framatome Inc., January 2018.

BASES

APPLICABLE
SAFETY ANALYSES,
LCO, and
APPLICABILITY
(continued)

2.f. Oscillation Power Range Monitor (OPRM) Upscale

The OPRM Upscale Function provides compliance with 10 CFR 50, Appendix A, General Design Criteria (GDC) 10 and 12, thereby providing protection from exceeding the fuel MCPR safety limit (SL) due to anticipated thermal-hydraulic power oscillations.

~~Reference 13 describes the Detect and Suppress – Confirmation Density (DSS-CD) long-term stability solution and the licensing-basis Confirmation Density Algorithm (CDA).~~ Reference 13 describes the Detect and Suppress – Confirmation Density (DSS-CD) long-term stability solution. Reference 13 also defines the Confirmation Density Algorithm (CDA) which is used in conjunction with DSS-CD for oscillation detection. The analytical portion of DSS-CD has since been replaced by the Best-estimate Enhanced Option III methodology with CDA as described in Reference 15. The hardware side of DSS-CD has been retained and is unchanged from Reference 13. This hybrid stability solution is referred to as BEO-III with CDA. Reference 13 also describes the ~~DSS-CDCDA~~ Armed Region and the three additional algorithms for detecting thermal-hydraulic instability related neutron flux oscillations: the period based detection algorithm (PBDA), the amplitude based algorithm (ABA), and the growth rate algorithm (GRA). All four algorithms are implemented in the OPRM Upscale Function, but the safety analysis takes credit only for the CDA. The remaining three algorithms provide defense in depth and additional protection against unanticipated oscillations. OPRM Upscale Function OPERABILITY is based only on the CDA.

The OPRM Upscale Function receives input signals from the local power range monitors (LPRMs) within the reactor core, which are combined into cells for evaluation by the OPRM algorithms.

~~DSS-CDCDA~~ OPERABILITY requires at least 8 responsive OPRM cells per channel. The ~~DSS-CDCDA~~ software includes a self-check for the responsive OPRM cells; therefore, no SR is necessary.

(continued)

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY	<u>2.f. Oscillation Power Range Monitor (OPRM) Upscale</u> (continued) The OPRM Upscale Function is required to be OPERABLE above a power level set at 5% of rated power below the lower boundary of the Armed Region, which is $\geq 18\%$ RTP. This requirement is designed to encompass the region of power-flow operation where anticipated events could lead to thermal-hydraulic instability and related neutron flux oscillations. The OPRM Upscale Function is automatically trip-enabled when THERMAL POWER, as indicated by the APRM Simulated Thermal Power, is $\geq 23\%$ RTP corresponding to the MCPR monitoring threshold and reactor recirculation drive flow, is less than 75% of rated flow. This region is the OPRM Armed Region. ~~Note (f) allows for entry into the DSS-CD Armed Region without automatic arming of DSS-CD prior to completely passing through the DSS-CD Armed Region during the first startup and the first shutdown following DSS-CD implementation.~~ If any OPRM auto-enabled <u>d</u> setpoint is in a non-conservative condition, i.e., the OPRM Upscale is not auto-enabled with RTP $\geq 23\%$ and reactor recirculation drive flow $\leq 75\%$ of rated, the associated channel is considered inoperable for the OPRM Upscale function. Alternatively, the auto-enabled <u>d</u> setpoint may be adjusted to place the channel in a conservative condition (armed). If placed in the armed condition, the channel is considered OPERABLE. ~~Note (f) reflects the need for plant data collection in order to test the DSS-CD equipment. Testing the DSS-CD equipment ensures its proper operation and prevents spurious reactor trips. Entry into the DSS-CD Armed Region without automatic arming of DSS-CD during this initial testing phase also allows for changes in plant operations to address maintenance or other operational needs. However, during this initial testing period, the OPRM upscale function is OPERABLE and DSS-CD operability and capability to automatically arm shall be maintained at recirculation drive flow rates above the DSS-CD Armed Region flow boundary.~~

(continued)

BASES

APPLICABLE
SAFETY ANALYSES, 2.f. Oscillation Power Range Monitor (OPRM) Upscale
LCO, and (continued)
APPLICABILITY

An OPRM Upscale trip is issued from an OPRM channel when the confirmation density algorithm in that channel detects oscillatory changes in the neutron flux, indicated by periodic confirmations and amplitude exceeding specified setpoints for a specified number of OPRM cells in the channel. An OPRM Upscale trip is also issued from the channel if any of the defense-in-depth algorithms (PBDA, ABA, GRA) exceed their trip condition for one or more cells in that channel.

Three of the four channels are required to be OPERABLE. Each channel is capable of detecting thermal-hydraulic instabilities, by detecting the related neutron flux oscillations, and issuing a trip signal before the SLMCPR is exceeded. There is no Allowable Value for this function.

The OPRM Upscale Function is not LSSS SL-related (Reference 13) and Reference 14 confirms that the OPRM Upscale Function settings based on DSS-CDBEO-III with CDA also do not have traditional instrumentation setpoints determined under an instrument setpoint methodology.

(continued)

BASES (continued)

REFERENCES

1. FSAR, Section 7.2.
2. FSAR, Chapter 14.
3. NEDO-23842, "Continuous Control Rod Withdrawal in the Startup Range," April 18, 1978.
4. FSAR, Appendix N.
5. FSAR, Section 14.6.2.
6. FSAR, Section 6.5.
7. FSAR, Section 14.5.
8. P. Check (NRC) letter to G. Lainas (NRC), "BWR Scram Discharge System Safety Evaluation," December 1, 1980.
9. NEDC-30851-P-A, "Technical Specification Improvement Analyses for BWR Reactor Protection System," March 1988.
10. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
11. MED-32-0286, "Technical Specification Improvement Analysis for Browns Ferry Nuclear Plant, Unit 2," October 1995.
12. NEDC-32410P-A, "Nuclear Measurement Analysis and Control Power Range Neutron Monitor (NUMAC PRNM) Retrofit Plus Option III Stability Trip Function," October 1995.
13. GE Hitachi Nuclear Energy, "GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density," NEDC-33075P-A, Revision 8, November 2013.
14. GEH letter to NRC, "NEDC-33075P-A, Detect and Suppress Solution – Confirmation Density (DCC-CD), Analytical Limit (TAC No. MD0277)," October 29, 2008, (ADAMS Accession No. ML083040052).
15. ANP-3907P Revision 0, "Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry," Framatome Inc., April 2021.

BASES

APPLICABLE
SAFETY ANALYSES,
LCO, and
APPLICABILITY
(continued)

2. Rod Worth Minimizer

The RWM enforces the banked position withdrawal sequence (BPWS) to ensure that the initial conditions of the CRDA analysis are not violated. The analytical methods and assumptions used in evaluating the CRDA are summarized in References ~~4~~, 5, 6, ~~7~~, 12, ~~13~~, and ~~14~~15. The standard BPWS requires that control rods be moved in groups, with all control rods assigned to a specific group required to be within specified banked positions. Requirements that the control rod sequence is in compliance with the BPWS are specified in LCO 3.1.6, "Rod Pattern Control."

When performing a shutdown of the plant, an optional BPWS control rod sequence (Ref. 12) may be used if the coupling of each withdrawn control rod has been confirmed. The rods may be inserted without the need to stop at intermediate positions. When using the Reference 12 control rod insertion sequence for shutdown, the Rod Worth Minimizer may be programmed to enforce the requirements of the improved BPWS control rod insertion process or bypassed if it is not programmed to reflect the optional BPWS shutdown sequence, as permitted by the Applicability Note for the Rod Worth Minimizer in Table 3.3.2-1.

The RWM Function satisfies Criterion 3 of the NRC Policy Statement (Ref. 10).

Since the RWM is designed to act as a backup to operator control of the rod sequences, only one channel of the RWM is available and required to be OPERABLE ~~(Ref. 7)~~. Special circumstances provided for in the Required Action of LCO 3.1.3, "Control Rod OPERABILITY," and LCO 3.1.6 may necessitate bypassing the RWM to allow continued operation with inoperable control rods, or to allow correction of a control rod pattern not in compliance with the BPWS. The RWM may be bypassed as required by these conditions, but then it must be considered inoperable and the Required Actions of this LCO followed.

(continued)

BASES

APPLICABLE
SAFETY ANALYSES,
LCO, and
APPLICABILITY
(continued)

2. Rod Worth Minimizer (continued)

Compliance with the BPWS, and therefore OPERABILITY of the RWM, is required in MODES 1 and 2 when THERMAL POWER is $\leq 10\%$ RTP. When THERMAL POWER is $> 10\%$ RTP, ~~there is no possible control rod configuration that results in a control rod worth that could exceed the 280 cal/gm-fuel damage limit during a CRDA (Refs. 5 and 7); the power pulse in the power range is much broader than that in the startup range due to the presence of voids in the core. For this reason, CRDA in the power range remains non-limiting (Ref. 15).~~ In MODES 3 and 4, all control rods are required to be inserted into the core; therefore, a CRDA cannot occur. In MODE 5, since only a single control rod can be withdrawn from a core cell containing fuel assemblies, adequate SDM ensures that the consequences of a CRDA are acceptable, since the reactor will be subcritical.

3. Reactor Mode Switch - Shutdown Position

During MODES 3 and 4, and during MODE 5 when the reactor mode switch is required to be in the shutdown position, the core is assumed to be subcritical; therefore, no positive reactivity insertion events are analyzed. The Reactor Mode Switch - Shutdown Position control rod withdrawal block ensures that the reactor remains subcritical by blocking control rod withdrawal, thereby preserving the assumptions of the safety analysis.

The Reactor Mode Switch - Shutdown Position Function satisfies Criterion 3 of the NRC Policy Statement (Ref. 10).

Two channels are required to be OPERABLE to ensure that no single channel failure will preclude a rod block when required. There is no Allowable Value for this Function since the channels are mechanically actuated based solely on reactor mode switch position.

(continued)

BASES (continued)

REFERENCES

1. FSAR, Section 7.5.8.2.3.
2. FSAR, Section 7.16.5.3.1.k.
3. NEDC-32433P, "Maximum Extended Load Line Limit and ARTS Improvement Program Analyses for Browns Ferry Nuclear Plant Unit 1, 2 and 3," April 1995.
4. ~~NEDE-24011-P-A-US, "General Electrical Standard Application for Reload Fuel," Supplement for United States, (revision specified in the COLR). Not used.~~
5. "Modifications to the Requirements for Control Rod Drop Accident Mitigating Systems," BWR Owners' Group, July 1986.
6. NEDO-21231, "Banked Position Withdrawal Sequence," January 1977.
7. ~~NRC SER, "Acceptance of Referencing of Licensing Topical Report NEDE-24011-P-A," "General Electric Standard Application for Reactor Fuel, Revision 8, Amendment 17," December 27, 1987. Not used.~~
8. NEDC-30851-P-A, Supplement 1, "Technical Specification Improvement Analysis for BWR Control Rod Block Instrumentation," October 1988.
9. GENE-770-06-1, "Addendum to Bases for Changes to Surveillance Test Intervals and Allowed Out-of-Service Times for Selected Instrumentation Technical Specifications," February 1991.
10. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
11. NEDC-32410P-A, "Nuclear Measurement Analysis and Control Power Range Neutron Monitor (NUMAC PRNM) Retrofit Plus Option III Stability Trip Function," October 1995.

(continued)

BASES

REFERENCES
(continued)

- 12. NEDO 33091-A, Revision 2, "Improved BPWS Control Rod Insertion Process," July 2004.
- 13. XN-NF-80-19(P)(A), Volume 1, "Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis," (as identified in the COLR).
- 14. EMF-2158(P)(A), "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," (as identified in the COLR).
- 15. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)," Framatome Inc., March 2018

(continued)

BASES (continued)

APPLICABLE
SAFETY ANALYSES

The operation of the Reactor Coolant Recirculation System is an initial condition assumed in the design basis loss of coolant accident (LOCA) (Ref. 1). During a LOCA caused by a recirculation loop pipe break, the intact loop is assumed to provide coolant flow during the first few seconds of the accident. The initial core flow decrease is rapid because the recirculation pump in the broken loop ceases to pump reactor coolant to the vessel almost immediately. The pump in the intact loop coasts down relatively slowly. This pump coastdown governs the core flow response for the next several seconds until the jet pump suction is uncovered (Ref. 1). The LOCA analysis accounts for the loop flow mismatch allowed by the LCO (Refs. [9](#) and [11](#)). The recirculation system is also assumed to have sufficient flow coastdown characteristics to maintain fuel thermal margins during abnormal operational transients (Ref. 2), which are analyzed in Chapter 14 of the FSAR.

(continued)

BASES

APPLICABLE SAFETY ANALYSES (continued)

Plant specific LOCA analyses have been performed assuming only one operating recirculation loop. These analyses have demonstrated that, in the event of a LOCA caused by a pipe break in the operating recirculation loop, the Emergency Core Cooling System response will provide adequate core cooling, provided the APLHGR requirements are modified accordingly (Refs. 7-9 and 811). The Maximum Extended Load Line Limit Analysis Plus (MELLLA+) operating domain has not been analyzed for single recirculation loop operation. Therefore, single loop operation is prohibited in the MELLLA+ operating domain (Ref. 10).

The transient analyses of Chapter 14 of the FSAR have also been performed for single recirculation loop operation (Ref. 7) and demonstrate sufficient flow coastdown characteristics to maintain fuel thermal margins during the abnormal operational transients analyzed provided the MCPR requirements are modified. During single recirculation loop operation, modification to the Reactor Protection System (RPS) average power range monitor (APRM) instrument setpoint is also required to account for the different relationships between recirculation drive flow and reactor core flow. The APLHGR and MCPR setpoints for single loop operation are specified in the COLR. The APRM Flow Biased Simulated Thermal Power-High setpoint is in LCO 3.3.1.1, "Reactor Protection System (RPS) Instrumentation."

Recirculation loops operating satisfies Criterion 2 of the NRC Policy Statement (Ref. 6).

(continued)

BASES (continued)

LCO	Two recirculation loops are required to be in operation with their flows matched within the limits specified in SR 3.4.1.1 to ensure that during a LOCA caused by a break of the piping of one recirculation loop the assumptions of the LOCA analysis are satisfied. With the limits specified in SR 3.4.1.1 not met, the recirculation loop with the lower flow must be considered not in operation. With only one recirculation loop in operation, modifications to the required APLHGR Limits (LCO 3.2.1, "AVERAGE PLANAR LINEAR HEAT GENERATION RATE (APLHGR)"), MCPR limits (LCO 3.2.2, "MINIMUM CRITICAL POWER RATIO (MCPR)"), and APRM Flow Biased Simulated Thermal Power-High Setpoint (LCO 3.3.1.1) may be applied to allow continued operation consistent with the assumptions of References <u>7-9</u> and <u>811</u>. Single loop operation is prohibited in the MELLLA+ operating domain. This prohibition is consistent with Reference 10.

APPLICABILITY	In MODES 1 and 2, requirements for operation of the Reactor Coolant Recirculation System are necessary since there is considerable energy in the reactor core and the limiting design basis transients and accidents are assumed to occur. In MODES 3, 4, and 5, the consequences of an accident are reduced and the coastdown characteristics of the recirculation loops are not important.

(continued)

BASES (continued)

REFERENCES

1. FSAR, Section 14.6.3.
 2. FSAR, Section 4.3.5.
 3. Deleted.
 4. Deleted.
 5. Deleted.
 6. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
 7. NEDO-24236, "Browns Ferry Nuclear Plant Units 1, 2, and 3, Single-Loop Operation," May 1981.
 8. ~~NEDC-32484P, "Browns Ferry Nuclear Plant Units 1, 2, and 3, SAFER/GESTR-LOCA Loss-of-Coolant Accident Analysis," Revision 6, February 2005. Not used.~~
 9. ~~ANP-3015(P), "Browns Ferry Units 1, 2, and 3 LOCA Break Spectrum Analysis," Revision 0, September 2011. ANP-3546P Revision 0, "Browns Ferry Units 1, 2, and 3 LOCA Break Spectrum Analysis for ATRIUM 10XM Fuel (EPU MELLLA+)," AREVA Inc., March 2017.~~
 10. NEDC-33006P-A, "General Electrical Boiling Water Reactor Maximum Extended Load Line Limit Analysis Plus Licensing Topical Report," Revision 3, June 2009.
 11. ANP-3905P Revision 1, "Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel," Framatome Inc., July 2021.
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BASES

BACKGROUND (continued)

RCS is still pressurized. If HPCI fails, it is backed up by ADS in combination with LPCI and CS. In this event, either the vessel would be manually depressurized or the ADS timed sequence would be allowed to time out and open the selected safety/relief valves (S/RVs) depressurizing the RCS, thus allowing the LPCI and CS to overcome RCS pressure and inject coolant into the vessel. If the break is large, RCS pressure initially drops rapidly and the LPCI and CS cool the core.

Water from the break returns to the suppression pool where it is used again and again. Water in the suppression pool may be circulated through a heat exchanger cooled by the RHR Service Water System. Depending on the location and size of the break, portions of the ECCS may be ineffective; however, the overall design is effective in cooling the core regardless of the size or location of the piping break.

All ECCS subsystems are designed to ensure that no single active component failure will prevent automatic initiation and successful operation of the minimum required ECCS equipment.

The CS System (Ref. 1) is composed of two independent subsystems. Each subsystem consists of two 50% capacity motor driven pumps, a spray sparger above the core, and piping and valves to transfer water from the suppression pool to the sparger. The LOCA analysis (Refs. 13 and 16) requires both pumps in a subsystem (loop) to be OPERABLE for the subsystem to be OPERABLE. Failure of one CS pump results in the loss of the associated CS loop for LOCA mitigation. The CS System is designed to provide cooling to the reactor core when reactor pressure is low. Upon receipt of an initiation signal, the CS pumps in both subsystems are automatically started (A pump

(continued)

BASES

APPLICABLE SAFETY ANALYSES (continued)

c. Maximum hydrogen generation from a zirconium water reaction is ≤ 0.01 times the hypothetical amount that would be generated if all of the metal in the cladding surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react;

d. The core is maintained in a coolable geometry; and

e. Adequate long term cooling capability is maintained.

The limiting single failures are discussed in References [13](#) and [16](#). For a large or small pipe break LOCA and events requiring ADS operation, selected battery failure is considered the most severe single failure. The remaining OPERABLE ECCS subsystems provide the capability to adequately cool the core and prevent excessive fuel damage.

The ECCS satisfy Criterion 3 of the NRC Policy Statement (Ref. 14).

LCO

Each ECCS injection/spray subsystem and six ADS valves are required to be OPERABLE. The ECCS injection/spray subsystems are defined as the two CS subsystems, the two LPCI subsystems, and one HPCI System. The low pressure ECCS injection/spray subsystems are defined as the two CS subsystems and the two LPCI subsystems.

With less than the required number of ECCS subsystems OPERABLE, the potential exists that during a limiting design basis LOCA concurrent with the worst case single failure, the limits specified in Reference 9 could be exceeded. All ECCS subsystems and ADS must therefore be OPERABLE to satisfy the single failure criterion required by Reference 9.

(continued)

BASES

ACTIONS (continued)

E.1

The LCO requires six ADS valves to be OPERABLE in order to provide the ADS function. References 13 and 16 contains the results of an analysis that evaluated the effect of one ADS valve being out of service. Per this analysis, operation of only five ADS valves will provide the required depressurization. However, overall reliability of the ADS is reduced, because a single failure in the OPERABLE ADS valves could result in a reduction in depressurization capability. Therefore, operation is only allowed for a limited time. The 14 day Completion Time is based on a reliability study cited in Reference 11 and has been found to be acceptable through operating experience.

F.1 and F.2

If any one low pressure ECCS injection/spray subsystem, or one LPCI pump in both LPCI subsystems, is inoperable in addition to one inoperable ADS valve, adequate core cooling is ensured by the OPERABILITY of HPCI and the remaining low pressure ECCS injection/spray subsystem. However, overall ECCS reliability is reduced because a single active component failure concurrent with a design basis LOCA could result in the minimum required ECCS equipment not being available. Since both a high pressure system (ADS) and a low pressure subsystem are inoperable, a more restrictive Completion Time of 72 hours is required to restore either the low pressure ECCS subsystem or the ADS valve to OPERABLE status. This Completion Time is based on a reliability study cited in Reference 11 and has been found to be acceptable through operating experience.

(continued)

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.5.1.6, SR 3.5.1.7, and SR 3.5.1.8

The performance requirements of the low pressure ECCS pumps are determined through application of the 10 CFR 50, Appendix K criteria (Ref. 7). This periodic Surveillance is performed (in accordance with the ASME OM Code requirements for the ECCS pumps) to verify that the ECCS pumps will develop the flow rates required by the respective analyses. The low pressure ECCS pump flow rates ensure that adequate core cooling is provided to satisfy the acceptance criteria of References 13, ~~and 15,~~ and 16. The pump flow rates are verified against a system head equivalent to the RPV pressure expected during a LOCA. The total system pump outlet pressure is adequate to overcome the elevation head pressure between the pump suction and the vessel discharge, the piping friction losses, and RPV pressure present during a LOCA. These values may be established by testing or analysis or during preoperational testing.

The flow tests for the HPCI System are performed at two different pressure ranges such that system capability to provide rated flow is tested at both the higher and lower operating ranges of the system. Additionally, adequate steam flow must be passing through the main turbine or turbine bypass valves to continue to control reactor pressure when the HPCI System diverts steam flow. Reactor steam pressure must be ≥ 950 psig to perform SR 3.5.1.7 and ≥ 150 psig to perform SR 3.5.1.8. Adequate steam flow is represented by at least two turbine bypass valves full open for SR 3.5.1.7 and SR 3.5.1.8. Therefore, sufficient time is allowed after adequate

(continued)

BASES (continued)

REFERENCES

1. FSAR, Section 6.4.3.
2. FSAR, Section 6.4.4.
3. FSAR, Section 6.4.1.
4. FSAR, Section 6.4.2.
5. FSAR, Section 14.6.3.
6. FSAR, Section 14.6.5.
7. 10 CFR 50, Appendix K.
8. FSAR, Section 6.5.3.
9. 10 CFR 50.46.
10. TVA BFN System Design Criteria BFN-50-7032, Control Air System - Units 1, 2, and 3.
11. Memorandum from R. L. Baer (NRC) to V. Stello, Jr. (NRC), "Recommended Interim Revisions to LCOs for ECCS Components," December 1, 1975.
12. 10 CFR 50, Appendix A, GDC 34, GDC 35, GDC 36, and GDC 37.
13. ANP-3377P Revision 3, Browns Ferry Units 1, 2, and 3 LOCA Break Spectrum Analysis for ATRIUM 10XM Fuel (EPU), August 2015; ANP-3546P Revision 0, "Browns Ferry Units 1, 2, and 3 LOCA Break Spectrum Analysis for ATRIUM 10XM Fuel (EPU MELLLA+)," AREVA Inc., March 2017.
14. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
15. GE-NE-B13-01755-2, "Relaxation of ECCS Parameters, Revision 2, December 1996.
16. ANP-3905P Revision 1, "Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel," Framatome Inc., July 2021.

B 3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS) AND REACTOR CORE ISOLATION COOLING (RCIC) SYSTEM

B 3.5.2 ECCS - Shutdown

BASES

BACKGROUND	A description of the Core Spray (CS) System and the low pressure coolant injection (LPCI) mode of the Residual Heat Removal (RHR) System is provided in the Bases for LCO 3.5.1, "ECCS - Operating." For LCO 3.5.2, only one pump is required for an OPERABLE subsystem, as stated in the LCO Bases below.

APPLICABLE SAFETY ANALYSES	The ECCS performance is evaluated for the entire spectrum of break sizes in the long term cooling analysis (Ref. 1 and 3) for a postulated loss of coolant accident (LOCA). The ECCS requirements are significantly reduced during shutdown since a LOCA is not postulated to occur. However, some ECCS capability may be required to restore and maintain the reactor coolant level in the event of an inadvertent draindown. It is reasonable to assume, based on engineering judgment, that while in MODES 4 and 5, one low pressure ECCS injection/spray subsystem can maintain adequate reactor vessel water level in the event of an inadvertent vessel draindown. To provide redundancy, a minimum of two low pressure ECCS injection/spray subsystems are required to be OPERABLE in MODES 4 and 5.

The low pressure ECCS subsystems satisfy Criterion 3 of the NRC Policy Statement (Ref. 2).

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.5.2.3 (continued)

In MODES 4 and 5, the RHR System may operate in the shutdown cooling mode to remove decay heat and sensible heat from the reactor. Therefore, RHR valves that are required for LPCI subsystem operation may be aligned for decay heat removal. Therefore, this SR is modified by a Note that allows one LPCI subsystem of the RHR System to be considered OPERABLE for the ECCS function if all the required valves in the LPCI flow path can be manually realigned (remote or local) to allow injection into the RPV, and the system is not otherwise inoperable. This will ensure adequate core cooling if an inadvertent RPV draindown should occur.

REFERENCES

1. ~~ANP-3377P Revision 3, Browns Ferry Units 1, 2, and 3 LOCA Break Spectrum Analysis for ATRIUM 10XM Fuel (EPU), August 2015.~~ ANP-3546P Revision 0, "Browns Ferry Units 1, 2, and 3 LOCA Break Spectrum Analysis for ATRIUM 10XM Fuel (EPU MELLLA+)," AREVA Inc., March 2017.
 2. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
 3. ANP-3905P Revision 1, "Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel," Framatome Inc., July 2021.
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BASES

SURVEILLANCE REQUIREMENTS

SR 3.6.1.1.2 (continued)

Satisfactory performance of this SR can be achieved by establishing a known differential pressure between the drywell and the suppression chamber and verifying that the pressure in either the suppression chamber or the drywell does not change by more than 0.25 inch of water per minute over a 10 minute period. The leakage test is performed every 24 months. The 24 month Frequency was developed considering it is prudent that this Surveillance be performed during a unit outage and also in view of the fact that component failures that might have affected this test are identified by other primary containment SRs.

REFERENCES

1. NEDC-~~33960P~~33860P, "Safety Analysis Report for Browns Ferry Nuclear Plant Units 1, 2, and 3 Extended Power Uprate," GE Hitachi Nuclear Energy, October 2016. Section 2.6.
 2. FSAR, Section 14.6.
 3. 10 CFR 50, Appendix J, Option B.
 4. NEI 94-01, Revision 3A, "Industry Guideline for Implementing Performance-Based Option of 10 CFR Part 50, Appendix J."
 5. ANSI/ANS-56.8-2002, "American National Standard for Containment System Leakage Testing Requirements."
 6. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
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B 3.6 CONTAINMENT SYSTEMS

B 3.6.3.1 Containment Atmosphere Dilution (CAD) System

BASES

BACKGROUND

The CAD System functions to maintain combustible gas concentrations within the primary containment at or below the flammability limits following a postulated loss of coolant accident (LOCA) by diluting hydrogen and oxygen with nitrogen. To ensure that a combustible gas mixture does not occur, oxygen concentration is kept < 5.0 volume percent (v/o), or hydrogen concentration is kept < 4.0 v/o.

The CAD System is manually initiated and consists of two independent, 100% capacity subsystems, each of which is capable of supplying nitrogen through separate piping systems to the drywell and suppression chamber of each unit. Each subsystem includes a liquid nitrogen supply tank, ambient vaporizer, electric heater (unqualified), and a manifold with branches to each primary containment (for Units 1, 2, and 3). The nitrogen storage tanks each contain ≥ 2615 gal, which is adequate for 7 days of CAD subsystem operation (Refs. 4 and 5).

The CAD System operates in conjunction with emergency operating procedures that are used to reduce primary containment pressure periodically during CAD System operation. This combination results in a feed and bleed approach to maintaining hydrogen and oxygen concentrations below combustible levels.

(continued)

BASES (continued)

REFERENCES

1. AEC Safety Guide 7, Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident, March 10, 1971.
 2. FSAR, Section 5.2.6.
 3. NRC No. 93-102, "Final Policy Statement on Technical Specification Improvements," July 23, 1993.
 4. ANP-3403P Revision 2, "Fuel Uprate Safety Analysis Report for Browns Ferry ~~Nuclear Plant~~ Units 1, 2, and 3," AREVA Inc., August 2015. Section 2.6.4.
 5. FS1-0055816 Revision 1.0, "Evaluation of ATRIUM 11 Fuel and the Containment Atmospheric Dilution System," Framatome Inc., April 1, 2021.
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B 3.10 SPECIAL OPERATIONS

B 3.10.7 Control Rod Testing - Operating

BASES

BACKGROUND

The purpose of this Special Operations LCO is to permit control rod testing, while in MODES 1 and 2, by imposing certain administrative controls. Control rod patterns during startup conditions are controlled by the operator and the rod worth minimizer (RWM) (LCO 3.3.2.1, "Control Rod Block Instrumentation"), such that only the specified control rod sequences and relative positions required by LCO 3.1.6, "Rod Pattern Control," are allowed over the operating range from all control rods inserted to the low power setpoint (LPSP) of the RWM. The sequences effectively limit the potential amount and rate of reactivity increase that could occur during a control rod drop accident (CRDA). During these conditions, control rod testing is sometimes required that may result in control rod patterns not in compliance with the prescribed sequences of LCO 3.1.6. These tests include SDM demonstrations, control rod scram time testing, and control rod friction testing. This Special Operations LCO provides the necessary exemption to the requirements of LCO 3.1.6 and provides additional administrative controls to allow the deviations in such tests from the prescribed sequences in LCO 3.1.6.

APPLICABLE SAFETY ANALYSES

The analytical methods and assumptions used in evaluating the CRDA are summarized in [References 1, 2, 3, and 4](#) [Reference 5](#). CRDA analyses assume the reactor operator follows prescribed withdrawal sequences. These sequences define the potential initial conditions for the CRDA analyses. The RWM provides backup to operator control of the withdrawal sequences to ensure the initial conditions of the CRDA analyses are not

(continued)

BASES

APPLICABLE SAFETY ANALYSES (continued)

violated. For special sequences developed for control rod testing, the initial control rod patterns assumed in the safety analysis of ~~References 1, 2, 3, and 4~~ Reference 5 may not be preserved. Therefore, special CRDA analyses may be required to demonstrate that these special sequences will not result in unacceptable consequences, should a CRDA occur during the testing. These analyses, performed in accordance with an NRC approved methodology, are dependent on the specific test being performed.

As described in LCO 3.0.7, compliance with Special Operations LCOs is optional, and therefore, no criteria of the NRC Policy Statement apply. Special Operations LCOs provide flexibility to perform certain operations by appropriately modifying requirements of other LCOs. A discussion of the criteria satisfied for the other LCOs is provided in their respective Bases.

LCO

As described in LCO 3.0.7, compliance with this Special Operations LCO is optional. Control rod testing may be performed in compliance with the prescribed sequences of LCO 3.1.6, and during these tests, no exceptions to the requirements of LCO 3.1.6 are necessary. For testing performed with a sequence not in compliance with LCO 3.1.6, the requirements of LCO 3.1.6 may be suspended, provided additional administrative controls are placed on the test to ensure that the assumptions of the special safety analysis for the test sequence are satisfied. Assurances that the test sequence is followed can be provided by either programming the test sequence into the RWM, with conformance verified as specified in SR 3.3.2.1.8 and allowing the RWM to monitor

(continued)

BASES

LCO (continued)	control rod withdrawal and provide appropriate control rod blocks if necessary, or by verifying conformance to the approved test sequence by a second licensed operator or other qualified member of the technical staff (i.e., personnel trained in accordance with an approved training program for this test). These controls are consistent with those normally applied to operation in the startup range as defined in the SRs and ACTIONS of LCO 3.3.2.1, "Control Rod Block Instrumentation."

APPLICABILITY	Control rod testing, while in MODES 1 and 2, with THERMAL POWER greater than 10% RTP, is adequately controlled by the existing LCOs on power distribution limits and control rod block instrumentation. Control rod movement during these conditions is not restricted to prescribed sequences and can be performed within the constraints of LCO 3.2.1, "AVERAGE PLANAR LINEAR HEAT GENERATION RATE (APLHGR)," LCO 3.2.2, "MINIMUM CRITICAL POWER RATIO (MCPR)," LCO 3.2.3, "LINEAR HEAT GENERATION RATE (LHGR)," and LCO 3.3.2.1. With THERMAL POWER less than or equal to 10% RTP, the provisions of this Special Operations LCO are necessary to perform special tests that are not in conformance with the prescribed sequences of LCO 3.1.6. While in MODES 3 and 4, control rod withdrawal is only allowed if performed in accordance with Special Operations LCO 3.10.3, "Single Control Rod Withdrawal - Hot Shutdown," or Special Operations LCO 3.10.4, "Single Control Rod Withdrawal - Cold Shutdown," which provide adequate controls to ensure that the assumptions of the safety analyses of ~~References 1, 2, 3, and 4~~ <u>Reference 5</u> are

(continued)

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.10.7.2

When the RWM provides conformance to the special test sequence, the test sequence must be verified to be correctly loaded into the RWM prior to control rod movement. This Surveillance demonstrates compliance with SR 3.3.2.1.8, thereby demonstrating that the RWM is OPERABLE. A Note has been added to indicate that this Surveillance does not need to be performed if SR 3.10.7.1 is satisfied.

REFERENCES

1. ~~NEDE-24011-P-A, Rev. 16, "General Electric Standard Application for Reactor Fuel," October 2007. Not used.~~
2. ~~Letter from T. Pickens (BWROG) to G. C. Lainas (NRC) "Amendment 17 to General Electric Licensing Topical Report NEDE-24011-P-A," August 15, 1986. Not used.~~
3. ~~XN-NF-80-19(P)(A), Volume 1, "Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis," (as identified by the COLR). Not used.~~
4. ~~EMF-2158(P)(A), "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," (as identified in the COLR). Not used.~~
5. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)," Framatome Inc., March 2018.

BASES (continued)

APPLICABLE
SAFETY ANALYSES

Prevention and mitigation of unacceptable reactivity excursions during control rod withdrawal, with the reactor mode switch in the startup/hot standby position while in MODE 5, is provided by the intermediate range monitor (IRM) neutron flux scram (LCO 3.3.1.1, "Reactor Protection System (RPS) Instrumentation"), and control rod block instrumentation (LCO 3.3.2.1, "Control Rod Block Instrumentation"). The limiting reactivity excursion during startup conditions while in MODE 5 is the control rod drop accident (CRDA).

CRDA analyses assume that the reactor operator follows prescribed withdrawal sequences. For SDM tests performed within these defined sequences, the analyses of ~~References 1, 2, 3, and 4~~ Reference 5 are applicable. However, for some sequences developed for the SDM testing, the control rod patterns assumed in the safety analyses of ~~References 1, 2, 3, and 4~~ Reference 5 may not be met. Therefore, special CRDA analyses, performed in accordance with an NRC approved methodology, may be required to demonstrate the SDM test sequence will not result in unacceptable consequences should a CRDA occur during the testing. For the purpose of this test, the protection provided by the normally required MODE 5 applicable LCOs, in addition to the requirements of this LCO, will maintain normal test operations as well as postulated accidents within the bounds of the appropriate safety analyses (~~Refs. 1, 2, 3, and 4~~ Ref. 5). In addition to the added requirements for the RWM, APRM, and control rod coupling, the notch out mode is specified for out of sequence withdrawals. Requiring the notch out mode limits withdrawal steps to a single notch, which limits inserted reactivity, and allows adequate monitoring of changes in neutron flux, which may occur during the test.

(continued)

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.10.8.5

Coupling verification is performed to ensure the control rod is connected to the control rod drive mechanism and will perform its intended function when necessary. The verification is required to be performed any time a control rod is withdrawn to the "full out" notch position, or prior to declaring the control rod OPERABLE after work on the control rod or CRD System that could affect coupling. This Frequency is acceptable, considering the low probability that a control rod will become uncoupled when it is not being moved as well as operating experience related to uncoupling events.

SR 3.10.8.6

CRD charging water header pressure verification is performed to ensure the motive force is available to scram the control rods in the event of a scram signal. Since the reactor is depressurized in MODE 5, there is insufficient reactor pressure to scram the control rods. Verification of charging water pressure ensures that if a scram is required, capability for rapid control rod insertion would exist. The minimum pressure of 940 psig, which is well below the expected pressure of approximately 1100 psig, ensures sufficient pressure for rapid control rod insertion. The 7 day Frequency has been shown to be acceptable through operating experience and takes into account indications available in the control room.

REFERENCES

1. ~~NEDE-24011 P-A, Rev. 16, "General Electric Standard Application for Reactor Fuel," October 2007. Not used.~~
2. ~~Letter from T. Pickens (BWROG) to G. C. Lainas, NRC, "Amendment 17 to General Electric Licensing Topical Report NEDE-24011 P-A," August 15, 1986. Not used.~~

(continued)

BASES

REFERENCES
(continued)

3. ~~XN-NF-80-19(P)(A), Volume 1 "Exxon Nuclear Methodology for Boiling Water Reactors – Neutronic Methods for Design and Analysis," (as identified in the COLR). Not used.~~
4. ~~EMF-2158(P)(A), "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," (as identified in the COLR). Not used.~~
5. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)," Framatome Inc., March 2018.

ATTACHMENT 4

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

List of Regulatory Commitments

List of Regulatory Commitments

Commitment Description	Scheduled Completion Date
TVA will submit the Browns Ferry Unit 2 Cycle 23 Fuel Cycle Design Report to the NRC for information.	15 days following TVA approval of the report
TVA will submit the Browns Ferry Unit 2 Cycle 23 Fuel Bundle Design Report to the NRC for information.	15 days following TVA approval of the report
TVA will submit the Browns Ferry Unit 2 Cycle 23 Safety Limit MCPR Report to the NRC for information.	15 days following TVA approval of the report
TVA will submit the Browns Ferry Unit 2 Cycle 23 Fuel Rod Design Report to the NRC for information.	15 days following TVA approval of the report
TVA will submit the Browns Ferry Unit 2 Cycle 23 Reload Safety Analysis Report to the NRC for information.	15 days following TVA approval of the report
TVA will submit the Browns Ferry Unit 3 Cycle 22 Reload Safety Analysis Report to the NRC for information.	Prior to startup from the Unit 3 Cycle 21 refueling outage
TVA will submit the Browns Ferry Unit 1 Cycle 16 Reload Safety Analysis Report to the NRC for information.	Prior to startup from the Unit 1 Cycle 15 refueling outage

ATTACHMENT 5a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3857P Revision 2

(Proprietary)

Design Limits for Framatome Critical Power Correlations

ATTACHMENT 5b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3857NP Revision 2

(Non Proprietary)

Design Limits for Framatome Critical Power Correlations

Design Limits for Framatome Critical Power Correlations

ANP-3857NP
Revision 2

July 2020

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Corrected the reference numbers in Table 1.

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1.0 INTRODUCTION

Design limits are provided for Boiling Water Reactor (BWR) critical power correlations. These limits are based solely on the critical power correlation uncertainty determined from benchmarking the correlation to experimental data. Pressurized Water Reactor (PWR) Departure from Nucleate Boiling (DNB) correlation design limits are typically determined from the correlation uncertainty. The statistical expectation for the design limit is provided in Reference 1 where it states,

For departure from nucleate boiling ratio (DNBR), CHF or CPR correlations, there should be a 95-percent probability at the 95-percent confidence level that the hot rod in the core does not experience a DNB or boiling transition condition during normal operation or AOOs

Design limits for PWR are typically reported and reviewed in the correlation topical reports (for example Reference 2) and are associated with the fuel, independent of the reactor. In this report, comparable limits are determined for BWR critical power correlations.

2.0 DEFINITIONS

With respect to the limit on Critical Heat Flux (CHF), the Safety Limit (SL) in the BWR is defined in the technical specifications as the lowest allowable Critical Power Ratio (CPR) in the reactor core. The CPR is defined in Reference 3.

The CPR is that power in the assembly that is calculated by application of the appropriate correlation(s) to cause some point in the assembly to experience boiling transition, divided by the actual assembly operating power.

The SL on MCPR (sometimes referred to as SLMCPR) includes the influence of plant dependent and fuel dependent uncertainties.

In this report, a design limit is established from the critical power correlation and its uncertainty. This limit determined to be the value of CPR such that, at the 95% confidence level, there is 95% probability that dryout is avoided.

3.0 CRITICAL POWER CORRELATION STATISTICS

In the context of the CPR defined above, an Experimental Critical Power Ratio (ECPR) is defined

$$ECPR = \frac{\text{Measured Critical Power}}{\text{Calculated Critical Power}} \quad (1)$$

According to this definition, an ECPR that is less than 1.0 is non-conservative and a value greater than 1.0 is conservative. For best estimate critical power correlations, the mean value of ECPR is 1.0 or very close to 1.0. The representation of the ECPR as a normal distribution is addressed directly in the critical power correlation topical report. With the conclusion that the distribution is represented by a normal distribution, the design limit is calculated

$$MCPR_{95/95} = \frac{1 + k_{95/95}s}{ECPR} \quad (2)$$

where k is the one sided tolerance limit factor generally attributed to D. B. Owen and given by Reference 4 or 5 and s is the sample standard deviation.

The ECPR definition applied by Framatome for statistical analysis of the critical power correlations is the inverse of the definition shown in Equation (1).

$$ECPR = \frac{\text{Calculated Critical Power}}{\text{Measured Critical Power}} \quad (3)$$

According to this definition of the ECPR, the design limit is calculated

$$MCPR_{95/95} = ECPR \times (1 + k_{95/95}s) \quad (4)$$

It is observed that when the ECPR is equal to 1.0, Equations (2) and (4) become equal.

4.0 DESIGN LIMITS

The design limits for Framatome fuel are calculated in Table 1 using Equation (4).

Table 1 MCPR_{95/95} Limits for Framatome Fuel

Correlation:	SPCB (ATRIUM 10)	ACE ATRIUM 10	ACE ATRIUM 10XM	ACE ATRIUM 11
Reference	6	7	8	9
Number of Data	[]	[]	[]	[]
Mean ECPR	[]	[]	[]	[]
Std. Dev.	[]	[]	[]	[]
D.B. Owen $k_{95/95}$ *	[]	[]	[]	[]
Design Limit [†]	1.04	1.04	1.05	1.05

* The D.B. Owen k factors were interpolated from the table and then conservatively rounded upward to three digits.

† The design limit was rounded upward to two digits.

5.0 REFERENCES

1. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition – Reactor," NUREG-0800, Chapter 4.4, Revision 2, page 4.4-5.
2. EMF-92-153(P)(A), Revision 1, "HTP: Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel," Siemens Power Corporation, Nuclear Division, January 2005.
3. "Standard Technical Specifications General Electric BWR/4 Plants Volume 1," NUREG-1433 Volume 1.0, Revision 4.0, ADAMS Ascension No. ML12104A192, page 1.1-4.
4. D. B. Owen, "Factors for One-sided Tolerance Limits and for Variables Sampling Plans," Sandia Corporation Report SCR-607, March 1963.
5. M. G. Natrella, "Experimental Statistics," National Bureau of Standards Handbook 91, August 1963.
6. EMF-2209(P)(A), Revision 3, "SPCB Critical Power Correlation," AREVA NP Inc., September 2009.
7. ANP-10249P-A, Revision 2, "ACE/ATRIUM-10 Critical Power Correlation," AREVA Inc., March 2014.
8. ANP-10298P-A, Revision 1, "ACE/ATRIUM 10XM Critical Power Correlation," AREVA Inc., March 2014.
9. ANP-10335P-A, Revision 0, "ACE/ATRIUM 11 Critical Power Correlation," Framatome Inc., May 2018.

ATTACHMENT 6a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3854P Revision 1

(Proprietary)

Browns Ferry ATRIUM 11 Equilibrium Cycle Fuel Cycle Design Report

ATTACHMENT 6b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3854NP Revision 1

(Non Proprietary)

Browns Ferry ATRIUM 11 Equilibrium Cycle Fuel Cycle Design Report

Browns Ferry ATRIUM 11 Equilibrium Cycle

ANP-3854NP
Revision 1

Fuel Cycle Design Report

June 2020

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	Pages 3-9 through 3-12	Changes were made in Proprietary version of this report.

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Nomenclature

Acronym	Definition
[]	the information contained within brackets is proprietary to Framatome Inc.
ACE	Framatome critical power correlation []
BOC	beginning of cycle
BOL	beginning of life
BWR	boiling water reactor
CSDM	cold shutdown margin
EOC	end of cycle
EOFP	end of full power capability
FFTR	final feedwater temperature reduction
GWd/MTU	gigawatt days per metric ton of initial uranium
HEXR	hot excess reactivity
LHGR	linear heat generation rate
MCPR	minimum critical power ratio
MELLLA+	maximum extended load line limit analysis plus
MICROBURN-B2	Framatome Inc. advanced BWR core simulator methodology with PPR capability
MWd/MTU	megawatt days per metric ton of initial uranium
NEOC	near end of cycle (MCPR limit exposure breakpoint)
NRC	(United States) Nuclear Regulatory Commission
PLFR	part length fuel rod
PPR	Pin Power Reconstruction. The PPR methodology accounts for variation in local rod power distributions due to neighboring assemblies and control state. The local rod power distributions are reconstructed based on the actual flux solution for each statepoint.
R Value	the larger of zero or the shutdown margin at BOC minus the minimum calculated shutdown margin in the cycle
SLC	standby liquid control

1.0 INTRODUCTION

Framatome Inc. has performed an equilibrium fuel cycle design for Browns Ferry. This design uses the ATRIUM 11 fuel assembly and the MELLLA+ operating domain. This analysis has been performed with the approved Framatome Inc. neutronic modeling methodology (Reference 1). The CASMO-4 lattice depletion code was used to generate nuclear data including cross sections and local power peaking factors. The MICROBURN-B2 three dimensional core simulator code, combined with the application of the ACE critical power correlation (Reference 2), was used to model the core. The MICROBURN-B2 pin power reconstruction (PPR) model was used to determine the thermal margins presented in this report. Design results including projected control rod patterns and evaluations of thermal and reactivity margins are also presented in this report. The following MICROBURN-B2 Version 2 modeling features were also used in the analyses supporting this document:

- Control Blade B-10 Depletion
- Explicit modeling treatment of spacer grids
- Explicit modeling of PLFR plenums
- Explicit modeling of the water rod flow

The following ATRIUM 11 fuel operating limits were assumed for the equilibrium cycle depletion:



2.0 SUMMARY

The fresh batch size [] and batch average enrichment [] were determined to meet the energy requirements provided by Tennessee Valley Authority (Reference 3). The complete description of the fresh reload assemblies is provided with Reference 6. The loading of the fuel as described in this report results in a projected full power energy capability of $2,506 \pm 42$ GWd ($18,107 \pm 300$ MWd/MTU). Beyond the full power capability, the cycle has been designed to achieve 180 GWd additional energy via FFTR and coastdown operation.

In order to obtain optimum operating flexibility, the projected control rod patterns were developed with acceptable margin to thermal limits in accordance with Reference 3. The cycle design calculations also demonstrate adequate hot excess reactivity and cold shutdown margin throughout the cycle. Key results from the design analysis are summarized in Table 2.1. Table 2.2 summarizes the assembly identification range by nuclear fuel type batch. Figures 2.1 and 2.2 provide a summary of the cycle design step-through projection.

**Table 2.1 Browns Ferry Equilibrium Cycle Energy and Key Results
Summary**

Cycle Energy, GWd (Cycle Exposure, MWd/MTU)	
Cycle N-1	
• Nominal EOC	2,685 (19,405)
• Short window EOC	2,602 (18,804)
• Long window EOC	2,740 (19,804)
Cycle N	
• EOFP Energy	2,506±42 (18,107±300)
• FFTR and coastdown Energy	180 (1,298)
• EOC Energy	2,685±42 (19,405±300)
Key Results	
BOC CSDM, %Δk/k (based on short EOC N-1)	1.16
Minimum CSDM, %Δk/k (based on short EOC N-1)	1.16
Cycle Exposure of Minimum CSDM, MWd/MTU (short basis)	0
Moderator Temperature of Minimum CSDM, °F (short basis)	68
Cycle R Value, %Δk/k (short basis)	0.00
BOC CSDM, %Δk/k (based on nominal EOC N-1)	1.41
Minimum CSDM, %Δk/k (based on nominal EOC N-1)	1.41
Cycle Exposure of Minimum CSDM, MWd/MTU (nominal basis)	0
Moderator Temperature of Minimum CSDM, °F (nominal basis)	68
Cycle R Value, %Δk/k (nominal basis)	0.00
BOC CSDM, %Δk/k (based on long EOC N-1)	1.64
Minimum CSDM, %Δk/k (based on long EOC N-1)	1.64
Cycle Exposure of Minimum CSDM, MWd/MTU (long basis)	0
Moderator Temperature of Minimum CSDM, °F (long basis)	68
Cycle R Value, %Δk/k (long basis)	0.00

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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Key Results	
Minimum SLC SDM, % $\Delta k/k$ (based on short EOC N-1)	1.57
Cycle Exposure of Minimum SLC SDM, MWd/MTU (short basis)	0
Minimum SLC SDM, % $\Delta k/k$ (based on nominal EOC N-1)	1.86
Cycle Exposure of Minimum SLC SDM, MWd/MTU (nominal basis)	0
Minimum SLC SDM, % $\Delta k/k$ (based on long EOC N-1)	2.07
Cycle Exposure of Minimum SLC SDM, MWd/MTU (long basis)	0
BOC HEXR, % $\Delta k/k$ (based on short EOC N-1)	1.77
Maximum HEXR, % $\Delta k/k$ (based on short EOC N-1)	2.44
Cycle Exposure of Maximum HEXR, MWd/MTU (short basis)	12,000
BOC HEXR, % $\Delta k/k$ (based on nominal EOC N-1)	1.42
Maximum HEXR, % $\Delta k/k$ (based on nominal EOC N-1)	1.99
Cycle Exposure of Maximum HEXR, MWd/MTU (nominal basis)	11,000
BOC HEXR, % $\Delta k/k$ (based on long EOC N-1)	1.18
Maximum HEXR, % $\Delta k/k$ (based on long EOC N-1)	1.80
Cycle Exposure of Maximum HEXR, MWd/MTU (long basis)	11,000
Minimum MAPLHGR Margin, %	11.2
Exposure of Minimum MAPLHGR Margin, MWd/MTU	6,900
Minimum LHGR Margin, %	12.1
Exposure of Minimum LHGR Margin, MWd/MTU	1,710
Minimum CPR Margin, %	7.5
Exposure of Minimum CPR Margin, MWd/MTU	17,451
Maximum Exposure Limit Ratio (Peak Rod)	0.97(Rod) 0.95(Bundle)
Exposure Limit Energy Basis, GWD (EOC N with long window step-out)	2,803.7
Reg. Guide 1.183 maximum rod average power (<6.3 kw/ft) for rods with burnup > 54 GWd/MTU	Met
Fuel Reliability Constraints and Core Loading Restrictions	
No peripheral fuel from previous cycle remaining in core	Met
No fresh fuel loaded with a corner on the periphery	Met
No startup sequence control rod cells that contain fuel from previous cycle which had a corner on the periphery	Met

Key Results	
No startup sequence control rod cells that contain fuel from the second row in from the periphery in the previous two cycles	Met
Do not load twice burnt assemblies in the central part of the core	Met
Satisfy C-lattice Channel Bow Requirements per SIL-320	Met
No same cell shuffles	Met
No cross quadrant shuffles with bundles going adjacent to an SRM	Met
Minimize cross quadrant shuffles	Met

**Table 2.2 Browns Ferry Equilibrium Cycle Fuel Cycle Design
Assembly ID Range by Nuclear Fuel Type**

Nuclear Fuel Type	Number of Assemblies	Assembly ID Range
13	[]	[]
14	[]	[]
15	[]	[]
16	[]	[]
17	[]	[]
18	[]	[]
19	[]	[]
20	[]	[]
21	[]	[]

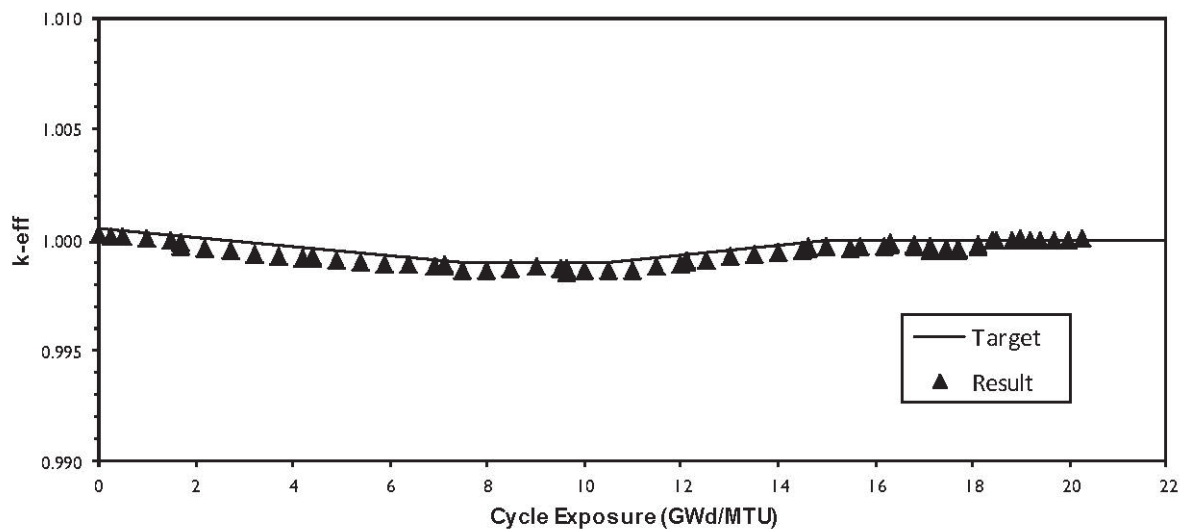


Figure 2.1 Browns Ferry Equilibrium Cycle Design Step-through k_{eff} versus Cycle Exposure

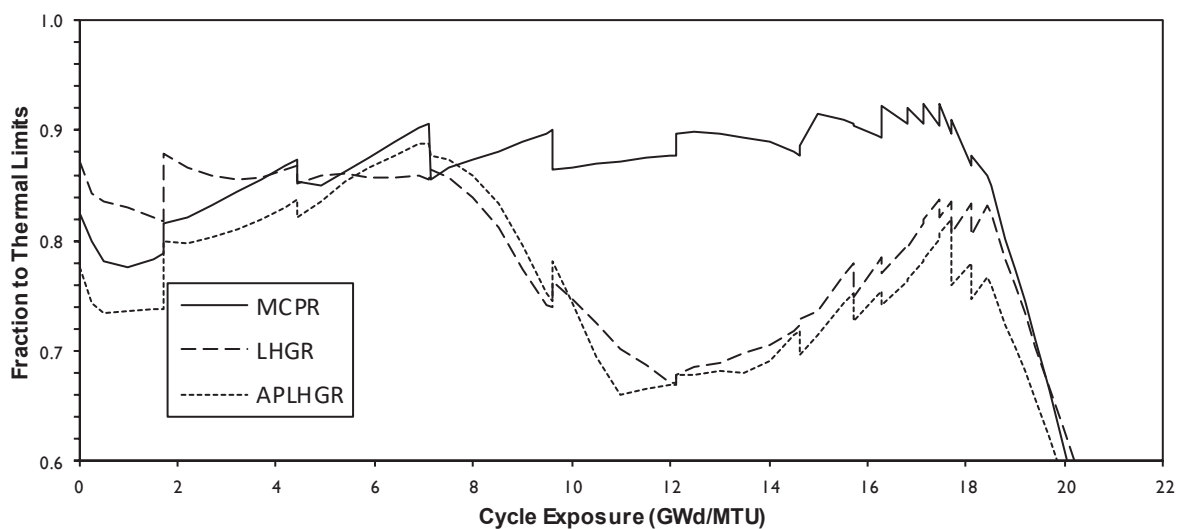


Figure 2.2 Browns Ferry Equilibrium Cycle Design Margin to Thermal Limits versus Cycle Exposure

3.0 EQUILIBRIUM CYCLE FUEL CYCLE DESIGN

3.1 *General Description*

The assembly design for the equilibrium cycle fresh reload fuel for Browns Ferry is described in detail in Reference 6. Elevation views of the fresh reload fuel design axial enrichment and gadolinia distributions are shown in Appendix B, Figures B.1 through B.3. The loading pattern maintains full core symmetry within a scatter load fuel management scheme. This loading in conjunction with the control rod patterns presented in Appendix A shows acceptable power peaking and associated margins to limits for projected equilibrium cycle operation. The analyses supporting this fuel cycle design were based on the core parameters shown in Table 3.1. Figures 3.1 through 3.5, along with Table 3.1 define the reference loading pattern used in the fuel cycle design. The specific core location of the fresh assemblies in the equilibrium cycle is provided in Appendix C. Key results for the cycle are summarized in Table 2.1.

3.2 *Control Rod Patterns and Thermal Limits*

Projected control rod patterns for the equilibrium cycle and resultant key operating parameters including thermal margins are shown in Appendix A. The thermal margins presented in this report were determined using the MICROBURN-B2 3D core simulator PPR model to provide adequate margin to thermal limits. A detailed summary of the core parameters resulting from the step-through projection analysis is provided in Tables A.1 and A.2. Limiting results from the step-through are summarized in Table 2.1 and in Figure 2.2. The hot operating target k-eff versus cycle exposure from Reference 4 which was determined to be appropriate for the equilibrium cycle is shown in Table 3.2. The k-eff and margin to limits results from the design cycle depletion are presented graphically in Figures 2.1 and 2.2. The k-eff values presented in Figure 2.1 and in Appendix A are not bias corrected. Selected exposure and radial power distributions from the design step-through are presented in Appendix D.

3.3 *Hot Excess Reactivity and Cold Shutdown Margin*

The equilibrium cycle design calculations demonstrate adequate hot excess reactivity, SLC shutdown margin, and cold shutdown margin throughout the equilibrium cycle. Key shutdown margin and R-Value results are presented in Table 2.1. The shutdown margin for the equilibrium cycle is in conformance with the Technical Specification limit of $R + 0.38 \% \Delta k/k$ at BOC. The cold target k-eff versus exposure from Reference 4 determined to be appropriate for calculation of cold shutdown margin for the equilibrium cycle is shown in Table 3.3. The core hot excess reactivity was calculated at full power with all rods out, 102.5 Mlb/hr core flow, with equilibrium xenon. Tables 3.4 through 3.6 summarize the equilibrium cycle reactivity margins versus cycle exposure, including the SLC shutdown margin for the cycle.

Table 3.1 Equilibrium Cycle Core Composition and Design Parameters

Fuel Description	Cycle Loaded	Nuclear Fuel Type	Number of Assemblies
ATRIUM 11 []	N-2	13	[]
ATRIUM 11 []	N-2	14	[]
ATRIUM 11 []	N-2	15	[]
ATRIUM 11 []	N-1	16	[]
ATRIUM 11 []	N-1	17	[]
ATRIUM 11 []	N-1	18	[]
ATRIUM 11 []	N	19	[]
ATRIUM 11 []	N	20	[]
ATRIUM 11 []	N	21	[]

Number of Fuel Assemblies in Core	764
Total Number of Fresh Assemblies	[]
Total Core Mass, MTU	[]
Rated Thermal Power Level, MW _t	3,952
Rated Core Flow, Mlb/hr	102.5
Reference Pressure, psia	1,050*
Reference Inlet Subcooling, Btu/lbm	26.94 [†]

* Value is representative of MICROBURN-B2 input for dome pressure at rated conditions and varies depending on core state point.

[†] Value is typically determined by MICROBURN-B2 using a heat balance method based on nominal feedwater temperature and other parameters identified in the cycle specific plant parameters document.

**Table 3.2 Browns Ferry Equilibrium Cycle Hot Operating Target k-eff
Versus Cycle Exposure**

Cycle Exposure (MWd/MTU)	Hot Operating k-eff*
0.0	1.0005
7,500.0	0.9990
10,500.0	0.9990
15,000.0	1.0000
25,000.0	1.0000

**Table 3.3 Browns Ferry Equilibrium Cycle Cold Critical Target k-eff
Versus Cycle Exposure**

Cycle Exposure (MWd/MTU)	Cold Critical k-eff*
0.0	0.9940
25,000.0	0.9940

* Values are linearly interpolated between cycle exposure points.

**Table 3.4 Browns Ferry Equilibrium Cycle Reactivity Margin
Summary (Short EOC N-1)**

Cycle Exposure (MWd/MTU)	Cold Shutdown Margin* (% $\Delta k/k$)	SLC Cold Shutdown Margin [†] (% $\Delta k/k$)	Hot Excess Reactivity (% $\Delta k/k$)
0	1.16	1.57	1.77
250	1.20	1.92	1.64
1,000	1.48	2.29	1.50
2,200	1.71	2.52	1.56
3,200	1.85	2.64	1.63
4,200	2.04	2.72	1.73
5,400	2.31	2.74	1.87
6,400	2.56	2.72	2.01
7,500	2.72	2.70	2.17
8,500	2.72	2.76	2.28
10,000	2.68	2.96	2.39
11,000	2.57	3.16	2.43
12,000	2.43	3.46	2.44
13,000	2.32	3.83	2.42
14,000	2.22	4.22	2.32
15,130	1.88	4.62	2.05
16,400	1.51	5.03	1.47
17,143	1.38	5.34	0.92
18,220	1.40	5.99	--
18,530	1.43	6.20	--
19,405	1.71	6.93	--
20,262	2.32	7.91	--

* Values in **BOLD** are limiting values at elevated moderator temperatures.[†] Calculated at 366.0 °F ARO conditions.

**Table 3.5 Browns Ferry Equilibrium Cycle Reactivity Margin
Summary (Nominal EOC N-1)**

Cycle Exposure (MWd/MTU)	Cold Shutdown Margin* (% $\Delta k/k$)	SLC Cold Shutdown Margin [†] (% $\Delta k/k$)	Hot Excess Reactivity (% $\Delta k/k$)
0	1.41	1.86	1.42
250	1.50	2.25	1.27
1,000	1.85	2.58	1.12
2,200	2.16	2.77	1.20
3,200	2.42	2.90	1.27
4,200	2.67	2.97	1.37
5,400	2.99	3.00	1.52
6,400	3.06	2.94	1.65
7,500	3.06	2.92	1.80
8,500	2.98	2.96	1.89
10,000	2.93	3.21	1.96
11,000	2.83	3.47	1.99
12,000	2.79	3.80	1.99
13,000	2.88	4.23	1.96
14,000	2.77	4.68	1.87
15,000	2.66	5.04	1.69
16,200	2.28	5.32	1.26
17,143	1.95	5.60	0.69
18,107	1.74	5.97	-0.14
18,500	1.72	6.17	--
19,405	1.79	6.79	--
20,262	2.25	7.74	--

* Values in **BOLD** are limiting values at elevated moderator temperatures.[†] Calculated at 366.0 °F ARO conditions.

**Table 3.6 Browns Ferry Equilibrium Cycle Reactivity Margin
Summary (Long EOC N-1)**

Cycle Exposure (MWd/MTU)	Cold Shutdown Margin* (% $\Delta k/k$)	SLC Cold Shutdown Margin [†] (% $\Delta k/k$)	Hot Excess Reactivity (% $\Delta k/k$)
0	1.64	2.07	1.18
250	1.82	2.41	1.02
1,000	2.22	2.76	0.87
2,200	2.58	2.99	0.94
3,200	2.88	3.08	1.02
4,200	3.16	3.18	1.13
5,400	3.31	3.16	1.29
6,400	3.31	3.12	1.44
7,500	3.17	3.10	1.61
8,500	3.07	3.12	1.70
10,000	3.04	3.36	1.78
11,000	2.95	3.62	1.80
12,000	2.91	3.95	1.79
13,000	3.07	4.35	1.73
14,000	2.98	4.83	1.61
15,000	2.80	5.31	1.35
16,200	2.38	5.73	0.79
17,380	2.01	6.13	-0.11
18,300	1.90	6.53	--
19,405	2.02	7.30	--
20,262	2.57	8.32	--

* Values in **BOLD** are limiting values at elevated moderator temperatures.

† Calculated at 366.0 °F ARO conditions.

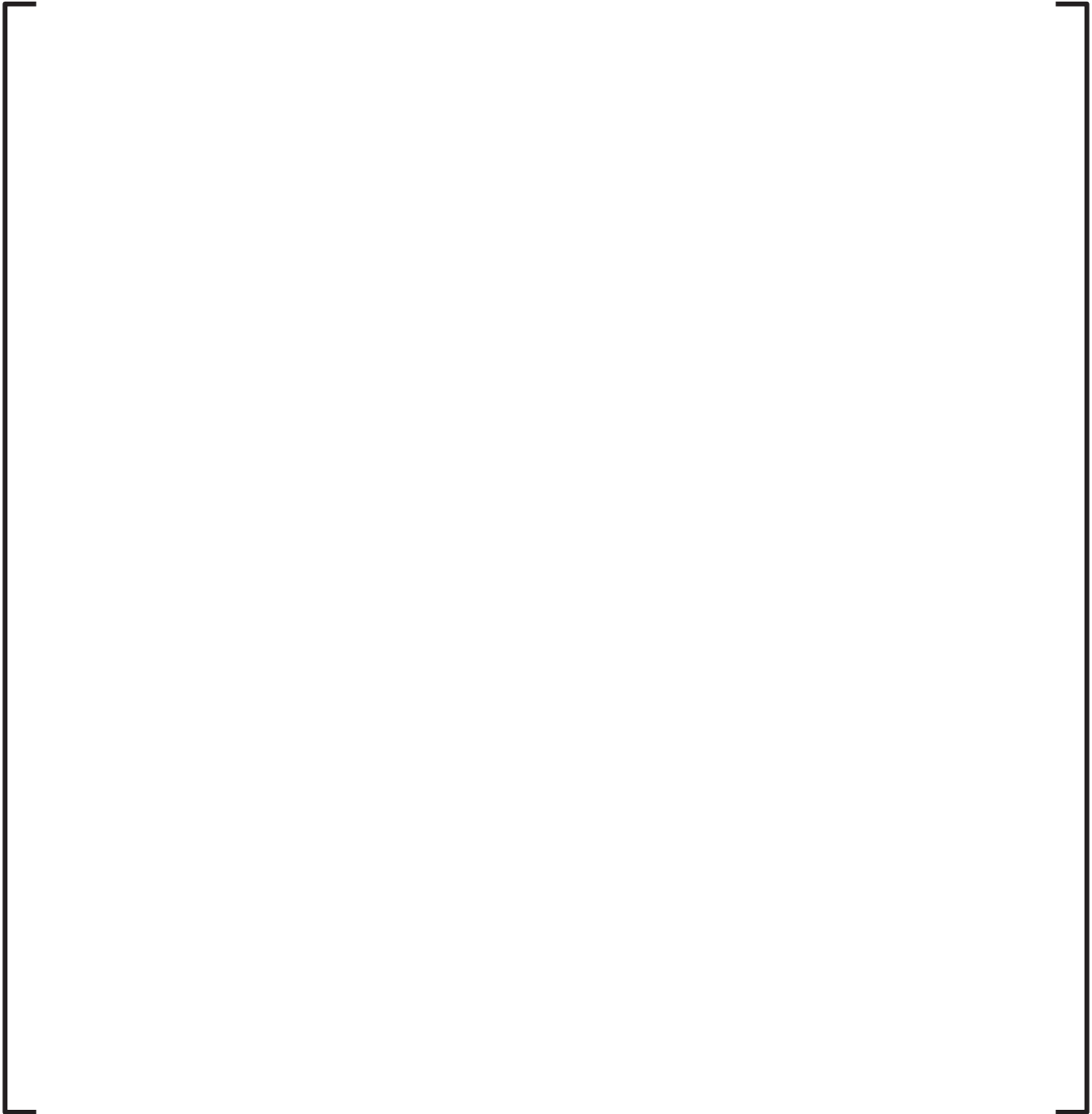


Figure 3.1 Browns Ferry Equilibrium Cycle Reference Loading Pattern



**Figure 3.2 Browns Ferry Equilibrium Cycle Upper Left Quarter Core
Layout by Fuel Type**

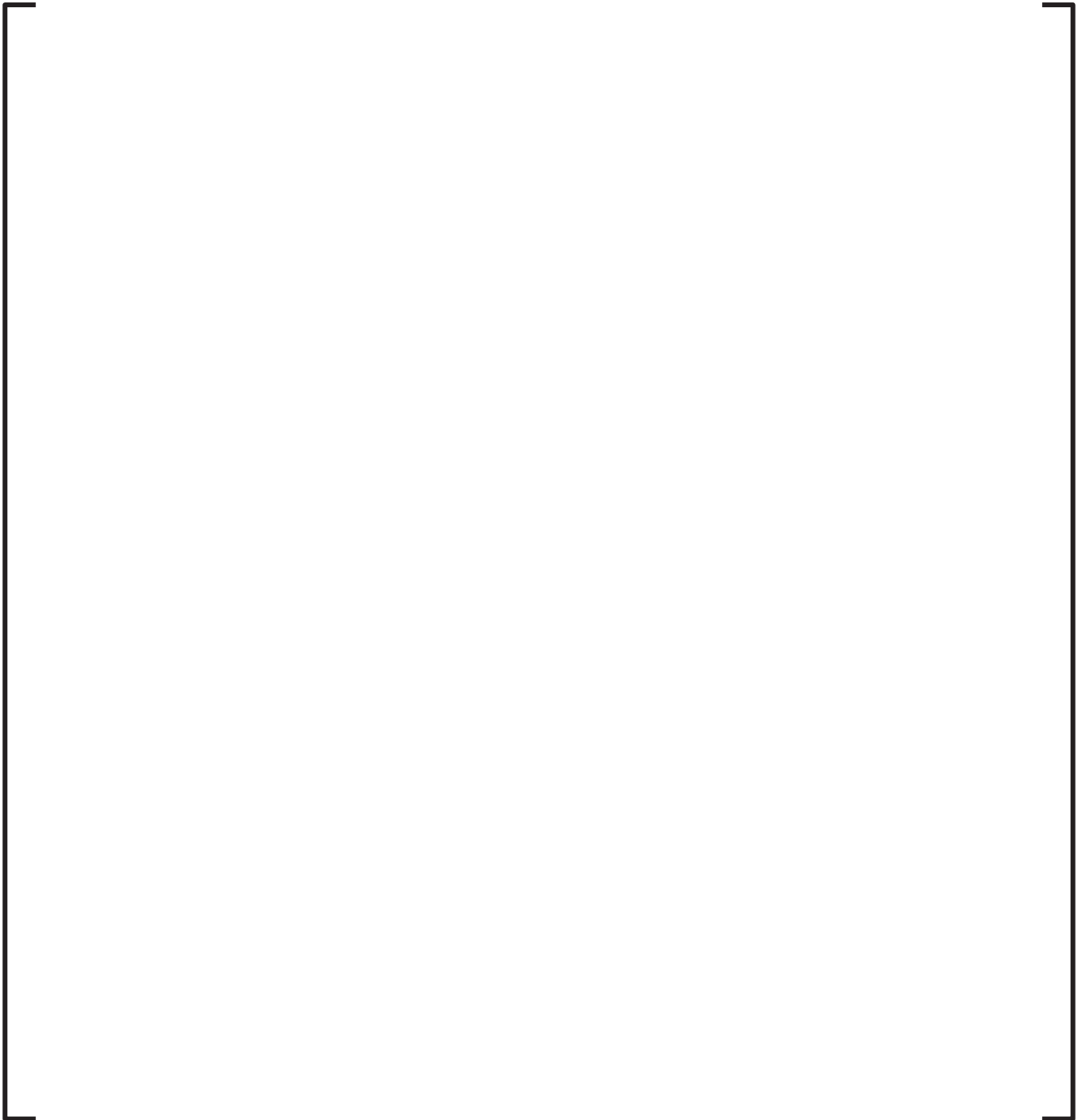


**Figure 3.3 Browns Ferry Equilibrium Cycle Upper Right Quarter
Core Layout by Fuel Type**

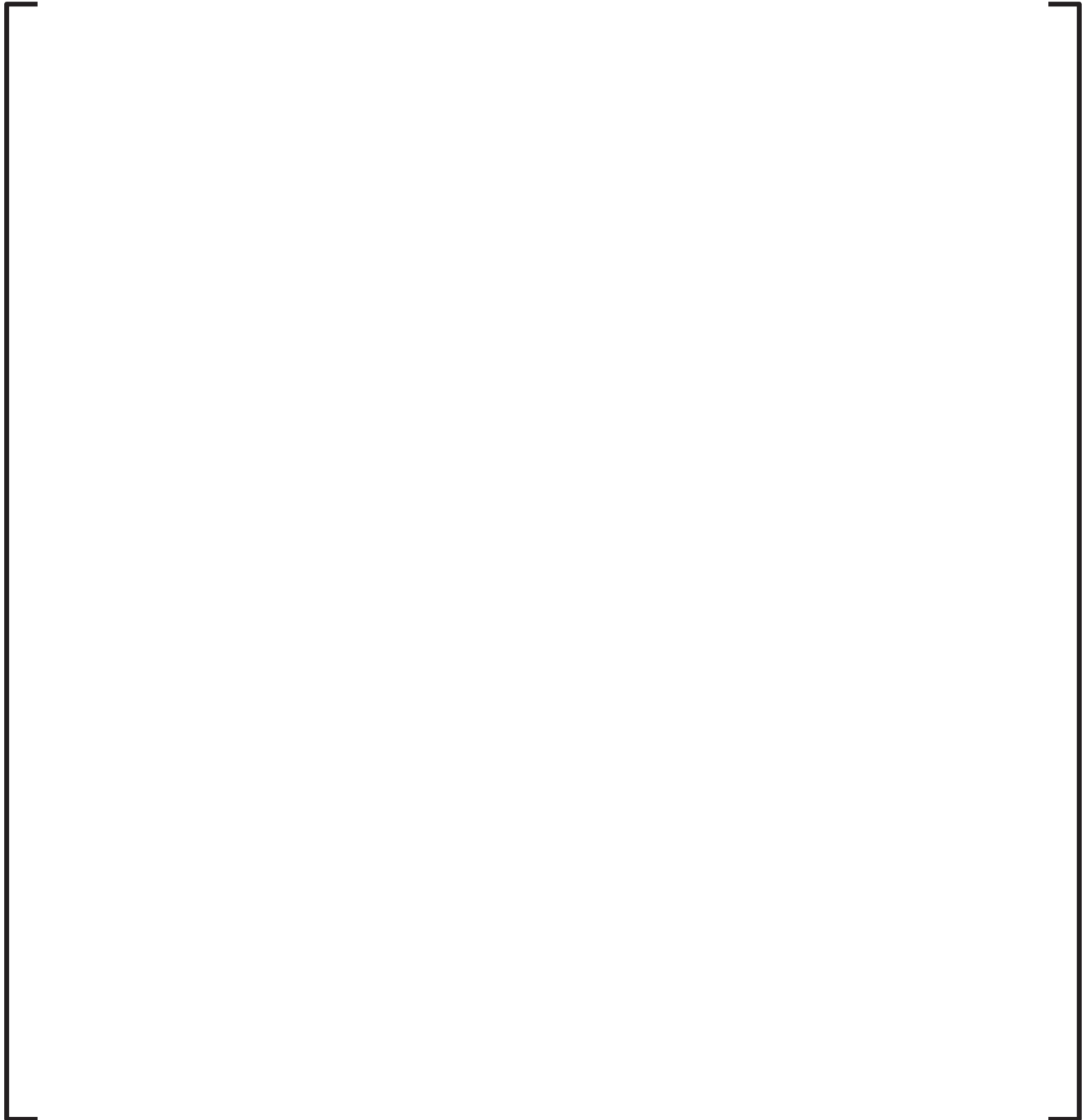


**Figure 3.4 Browns Ferry Equilibrium Cycle Lower Left Quarter Core
Layout by Fuel Type**

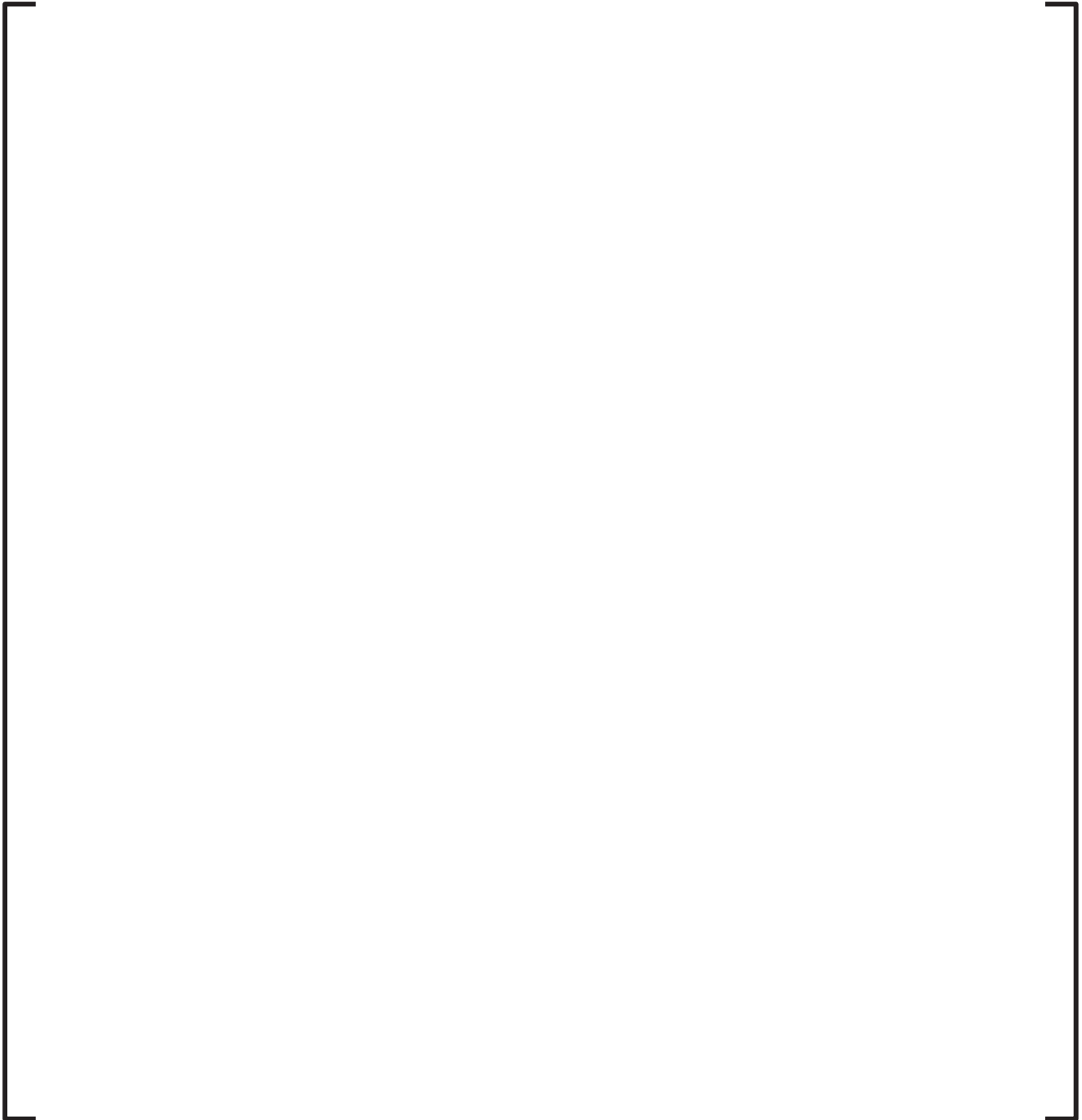


**Figure 3.5 Browns Ferry Equilibrium Cycle Lower Right Quarter
Core Layout by Fuel Type**

3.4 Voiding in the Channel Bypass Region

To demonstrate compliance with the NRC's requirement that there be less than 5% bypass voiding around the LPRMs (see Section 5.1.1.5.1 of Reference 5), the bypass void level has been evaluated throughout the equilibrium cycle. The maximum bypass void value applicable to the equilibrium cycle design [

]

Table 3.7 Maximum Bypass Voiding at LPRM Level D

Power (%), Flow (%) Condition	Cycle Exposure (GWd/MTU)	Bypass Void (%)
[		]

Note: There is no bypass voiding at LPRM levels A, B, or C.

[
[

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4.0 REFERENCES

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2. ANP-10335P-A Revision 0, ACE/ATRIUM 11 Critical Power Correlation, Framatome Inc., May 2018.
3. FS1-0049790 Revision 1.0, TVA Reload Requirements Specification for ATRIUM 11 equilibrium cycle (TVA Document BFE-4494 Revision 0).
4. 47-9310936-000, Browns Ferry Unit 3 Cycle 21 FSDD Response - ATRIUM 11 Equilibrium Cycle Design.
5. NEDO-33006-A Revision 3, *General Electric Boiling Water Reactor Maximum Extended Load Line Limit Analysis Plus*, General Electric Hitachi Nuclear Energy America, LLC, June 2009. (ADAMS Accession Number ML091800530)
6. ANP-3850P Revision 0, Browns Ferry ATRIUM 11 Equilibrium Cycle Nuclear Fuel Design Report, Framatome Inc. May 2020.

Appendix A Browns Ferry Equilibrium Cycle Step-through Depletion Summary, Control Rod Patterns and Core Average Axial Power and Exposure Distributions

**Table A.1 Browns Ferry Equilibrium Cycle Design Depletion
Summary**

Cycle Exposure (GWd/MT)	Calculated K-eff	Control Rod Density	Total Core Power MWt	Total Core Flow (Mlb/hr)	Ref. Pressure (psia)	Inlet Sub- Cooling (Btu/lb)	Void Fraction	Core Minimum CPR	Core Maximum LHGR (kW/ft)	Core Maximum APLHGR (kW/ft)
0.000	1.00029	4.41	3952.0	88.15	1050.04	31.69	0.524	1.710	11.86	8.92
0.250	1.00015	4.41	3952.0	93.17	1050.04	29.86	0.508	1.764	11.46	8.55
0.500	1.00015	4.41	3952.0	98.30	1050.04	28.19	0.496	1.806	11.35	8.44
1.000	1.00006	4.41	3952.0	99.63	1050.04	27.78	0.492	1.817	11.28	8.48
1.500	0.99995	4.41	3952.0	98.09	1050.04	28.25	0.493	1.799	11.17	8.48
1.709	0.99986	4.41	3952.0	97.07	1050.04	28.57	0.494	1.789	11.11	8.48
1.710	0.99970	4.14	3952.0	97.99	1050.04	28.28	0.503	1.728	11.95	9.19
2.200	0.99963	4.14	3952.0	96.76	1050.04	28.67	0.503	1.715	11.79	9.18
2.700	0.99956	4.14	3952.0	95.22	1050.04	29.17	0.504	1.695	11.70	9.23
3.200	0.99930	4.14	3952.0	92.76	1050.04	30.00	0.507	1.669	11.64	9.31
3.700	0.99925	4.14	3952.0	91.12	1050.04	30.58	0.509	1.648	11.67	9.41
4.200	0.99918	4.14	3952.0	89.18	1050.04	31.30	0.512	1.623	11.77	9.55
4.410	0.99922	4.14	3952.0	88.56	1050.04	31.53	0.513	1.615	11.81	9.62
4.410	0.99915	5.14	3952.0	100.76	1050.04	27.44	0.492	1.652	11.59	9.45
4.900	0.99908	5.14	3952.0	98.30	1050.04	28.19	0.496	1.657	11.68	9.62
5.400	0.99899	5.14	3952.0	95.84	1050.04	28.97	0.501	1.635	11.71	9.82
5.900	0.99893	5.14	3952.0	93.48	1050.04	29.75	0.505	1.611	11.66	9.97
6.400	0.99887	5.14	3952.0	91.02	1050.04	30.62	0.509	1.586	11.67	10.09
6.900	0.99884	5.14	3952.0	88.66	1050.04	31.49	0.513	1.562	11.69	10.21
7.111	0.99893	5.14	3952.0	88.15	1050.04	31.69	0.513	1.556	11.65	10.21
7.118	0.99882	5.59	3952.0	95.94	1050.04	28.93	0.505	1.648	11.76	10.10
7.500	0.99864	5.59	3952.0	93.68	1050.04	29.68	0.508	1.627	11.65	10.05
8.000	0.99865	5.59	3952.0	92.05	1050.04	30.25	0.508	1.613	11.42	9.89
8.500	0.99869	5.59	3952.0	90.92	1050.04	30.66	0.505	1.602	11.05	9.59
9.000	0.99879	5.59	3952.0	90.20	1050.04	30.92	0.500	1.587	10.53	9.16
9.500	0.99872	5.59	3952.0	88.97	1050.04	31.38	0.494	1.570	9.91	8.66
9.619	0.99875	5.59	3952.0	88.76	1050.04	31.45	0.493	1.565	9.78	8.56
9.620	0.99853	6.33	3952.0	93.28	1050.04	29.82	0.485	1.631	10.21	8.99
10.000	0.99865	6.33	3952.0	93.38	1050.04	29.79	0.478	1.628	9.65	8.55
10.500	0.99859	6.33	3952.0	92.56	1050.04	30.07	0.470	1.621	8.98	7.98
11.000	0.99863	6.33	3952.0	92.25	1050.04	30.18	0.461	1.616	8.83	7.56
11.500	0.99877	6.33	3952.0	92.25	1050.04	30.18	0.451	1.610	8.92	7.65
12.000	0.99888	6.33	3952.0	92.25	1050.04	30.18	0.441	1.608	9.00	7.71
12.127	0.99896	6.33	3952.0	92.25	1050.04	30.18	0.438	1.608	8.99	7.71
12.127	0.99906	5.95	3952.0	92.05	1050.04	30.25	0.443	1.572	9.12	7.79
12.500	0.99909	5.95	3952.0	92.25	1050.04	30.18	0.435	1.569	9.13	7.79
13.000	0.99922	5.95	3952.0	92.97	1050.04	29.93	0.423	1.571	9.11	7.84
13.500	0.99930	5.95	3952.0	93.79	1050.04	29.65	0.411	1.576	9.08	7.83
14.000	0.99948	5.95	3952.0	95.43	1050.04	29.10	0.398	1.586	9.17	7.95
14.500	0.99955	5.95	3952.0	97.38	1050.04	28.47	0.385	1.601	9.30	8.22
14.635	0.99964	5.95	3952.0	98.09	1050.04	28.25	0.382	1.608	9.31	8.27
14.636	0.99968	6.04	3952.0	94.30	1050.04	29.48	0.390	1.590	9.36	8.01
15.000	0.99970	6.04	3952.0	96.66	1050.04	28.70	0.379	1.606	9.53	8.21
15.500	0.99963	6.04	3952.0	100.45	1050.04	27.53	0.363	1.617	9.75	8.54
15.700	0.99967	6.04	3952.0	102.50	1050.04	26.94	0.357	1.620	9.81	8.66
15.701	0.99970	4.32	3952.0	93.17	1050.04	29.86	0.378	1.625	9.43	8.36
16.200	0.99974	4.32	3952.0	100.76	1050.04	27.44	0.357	1.643	9.67	8.62
16.300	0.99986	4.32	3952.0	102.50	1050.04	26.94	0.353	1.646	9.72	8.67
16.301	0.99980	3.78	3952.0	92.15	1050.04	30.22	0.361	1.595	9.55	8.54
16.800	0.99969	3.78	3952.0	100.86	1050.04	27.41	0.340	1.622	9.85	8.79
16.801	0.99979	3.60	3952.0	95.53	1050.04	29.07	0.344	1.598	9.83	8.79
17.143	0.99967	3.60	3952.0	102.91	1050.04	26.82	0.328	1.622	10.15	8.98
17.143	0.99953	2.66	3952.0	93.68	1050.04	29.68	0.345	1.591	10.22	9.02
17.450	0.99955	2.66	3952.0	102.09	1050.04	27.05	0.329	1.624	10.44	9.21
17.451	0.99963	1.71	3952.0	95.12	1050.04	29.20	0.342	1.590	10.23	9.28
17.700	0.99957	1.71	3952.0	102.50	1050.04	26.94	0.328	1.638	10.39	9.42
17.701	0.99961	0.00	3952.0	93.68	1050.04	29.68	0.348	1.618	9.66	8.73
18.107	0.99972	0.00	3952.0	107.62	1050.04	25.55	0.323	1.694	9.90	8.93
18.115	0.99978	0.00	3952.0	95.74	1044.36	36.06	0.321	1.674	9.45	8.54
18.420	1.00002	0.00	3952.0	107.62	1044.36	31.83	0.300	1.710	9.74	8.79

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18.500	0.99998	0.00	3889.3	107.62	1043.08	31.25	0.297	1.729	9.63	8.69
18.804	1.00002	0.00	3597.1	107.62	1037.12	28.61	0.281	1.834	9.20	8.27
19.000	1.00003	0.00	3438.5	107.62	1033.88	27.18	0.273	1.898	8.93	8.04
19.200	1.00002	0.00	3277.4	107.62	1030.60	25.74	0.264	1.970	8.66	7.79
19.405	0.99997	0.00	3085.3	107.62	1026.68	24.01	0.254	2.068	8.33	7.47
19.691	1.00000	0.00	2840.1	107.62	1021.69	21.84	0.240	2.212	7.94	7.05
19.976	0.99996	0.00	2586.6	107.62	1016.52	19.60	0.225	2.391	7.50	6.60
20.262	1.00003	0.00	2330.1	107.62	1011.30	17.37	0.209	2.608	7.02	6.14

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**Table A.2 Browns Ferry Equilibrium Cycle Design Depletion
 Thermal Margin Summary**

Cycle Exposure (Gwd/MT)	Calculated K-eff	Control Rod Density	Core Limiting CPR	Fraction of Limiting CPR	Core Limiting LHGR (kW/ft)	Fraction of Limiting LHGR	Core Limiting APLHGR (kW/ft)	Fraction of Limiting APLHGR
0.000	1.00029	4.414	1.710	0.825	11.86	0.872	8.92	0.776
0.250	1.00015	4.414	1.764	0.799	11.46	0.843	8.55	0.744
0.500	1.00015	4.414	1.806	0.781	11.35	0.835	8.44	0.734
1.000	1.00006	4.414	1.817	0.776	11.28	0.830	8.48	0.737
1.500	0.99995	4.414	1.799	0.784	11.17	0.821	8.48	0.738
1.709	0.99986	4.414	1.789	0.788	11.11	0.817	8.48	0.738
1.710	0.99970	4.144	1.728	0.816	11.95	0.879	9.19	0.799
2.200	0.99963	4.144	1.715	0.822	11.79	0.867	9.18	0.798
2.700	0.99956	4.144	1.695	0.832	11.70	0.860	9.23	0.803
3.200	0.99930	4.144	1.669	0.845	11.64	0.856	9.31	0.810
3.700	0.99925	4.144	1.648	0.856	11.67	0.858	9.41	0.819
4.200	0.99918	4.144	1.623	0.869	11.77	0.865	9.55	0.831
4.410	0.99922	4.144	1.615	0.873	11.81	0.869	9.62	0.837
4.410	0.99915	5.135	1.652	0.854	11.59	0.852	9.45	0.822
4.900	0.99908	5.135	1.657	0.851	11.68	0.859	9.62	0.836
5.400	0.99899	5.135	1.635	0.862	11.71	0.861	9.82	0.854
5.900	0.99893	5.135	1.611	0.875	11.66	0.857	9.97	0.867
6.400	0.99887	5.135	1.586	0.889	11.67	0.858	10.09	0.877
6.900	0.99884	5.135	1.562	0.903	11.69	0.860	10.21	0.888
7.111	0.99893	5.135	1.556	0.906	11.65	0.856	10.21	0.888
7.118	0.99882	5.586	1.648	0.856	11.76	0.865	10.10	0.878
7.500	0.99864	5.586	1.627	0.866	11.65	0.857	10.05	0.874
8.000	0.99865	5.586	1.613	0.874	11.42	0.840	9.89	0.860
8.500	0.99869	5.586	1.602	0.880	11.05	0.812	9.59	0.834
9.000	0.99879	5.586	1.587	0.889	10.53	0.774	9.16	0.796
9.500	0.99872	5.586	1.570	0.898	7.21	0.742	8.66	0.753
9.619	0.99875	5.586	1.565	0.901	7.14	0.740	8.56	0.745
9.620	0.99853	6.329	1.631	0.865	7.22	0.764	8.99	0.782
10.000	0.99865	6.329	1.628	0.866	6.94	0.748	8.55	0.743
10.500	0.99859	6.329	1.621	0.870	6.57	0.725	7.98	0.695
11.000	0.99863	6.329	1.616	0.872	6.46	0.702	7.55	0.661
11.500	0.99877	6.329	1.610	0.876	6.22	0.688	7.65	0.665
12.000	0.99888	6.329	1.608	0.877	5.95	0.672	7.71	0.670
12.127	0.99896	6.329	1.608	0.877	8.99	0.671	7.71	0.670
12.127	0.99906	5.946	1.572	0.897	9.12	0.679	7.79	0.678
12.500	0.99909	5.946	1.569	0.899	9.13	0.686	7.79	0.678
13.000	0.99922	5.946	1.571	0.897	9.11	0.690	7.84	0.682
13.500	0.99930	5.946	1.576	0.894	6.94	0.698	7.83	0.681
14.000	0.99948	5.946	1.586	0.889	6.86	0.706	7.95	0.691
14.500	0.99955	5.946	1.601	0.881	7.51	0.719	8.22	0.714
14.635	0.99964	5.946	1.608	0.877	7.53	0.723	8.27	0.719
14.636	0.99968	6.036	1.590	0.887	6.98	0.729	8.01	0.696
15.000	0.99970	6.036	1.606	0.915	7.88	0.737	8.21	0.714
15.500	0.99963	6.036	1.617	0.909	8.12	0.768	8.54	0.743
15.700	0.99967	6.036	1.620	0.907	8.20	0.779	8.66	0.753
15.701	0.99970	4.324	1.625	0.905	7.89	0.749	8.36	0.727
16.200	0.99974	4.324	1.643	0.895	8.14	0.780	8.62	0.750
16.300	0.99986	4.324	1.646	0.893	8.17	0.785	8.67	0.754
16.301	0.99980	3.784	1.595	0.922	8.03	0.771	8.54	0.742
16.800	0.99969	3.784	1.622	0.907	8.20	0.796	8.79	0.764
16.801	0.99979	3.604	1.598	0.920	8.44	0.794	8.79	0.765
17.143	0.99967	3.604	1.622	0.906	8.60	0.815	8.98	0.781
17.143	0.99953	2.658	1.591	0.924	8.64	0.819	9.02	0.784
17.450	0.99955	2.658	1.624	0.905	8.77	0.837	9.21	0.801
17.451	0.99963	1.712	1.590	0.925	8.60	0.821	9.28	0.807
17.700	0.99957	1.712	1.638	0.897	8.71	0.836	9.42	0.820
17.701	0.99961	0.000	1.618	0.909	8.40	0.806	8.73	0.759
18.107	0.99972	0.000	1.694	0.868	8.35	0.834	8.90	0.779
18.115	0.99978	0.000	1.674	0.878	8.05	0.805	8.54	0.748
18.420	1.00002	0.000	1.710	0.860	8.20	0.832	8.73	0.767

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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18.500	0.99998	0.000	1.729	0.850	8.08	0.824	8.69	0.760
18.804	1.00002	0.000	1.834	0.801	7.55	0.783	8.24	0.723
19.000	1.00003	0.000	1.898	0.774	7.24	0.759	8.04	0.703
19.200	1.00002	0.000	1.970	0.746	6.89	0.734	7.74	0.683
19.405	0.99997	0.000	2.068	0.711	6.54	0.704	7.43	0.657
19.691	1.00000	0.000	2.212	0.665	6.97	0.668	7.02	0.623
19.976	0.99996	0.000	2.391	0.615	6.55	0.632	6.56	0.585
20.262	1.00003	0.000	2.608	0.564	6.17	0.593	6.13	0.545

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	17775.7
Exposure: MWd/MTU (GWd)	0.0 (0.00)		
Delta E: MWd/MTU, (GWd)	0.0 (0.00)		
Power: MWt	3952.0 (100.00 %)	Axial Profile	Edit Radial Power
Core Pressure: psia	1050.0	N(PRA) Power Exposure	Zone Avg. Max. IR JR
Inlet Subcooling: Btu/lbm	-31.69	Top 25 0.143 3.779	13 0.487 0.696 7 16
Flow: Mlb/hr	88.15 (86.00 %)	24 0.397 10.166	14 0.397 0.694 27 4
		23 0.503 13.001	15 0.483 0.746 33 58
		22 0.571 14.871	16 1.127 1.269 37 24
		21 0.620 16.109	17 1.114 1.267 35 22
2 6 10 14 18 22 26 30 34 38 42 46 50 54 58		20 0.661 17.079	18 1.010 1.277 29 48
59		19 0.686 17.710	19 1.152 1.314 35 24
55		18 0.718 18.375	20 1.253 1.313 37 22
51		17 0.755 18.951	21 1.106 1.219 31 54
47		16 0.805 19.078	
43		15 0.870 19.081	
39		14 0.914 19.683	
35		13 0.963 20.224	
31		12 1.027 20.909	
27		11 1.090 21.197	
23		10 1.239 20.341	
19		9 1.356 20.877	
15		8 1.462 21.283	
11		7 1.583 21.737	
7		6 1.701 22.045	
3		5 1.791 22.060*	
2 6 10 14 18 22 26 30 34 38 42 46 50 54 58		4 1.791* 21.385	
		3 1.681 19.757	
Control Rod Density: %	4.41	2 1.322 15.244	
		Bottom 1 0.350 4.571	
k-effective:	1.00029		
Void Fraction:	0.524		
Core Delta-P: psia	20.212	% AXIAL TILT -36.405 -10.471	
Core Plate Delta-P: psia	15.657	AVG BOT 8ft/12ft 1.2036 1.0598	
Coolant Temp: Deg-F	548.5		
In Channel Flow: Mlb/hr	77.07	Active Channel Flow: Mlb/hr	74.18
Total Bypass Flow (%):	12.6	(of total core flow)	
Total Water Rod Flow (%):	3.3	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR					LHGR				
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	Value	Margin	Exp.	FT	IR
1.314	19	35	24	1.710	0.825	20	37	8.92	0.776	0.0	21	31	11.86	0.872	0.0	20	29
1.313	20	37	22	1.711	0.824	20	21	8.77	0.763	0.0	21	7	11.84	0.871	0.0	21	31
1.311	20	21	24	1.711	0.824	20	29	8.75	0.761	0.0	21	35	11.78	0.866	0.0	20	29
1.311	19	37	26	1.713	0.823	21	31	8.73	0.759	0.0	20	31	11.74	0.864	0.0	19	33
1.302	20	31	46	1.723	0.819	20	45	8.70	0.757	0.0	19	25	11.74	0.863	0.0	19	35
1.296	20	15	30	1.731	0.815	21	7	8.70	0.756	0.0	19	33	11.72	0.862	0.0	20	11
1.291	20	35	42	1.746	0.807	20	29	8.68	0.755	0.0	19	23	11.71	0.861	0.0	20	37
1.287	19	33	26	1.749	0.806	19	35	8.66	0.753	0.0	21	37	11.70	0.860	0.0	20	39
1.287	20	33	30	1.753	0.804	19	37	8.63	0.750	0.0	20	29	11.70	0.860	0.0	20	45
1.287	20	19	22	1.754	0.804	20	39	8.63	0.750	0.0	21	7	11.68	0.859	0.0	19	25

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure A.1 Browns Ferry Equilibrium Cycle Control Rod Pattern and Axial Distributions at 0.0 MWd/MTU

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	18024.1
Exposure: MWd/MTU (GWd)	250.0 (34.59)		
Delta E: MWd/MTU, (GWd)	250.0 (34.59)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.86		
Flow: Mlb/hr	93.17 (90.90 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.151 3.819	13 0.488 0.697 7 16
		24 0.422 10.278	14 0.398 0.694 27 4
		23 0.534 13.143	15 0.485 0.747 33 58
		22 0.605 15.033	16 1.129 1.270 37 24
		21 0.656 16.285	17 1.116 1.269 35 22
		20 0.697 17.266	18 1.013 1.280 29 48
		19 0.721 17.904	19 1.150 1.310 35 24
		18 0.752 18.578	20 1.250 1.309 37 22
		17 0.786 19.164	21 1.102 1.213 31 54
		16 0.834 19.299	
		15 0.897 19.305	
		14 0.937 19.918	
		13 0.982 20.470	
		12 1.042 21.171	
		11 1.100 21.475	
		10 1.245 20.624	
		9 1.356 21.183	
		8 1.454 21.612	
		7 1.564 22.092	
		6 1.667 22.425	
		5 1.739* 22.458*	
		4 1.716 21.781	
		3 1.584 20.126	
		2 1.232 15.533	
		Bottom 1 0.326 4.656	
Control Rod Density: %	4.41		
k-effective:	1.00015		
Void Fraction:	0.508		
Core Delta-P: psia	21.816	% AXIAL TILT -33.443 -10.712	
Core Plate Delta-P: psia	17.260	AVG BOT 8ft/12ft 1.1876 1.0609	
Coolant Temp: Deg-F	548.5		
In Channel Flow: Mlb/hr	81.60	Active Channel Flow: Mlb/hr	78.59
Total Bypass Flow (%):	12.4	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.310	19	35	24	1.764	0.799	20	37	22	8.55	0.744	0.5	21	31	54	4	11.46	0.843	0.7	20	29	50	5
1.309	20	37	22	1.764	0.799	21	31	54	8.47	0.737	0.5	20	31	50	5	11.38	0.837	0.7	20	29	46	5
1.308	20	21	24	1.765	0.799	20	29	46	8.40	0.731	0.5	21	7	32	4	11.32	0.833	0.7	20	11	32	5
1.307	19	37	26	1.765	0.799	20	21	38	8.38	0.729	0.5	21	35	54	4	11.31	0.832	0.7	21	31	54	4
1.298	20	31	46	1.776	0.794	20	45	30	8.38	0.728	0.5	20	29	46	5	11.31	0.831	0.7	20	37	40	5
1.292	20	15	30	1.781	0.792	21	7	32	8.38	0.728	0.5	20	11	30	5	11.30	0.831	0.7	20	45	30	5
1.287	20	35	42	1.792	0.787	19	35	24	8.35	0.726	0.5	20	23	40	5	11.30	0.831	0.7	20	39	38	5
1.284	20	19	22	1.796	0.785	19	37	26	8.35	0.726	0.5	20	21	24	5	11.28	0.829	0.7	20	33	52	5
1.284	20	39	42	1.799	0.784	20	39	20	8.34	0.725	0.5	19	25	38	4	11.19	0.823	0.7	19	33	54	4
1.284	20	33	30	1.802	0.782	20	19	22	8.34	0.725	0.5	20	33	52	5	11.18	0.822	0.7	20	9	28	5

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.2 Browns Ferry Equilibrium Cycle Control Rod Pattern and
Axial Distributions at 250.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	18274.2
Exposure: MWd/MTU (GWd)	500.0 (69.19)		
Delta E: MWd/MTU, (GWd)	250.0 (34.59)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.19		
Flow: Mlb/hr	98.30 (95.90 %)		
		Axial Profile	Edit Radial Power
		N (PRA)	Power Exposure Zone Avg. Max. IR JR
		Top 25	0.156 3.860 13 0.486 0.695 7 16
		24	0.435 10.396 14 0.396 0.692 27 4
		23	0.550 13.292 15 0.482 0.746 33 58
		22	0.623 15.202 16 1.131 1.272 37 24
		21	0.673 16.468 17 1.117 1.270 35 22
		20	0.714 17.461 18 1.013 1.282 29 48
		19	0.736 18.105 19 1.151 1.310 35 24
		18	0.765 18.787 20 1.251 1.310 37 22
		17	0.799 19.382 21 1.101 1.214 31 54
		16	0.844 19.525
		15	0.906 19.533
		14	0.944 20.156
		13	0.987 20.719
		12	1.047 21.435
		11	1.104 21.754
		10	1.247 20.908
		9	1.358 21.489
		8	1.453 21.940
		7	1.559 22.444
		6	1.657 22.800
		5	1.719* 22.849*
		4	1.682 22.164
		3	1.538 20.479
		2	1.188 15.806
		Bottom 1	0.316 4.736
Control Rod Density: %	4.41		
k-effective:	1.00015		
Void Fraction:	0.496		
Core Delta-P: psia	23.578	% AXIAL TILT	-32.165 -10.917
Core Plate Delta-P: psia	19.020	AVG BOT 8ft/12ft	1.1803 1.0619
Coolant Temp: Deg-F	548.6		
In Channel Flow: Mlb/hr	86.20	Active Channel Flow: Mlb/hr	83.07
Total Bypass Flow (%):	12.3	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.310	19	35	24	1.806	0.781	21	31	54	8.44	0.734	1.1	21	31	54	4	11.35	0.835	1.5	20	29	50	5
1.310	20	37	22	1.810	0.779	20	37	22	8.44	0.734	1.1	20	31	50	5	11.27	0.828	1.5	20	29	46	5
1.308	20	21	24	1.811	0.779	20	29	46	8.33	0.725	1.1	20	29	46	5	11.21	0.824	1.5	20	11	32	5
1.307	19	37	26	1.812	0.778	20	21	38	8.33	0.725	1.1	20	11	30	5	11.18	0.822	1.4	20	45	30	5
1.299	20	31	46	1.822	0.774	20	45	30	8.30	0.722	1.1	20	23	40	5	11.18	0.822	1.5	20	37	40	5
1.294	20	15	30	1.823	0.774	21	7	32	8.30	0.722	1.1	20	21	24	5	11.17	0.821	1.5	20	39	38	5
1.288	20	35	42	1.838	0.767	19	35	24	8.30	0.721	1.1	20	33	52	5	11.16	0.821	1.5	20	33	52	5
1.285	20	19	22	1.842	0.765	19	37	26	8.29	0.721	1.1	20	15	30	5	11.13	0.819	1.5	21	31	54	4
1.285	20	39	42	1.845	0.764	20	39	20	8.28	0.720	1.1	21	7	32	4	11.06	0.813	1.4	20	9	28	5
1.284	20	19	26	1.848	0.763	20	29	50	8.27	0.719	1.1	21	35	54	4	11.02	0.810	1.4	19	35	50	5

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure A.3 Browns Ferry Equilibrium Cycle Control Rod Pattern and Axial Distributions at 500.0 MWd/MTU

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU										18774.1					
Exposure: MWd/MTU (Gwd)	1000.0	(138.37)															
Delta E: MWd/MTU, (Gwd)	500.0	(69.19)															
Power: MWt	3952.0	(100.00 %)															
Core Pressure: psia	1050.0																
Inlet Subcooling: Btu/lbm	-27.78																
Flow: Mlb/hr	99.63	(97.20 %)															
	2	6	10	14	18	22	26	30	34	38	42	46	50	54	58		
59					--	--	--	--	--	--	--					59	
55				--	--	--	--	--	--	--	--					55	
51		--	--	--	--	--	--	--	--	--	--					51	
47	--	--	--	--	--	18	--	--	--	18	--	--	--	--		47	
43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	43	
39	--	--	--	--	18	--	--	--	10	--	--	--	18	--	--	39	
35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	35	
31	--	--	--	--	--	10	--	--	--	10	--	--	--	--	--	31	
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	
23	--	--	--	--	18	--	--	--	10	--	--	--	18	--	--	23	
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19	
15	--	--	--	--	--	18	--	--	--	18	--	--	--	--	--	15	
11		--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	
7			--	--	--	--	--	--	--	--	--	--	--	--	--	7	
3				--	--	--	--	--	--	--	--	--	--	--	--	3	
	2	6	10	14	18	22	26	30	34	38	42	46	50	54	58		
Control Rod Density: %																	
										4.41							
k-effective:	1.00006																
Void Fraction:	0.492																
Core Delta-P: psia	24.048											% AXIAL TILT -31.768 -11.287					
Core Plate Delta-P: psia	19.490											AVG BOT 8ft/12ft 1.1777 1.0636					
Coolant Temp: Deg-F	548.6																
In Channel Flow: Mlb/hr	87.40											Active Channel Flow: Mlb/hr 84.24					
Total Bypass Flow (%):	12.3											(of total core flow)					
Total Water Rod Flow (%):	3.2											(of total core flow)					
Source Convergence	0.00008																

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.318	20	37	22	1.817	0.776	20	37	22	8.48	0.737	2.1	20	31	50	5	11.28	0.830	2.9	20	29	50	5
1.317	19	35	24	1.819	0.775	21	31	54	8.43	0.733	2.1	21	31	54	4	11.20	0.823	2.9	20	29	46	5
1.316	20	21	24	1.819	0.775	20	21	38	8.37	0.728	2.1	20	29	46	5	11.14	0.819	2.9	20	11	32	5
1.314	19	37	26	1.820	0.775	20	29	46	8.37	0.728	2.1	20	11	30	5	11.12	0.817	2.9	20	45	30	5
1.308	20	31	46	1.831	0.770	20	45	30	8.34	0.725	2.1	20	23	40	5	11.10	0.816	2.9	20	37	40	5
1.301	20	15	30	1.836	0.768	21	7	32	8.33	0.725	2.1	20	21	24	5	11.09	0.816	2.9	20	39	38	5
1.296	20	35	42	1.844	0.765	19	35	24	8.33	0.725	2.1	20	33	52	5	11.09	0.816	2.9	20	33	52	5
1.292	20	19	22	1.848	0.763	19	37	26	8.33	0.724	2.1	20	15	30	5	11.04	0.812	2.9	21	31	54	4
1.292	20	39	42	1.853	0.761	20	39	20	8.29	0.721	2.1	19	25	38	5	10.99	0.808	2.9	20	9	28	5
1.292	20	19	26	1.856	0.760	20	19	22	8.28	0.720	2.1	21	7	32	4	10.95	0.805	2.8	19	35	50	5

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.4 Browns Ferry Equilibrium Cycle Control Rod Pattern and
Axial Distributions at 1,000.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU										19274.0			
Exposure: MWd/MTU (GWd)	1500.0	(207.56)													
Delta E: MWd/MTU, (GWd)	500.0	(69.19)													
Power: MWt	3952.0	(100.00 %)													
Core Pressure: psia	1050.0														
Inlet Subcooling: Btu/lbm	-28.25														
Flow: Mlb/hr	98.09	(95.70 %)													
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
59				--	--	--	--	--	--	--				59	
55				--	--	--	--	--	--	--				55	
51			--	--	--	--	--	--	--	--				51	
47		--	--	--	--	--	18	--	--	18	--	--	--	47	
43	--	--	--	--	--	--	--	--	--	--	--	--	--	43	
39	--	--	--	--	18	--	--	--	10	--	--	--	18	39	
35	--	--	--	--	--	--	--	--	--	--	--	--	--	35	
31	--	--	--	--	--	--	10	--	--	--	10	--	--	31	
27	--	--	--	--	--	--	--	--	--	--	--	--	--	27	
23	--	--	--	--	18	--	--	--	10	--	--	--	18	23	
19	--	--	--	--	--	--	--	--	--	--	--	--	--	19	
15	--	--	--	--	--	18	--	--	--	--	--	--	--	15	
11			--	--	--	--	--	--	--	--	--	--	--	11	
7			--	--	--	--	--	--	--	--	--	--	--	7	
3				--	--	--	--	--	--	--	--	--	--	3	
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
												5	1.702*	24.394*	
												4	1.664	23.675	
												3	1.520	21.859	
												2	1.173	16.871	
Control Rod Density: %	4.41											Bottom	1	0.319	5.053
k-effective:	0.99995														
Void Fraction:	0.493														
Core Delta-P: psia	23.481											% AXIAL TILT -31.317 -11.627			
Core Plate Delta-P: psia	18.923											AVG BOT 8ft/12ft 1.1752 1.0651			
Coolant Temp: Deg-F	548.5														
In Channel Flow: Mlb/hr	86.03											Active Channel Flow: Mlb/hr 82.92			
Total Bypass Flow (%):	12.3											(of total core flow)			
Total Water Rod Flow (%):	3.2											(of total core flow)			
Source Convergence	0.00009														

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.326	20	37	22	1.799	0.784	20	37	22	8.48	0.738	3.2	20	31	50	5	11.17	0.821	4.3	20	29	50	5
1.324	20	21	24	1.801	0.783	20	21	38	8.42	0.732	3.2	21	31	54	4	11.08	0.815	4.3	20	29	46	5
1.324	19	35	24	1.808	0.780	20	29	46	8.38	0.729	3.2	20	29	46	5	11.02	0.811	4.3	20	11	32	5
1.320	19	37	26	1.811	0.778	21	31	54	8.38	0.729	3.2	20	11	30	5	11.00	0.809	4.3	20	45	30	5
1.315	20	31	46	1.819	0.775	20	45	30	8.34	0.725	3.2	20	33	52	5	10.98	0.808	4.3	20	37	40	5
1.309	20	15	30	1.821	0.774	19	35	24	8.34	0.725	3.2	20	23	40	5	10.98	0.807	4.3	20	33	52	5
1.303	20	35	42	1.825	0.772	19	37	26	8.34	0.725	3.2	20	21	24	5	10.97	0.807	4.3	20	39	38	5
1.300	20	19	22	1.828	0.771	21	7	32	8.33	0.725	3.2	20	15	30	5	10.93	0.804	4.3	21	31	54	4
1.299	20	39	42	1.836	0.768	20	39	20	8.28	0.720	3.1	19	25	38	5	10.87	0.800	4.3	20	9	28	5
1.299	20	19	26	1.836	0.768	19	35	28	8.26	0.719	3.1	20	33	48	5	10.84	0.797	4.2	19	35	50	5

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure A.5 Browns Ferry Equilibrium Cycle Control Rod Pattern and Axial Distributions at 1,500.0 MWd/MTU

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	19482.8
Exposure: MWd/MTU (GWd)	1708.8 (236.45)		
Delta E: MWd/MTU, (GWd)	208.8 (28.89)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.57		
Flow: Mlb/hr	97.07 (94.70 %)		
		Axial Profile	Edit Radial Power
		N (PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.163 4.070	13 0.476 0.685 7 16
		24 0.446 10.980	14 0.385 0.682 27 4
		23 0.562 14.029	15 0.471 0.734 33 58
		22 0.636 16.042	16 1.127 1.270 37 24
		21 0.687 17.376	17 1.113 1.268 35 22
		20 0.728 18.422	18 1.003 1.281 29 48
		19 0.750 19.095	19 1.163 1.326 35 24
		18 0.778 19.815	20 1.268 1.329 37 22
		17 0.809 20.454	21 1.103 1.221 31 54
		16 0.851 20.628	
		15 0.911 20.645	
		14 0.948 21.315	
		13 0.990 21.930	
		12 1.049 22.719	
		11 1.104 23.105	
		10 1.243 22.283	
		9 1.349 22.968	
		8 1.441 23.522	
		7 1.544 24.140	
		6 1.638 24.600	
		5 1.697* 24.714*	
		4 1.661 23.989	
		3 1.519 22.146	
		2 1.173 17.092	
		Bottom 1 0.321 5.119	
Control Rod Density: %	4.41		
k-effective:	0.99986		
Void Fraction:	0.494		
Core Delta-P: psia	23.109	% AXIAL TILT -31.113 -11.760	
Core Plate Delta-P: psia	18.552	AVG BOT 8ft/12ft 1.1741 1.0657	
Coolant Temp: Deg-F	548.5		
In Channel Flow: Mlb/hr	85.12	Active Channel Flow: Mlb/hr	82.04
Total Bypass Flow (%):	12.3	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.329	20	37	22	1.789	0.788	20	37	22	8.48	0.738	3.7	20	31	50	5	11.11	0.817	4.9	20	29	50	5
1.327	20	21	24	1.790	0.788	20	21	38	8.41	0.732	3.7	21	31	54	4	11.03	0.811	4.9	20	29	46	5
1.326	19	35	24	1.800	0.783	20	29	46	8.38	0.729	3.6	20	29	46	5	10.97	0.807	4.9	20	11	32	5
1.323	19	37	26	1.806	0.781	21	31	54	8.38	0.729	3.6	20	11	30	5	10.95	0.805	4.9	20	45	30	5
1.318	20	31	46	1.808	0.780	19	35	24	8.34	0.725	3.6	20	33	52	5	10.93	0.804	4.9	20	37	40	5
1.312	20	15	30	1.812	0.778	20	45	30	8.34	0.725	3.6	20	23	40	5	10.92	0.803	4.9	20	33	52	5
1.306	20	35	42	1.812	0.778	19	37	26	8.34	0.725	3.6	20	21	24	5	10.92	0.803	4.9	20	39	38	5
1.303	20	19	22	1.822	0.774	21	7	32	8.33	0.725	3.6	20	15	30	5	10.88	0.800	4.8	21	31	54	4
1.302	20	19	26	1.823	0.773	19	35	28	8.28	0.720	3.6	19	25	38	5	10.82	0.796	4.8	20	9	28	5
1.302	20	39	42	1.825	0.773	19	27	36	8.26	0.719	3.6	20	33	48	5	10.79	0.793	4.8	19	35	50	5

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure A.6 Browns Ferry Equilibrium Cycle Control Rod Pattern and Axial Distributions at 1,708.8 MWd/MTU

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	19483.9
Exposure: MWd/MTU (GWd)	1709.9 (236.60)		
Delta E: MWd/MTU, (GWd)	1.1 (0.15)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.28		
Flow: Mlb/hr	97.99 (95.60 %)		
		Axial Profile	Edit Radial Power
		N (PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.150 4.070	13 0.478 0.695 15 8
		24 0.410 10.981	14 0.386 0.694 27 4
		23 0.516 14.030	15 0.472 0.746 33 58
		22 0.581 16.043	16 1.103 1.281 29 44
		21 0.624 17.376	17 1.124 1.279 39 30
		20 0.655 18.423	18 1.004 1.310 29 48
		19 0.671 19.096	19 1.248 1.342 37 30
		18 0.696 19.816	20 1.195 1.352 31 46
		17 0.725 20.455	21 1.120 1.252 31 54
		16 0.777 20.629	
		15 0.862 20.646	
		14 0.922 21.316	
		13 0.983 21.931	
		12 1.056 22.720	
		11 1.125 23.107	
		10 1.275 22.284	
		9 1.391 22.969	
		8 1.491 23.523	
		7 1.603 24.142	
		6 1.706 24.602	
		5 1.777* 24.716*	
		4 1.756 23.990	
		3 1.626 22.148	
		2 1.271 17.094	
		Bottom 1 0.350 5.120	
Control Rod Density: %	4.14		
k-effective:	0.99970		
Void Fraction:	0.503		
Core Delta-P: psia	23.620	% AXIAL TILT -36.801 -11.761	
Core Plate Delta-P: psia	19.063	AVG BOT 8ft/12ft 1.2055 1.0657	
Coolant Temp: Deg-F	548.6		
In Channel Flow: Mlb/hr	85.85	Active Channel Flow: Mlb/hr	82.70
Total Bypass Flow (%):	12.4	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.352	20	31	46	1.728	0.816	20	29	46	9.19	0.799	3.5	19	35	50	4	11.95	0.879	4.7	19	37	52	4
1.342	19	37	30	1.744	0.808	21	31	54	9.14	0.795	3.3	19	39	50	4	11.95	0.878	4.5	19	21	50	4
1.338	20	33	48	1.759	0.802	20	27	48	9.11	0.792	3.5	19	37	52	4	11.94	0.878	4.8	19	35	50	4
1.335	19	39	28	1.764	0.799	20	29	50	9.08	0.789	3.7	20	31	50	5	11.84	0.871	4.9	20	29	50	5
1.335	20	31	50	1.774	0.795	19	35	50	9.01	0.783	3.6	20	27	48	5	11.81	0.869	4.9	20	29	46	5
1.327	19	37	26	1.777	0.793	20	29	42	8.99	0.782	3.6	20	29	46	5	11.80	0.867	4.9	20	33	52	5
1.325	20	29	42	1.782	0.791	20	33	52	8.96	0.779	2.3	19	37	48	4	11.72	0.862	1.8	19	37	14	4
1.322	19	35	50	1.787	0.789	21	35	54	8.95	0.778	3.7	21	31	54	4	11.71	0.861	4.7	21	43	12	4
1.313	20	27	44	1.789	0.788	19	37	30	8.95	0.778	3.6	20	33	52	5	11.70	0.860	4.7	21	41	52	4
1.310	18	29	48	1.789	0.788	21	17	50	8.91	0.774	3.6	21	35	54	4	11.66	0.857	4.7	20	27	48	5

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure A.7 Browns Ferry Equilibrium Cycle Control Rod Pattern and Axial Distributions at 1,709.9 MWd/MTU

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	19973.9
Exposure: MWd/MTU (GWd)	2200.0 (304.42)		
Delta E: MWd/MTU, (GWd)	490.1 (67.82)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.67		
Flow: Mlb/hr	96.76 (94.40 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.153 4.150	13 0.474 0.690 15 8
		24 0.416 11.203	14 0.382 0.690 27 4
		23 0.523 14.309	15 0.468 0.741 33 58
		22 0.589 16.359	16 1.101 1.279 29 44
		21 0.632 17.716	17 1.121 1.277 39 30
		20 0.663 18.779	18 1.000 1.308 29 48
		19 0.680 19.462	19 1.253 1.347 37 30
		18 0.704 20.195	20 1.202 1.359 31 46
		17 0.733 20.849	21 1.121 1.255 31 54
		16 0.784 21.042	
		15 0.868 21.076	
		14 0.927 21.775	
		13 0.986 22.421	
		12 1.059 23.246	
		11 1.125 23.665	
		10 1.272 22.854	
		9 1.385 23.584	
		8 1.483 24.181	
		7 1.592 24.848	
		6 1.693 25.354	
		5 1.763* 25.499*	
		4 1.744 24.765	
		3 1.615 22.866	
		2 1.262 17.655	
		Bottom 1 0.350 5.291	
			% AXIAL TILT -36.110 -12.195
			AVG BOT 8ft/12ft 1.2018 1.0678
Control Rod Density: %	4.14		
k-effective:	0.99963		
Void Fraction:	0.503		
Core Delta-P: psia	23.158		
Core Plate Delta-P: psia	18.602		
Coolant Temp: Deg-F	548.6		
In Channel Flow: Mlb/hr	84.76	Active Channel Flow: Mlb/hr	81.65
Total Bypass Flow (%):	12.4	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR								LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K	
1.359	20	31	46	1.715	0.822	20	29	46	9.18	0.798	4.6	19	35	50	4	11.79	0.867	6.3	19	35	50	4	
1.347	20	37	30	1.739	0.811	21	31	54	9.10	0.792	4.4	19	39	50	4	11.77	0.865	6.2	19	37	52	4	
1.344	20	33	48	1.749	0.806	20	27	48	9.09	0.790	4.7	19	37	52	4	11.76	0.864	6.0	19	21	50	4	
1.342	19	39	28	1.752	0.805	20	29	50	9.07	0.789	4.8	20	31	50	5	11.69	0.859	6.4	20	29	50	5	
1.342	20	31	50	1.765	0.799	19	35	50	9.00	0.782	4.7	20	27	48	5	11.66	0.858	6.4	20	29	46	5	
1.333	19	37	26	1.766	0.799	20	29	42	8.98	0.781	4.7	20	29	46	5	11.64	0.856	6.4	20	33	52	5	
1.332	20	29	42	1.773	0.795	20	33	52	8.94	0.777	4.7	20	33	52	5	11.55	0.849	3.3	19	37	14	4	
1.327	19	35	50	1.780	0.792	21	35	54	8.93	0.776	3.4	19	37	48	4	11.54	0.848	6.2	21	43	12	4	
1.320	20	27	44	1.784	0.790	21	17	50	8.92	0.776	4.8	21	31	54	4	11.52	0.847	6.2	21	41	52	4	
1.311	19	27	40	1.784	0.790	19	37	30	8.89	0.773	4.7	21	35	54	4	11.50	0.846	6.2	20	27	48	5	

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure A.8 Browns Ferry Equilibrium Cycle Control Rod Pattern and Axial Distributions at 2,200.0 MWd/MTU

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	20474.0
Exposure: MWd/MTU (GWd)	2700.0 (373.61)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.17		
Flow: Mlb/hr	95.22 (92.90 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.155 4.234	13 0.470 0.686 15 8
		24 0.420 11.432	14 0.378 0.686 27 4
		23 0.528 14.597	15 0.464 0.736 33 58
		22 0.595 16.686	16 1.099 1.277 29 44
		21 0.638 18.066	17 1.119 1.274 39 30
		20 0.670 19.147	18 0.996 1.307 29 48
		19 0.687 19.839	19 1.259 1.353 37 30
		18 0.711 20.585	20 1.209 1.367 31 46
		17 0.739 21.255	21 1.123 1.258 31 54
		16 0.789 21.465	
		15 0.872 21.517	
		14 0.929 22.245	
		13 0.988 22.921	
		12 1.058 23.782	
		11 1.123 24.234	
		10 1.267 23.433	
		9 1.377 24.207	
		8 1.473 24.848	
		7 1.580 25.564	
		6 1.682 26.116	
		5 1.753* 26.293*	
		4 1.738 25.552	
		3 1.614 23.595	
		2 1.263 18.225	
		Bottom 1 0.352 5.466	
Control Rod Density: %	4.14		
k-effective:	0.99956		
Void Fraction:	0.504		
Core Delta-P: psia	22.600	% AXIAL TILT -35.597 -12.601	
Core Plate Delta-P: psia	18.044	AVG BOT 8ft/12ft 1.1989 1.0697	
Coolant Temp: Deg-F	548.5		
In Channel Flow: Mlb/hr	83.40	Active Channel Flow: Mlb/hr	80.33
Total Bypass Flow (%):	12.4	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.367	20	31	46	1.695	0.832	20	29	46	9.23	0.803	5.8	19	35	50	4	11.70	0.860	7.8	19	35	50	4
1.353	19	37	30	1.731	0.815	21	31	54	9.13	0.794	5.8	19	37	52	4	11.65	0.857	7.7	19	37	52	4
1.353	20	33	48	1.732	0.814	20	29	50	9.12	0.793	5.6	19	39	50	4	11.64	0.856	7.5	19	21	50	4
1.350	20	31	50	1.733	0.814	20	27	48	9.10	0.791	5.9	20	31	50	5	11.63	0.855	7.8	20	29	50	4
1.348	19	39	28	1.747	0.807	20	29	42	9.02	0.784	5.8	20	27	48	5	11.58	0.851	7.8	20	33	52	4
1.340	20	29	42	1.750	0.806	19	35	50	9.00	0.783	5.9	20	29	46	5	11.57	0.851	7.7	20	29	46	5
1.340	19	37	26	1.756	0.803	20	27	52	8.96	0.779	5.8	20	33	52	5	11.42	0.840	4.8	19	37	14	4
1.334	19	35	50	1.768	0.798	19	37	30	8.96	0.779	4.6	19	37	48	4	11.42	0.840	7.6	21	43	12	4
1.328	20	27	44	1.770	0.797	21	35	54	8.94	0.777	5.9	21	31	54	4	11.40	0.838	7.6	21	41	52	4
1.318	19	27	40	1.771	0.796	20	25	46	8.91	0.775	5.8	21	35	54	4	11.40	0.838	7.6	20	27	48	5

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.9 Browns Ferry Equilibrium Cycle Control Rod Pattern and
Axial Distributions at 2,700.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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Cycle:	21	Core Average Exposure: MWd/MTU										20973.8				
Exposure: MWd/MTU (Gwd)	3200.0	(442.80)														
Delta E: MWd/MTU, (Gwd)	500.0	(69.19)														
Power: MWt	3952.0	(100.00 %)														
Core Pressure: psia	1050.0															
Inlet Subcooling: Btu/lbm	-30.00															
Flow: Mlb/hr	92.76	(90.50 %)														
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58		
59				--	--	--	--	--	--	--					59	
55			--	--	--	--	--	--	--	--					55	
51		--	--	--	--	--	--	--	--	--					51	
47	--	--	--	--	--	--	--	--	--	--					47	
43	--	--	--	--	--	10	--	--	10	--	--	--	--	--	43	
39	--	--	--	--	--	--	--	--	--	--					39	
35	--	--	--	14	--	--	--	8	--	--	14	--	--	--	35	
31	--	--	--	--	--	--	--	--	--	--					31	
27	--	--	--	14	--	--	--	8	--	--	14	--	--	--	27	
23	--	--	--	--	--	--	--	--	--	--					23	
19	--	--	--	--	--	10	--	--	10	--	--	--	--	--	19	
15	--	--	--	--	--	--	--	--	--	--					15	
11		--	--	--	--	--	--	--	--	--					11	
7			--	--	--	--	--	--	--	--					7	
3				--	--	--	--	--	--	--					3	
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58		
Control Rod Density: %	4.14															
k-effective:	0.99930											Bottom	1	0.358	5.643	
Void Fraction:	0.507															
Core Delta-P: psia	21.738											% AXIAL TILT	-35.332	-12.979		
Core Plate Delta-P: psia	17.183											AVG BOT 8ft/12ft	1.1972	1.0714		
Coolant Temp: Deg-F	548.5															
In Channel Flow: Mlb/hr	81.21											Active Channel Flow: Mlb/hr	78.21			
Total Bypass Flow (%):	12.5											(of total core flow)				
Total Water Rod Flow (%):	3.2											(of total core flow)				
Source Convergence	0.00008															

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR								LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K	
1.376	20	31	46	1.669	0.845	20	29	46	9.31	0.810	6.9	19	35	50	4	11.64	0.856	9.1	19	35	50	4	
1.361	20	33	48	1.705	0.827	20	29	50	9.20	0.800	7.0	19	37	52	4	11.61	0.854	9.3	20	29	50	4	
1.358	19	37	30	1.705	0.827	20	27	48	9.17	0.798	6.7	19	39	50	4	11.58	0.851	9.1	20	27	52	4	
1.358	20	31	50	1.716	0.822	21	31	54	9.14	0.795	7.1	20	31	50	5	11.57	0.851	9.2	19	37	52	4	
1.355	19	39	28	1.721	0.819	20	29	42	9.05	0.787	6.9	20	27	48	5	11.54	0.849	9.0	19	21	50	4	
1.348	20	29	42	1.723	0.818	19	35	50	9.04	0.786	7.0	20	29	46	5	11.52	0.847	9.2	20	29	46	5	
1.346	19	37	26	1.728	0.816	20	27	52	9.03	0.786	6.8	20	33	52	4	11.34	0.834	8.9	20	27	48	4	
1.341	19	35	50	1.737	0.812	19	37	30	9.02	0.784	5.7	19	37	48	4	11.34	0.834	9.0	21	43	12	4	
1.336	20	27	44	1.745	0.808	20	25	46	8.99	0.782	7.0	21	31	54	4	11.33	0.833	6.2	19	37	14	4	
1.324	19	27	40	1.751	0.805	19	39	28	8.98	0.781	6.9	21	35	54	4	11.33	0.833	9.1	21	41	52	4	

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.10 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 3,200.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	21473.9
Exposure: MWd/MTU (GWd)	3700.0 (511.98)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.58		
Flow: Mlb/hr	91.12 (88.90 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.158 4.404 13 0.463 0.678 15 8
		24	0.425 11.895 14 0.371 0.678 27 4
		23	0.532 15.179 15 0.456 0.727 33 58
		22	0.601 17.346 16 1.095 1.274 29 44
		21	0.645 18.774 17 1.114 1.268 21 32
		20	0.677 19.890 18 0.987 1.303 29 48
		19	0.694 20.600 19 1.270 1.364 23 32
		18	0.717 21.373 20 1.222 1.385 31 46
		17	0.744 22.073 21 1.126 1.266 31 54
		16	0.792 22.318
		15	0.872 22.401
		14	0.928 23.187
		13	0.984 23.921
		12	1.052 24.852
		11	1.113 25.366
		10	1.252 24.582
		9	1.357 25.441
		8	1.452 26.168
		7	1.560 26.982
		6	1.665 27.626
		5	1.745 27.871*
		4	1.747* 27.126
		3	1.637 25.064
		2	1.286 19.377
		Bottom 1	0.363 5.823
Control Rod Density: %	4.14		
k-effective:	0.99925		
Void Fraction:	0.509		
Core Delta-P: psia	21.175	% AXIAL TILT	-35.165 -13.334
Core Plate Delta-P: psia	16.621	AVG BOT 8ft/12ft	1.1960 1.0731
Coolant Temp: Deg-F	548.4		
In Channel Flow: Mlb/hr	79.75	Active Channel Flow: Mlb/hr	76.79
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	Value	Margin
1.385	20	31	46	1.648	0.856	20	29	9.41	0.819	8.1	19	35	50	11.67	0.858
1.370	20	33	48	1.683	0.838	20	29	9.29	0.808	8.1	19	37	52	11.66	0.858
1.367	20	31	50	1.683	0.838	20	27	9.26	0.805	8.0	20	31	50	11.62	0.855
1.364	19	23	32	1.700	0.829	20	29	9.25	0.804	7.9	19	39	50	11.53	0.848
1.361	19	39	28	1.702	0.828	19	35	9.19	0.799	8.0	20	33	52	11.53	0.847
1.356	20	29	42	1.706	0.826	21	31	9.13	0.794	7.9	20	33	48	11.52	0.847
1.353	19	37	26	1.707	0.826	20	27	9.11	0.792	8.1	20	29	46	11.36	0.835
1.349	19	35	50	1.714	0.823	19	37	9.10	0.791	6.8	19	37	48	11.30	0.831
1.345	20	27	44	1.725	0.817	20	25	9.06	0.788	8.1	21	31	54	11.29	0.830
1.331	19	27	40	1.727	0.816	19	39	9.06	0.788	8.1	21	35	54	11.28	0.829

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.11 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 3,700.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	21973.9
Exposure: MWd/MTU (GWd)	4200.0 (581.17)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-31.30		
Flow: Mlb/hr	89.18 (87.00 %)		
		Axial Profile	Edit Radial Power
		N (PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.159 4.491 13 0.459 0.674 15 8
		24	0.425 12.128 14 0.367 0.674 27 4
		23	0.532 15.471 15 0.452 0.723 33 58
		22	0.601 17.677 16 1.093 1.273 29 44
		21	0.645 19.130 17 1.111 1.265 21 32
		20	0.678 20.263 18 0.982 1.302 29 48
		19	0.695 20.983 19 1.276 1.370 23 32
		18	0.718 21.769 20 1.229 1.395 31 46
		17	0.745 22.484 21 1.128 1.271 31 54
		16	0.791 22.745
		15	0.870 22.843
		14	0.924 23.656
		13	0.980 24.418
		12	1.047 25.384
		11	1.107 25.928
		10	1.243 25.151
		9	1.346 26.052
		8	1.441 26.821
		7	1.551 27.684
		6	1.660 28.377
		5	1.747 28.660*
		4	1.759* 27.917
		3	1.658 25.808
		2	1.306 19.963
		Bottom 1	0.370 6.005
Control Rod Density: %	4.14		
k-effective:	0.99918		
Void Fraction:	0.512		
Core Delta-P: psia	20.523	% AXIAL TILT	-35.188 -13.671
Core Plate Delta-P: psia	15.969	AVG BOT 8ft/12ft	1.1957 1.0746
Coolant Temp: Deg-F	548.4		
In Channel Flow: Mlb/hr	78.01	Active Channel Flow: Mlb/hr	75.11
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.3	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.395	20	31	46	1.623	0.869	20	29	9.55	0.831	9.3	19	35	50	4	11.77
1.379	20	33	48	1.657	0.851	20	29	9.46	0.822	9.2	20	31	50	4	11.74
1.377	20	31	50	1.658	0.850	20	27	9.41	0.819	9.3	19	37	52	4	11.72
1.370	19	23	32	1.676	0.841	20	29	9.38	0.816	9.1	20	33	52	4	11.63
1.368	19	39	28	1.678	0.840	19	35	9.35	0.813	9.1	19	39	50	4	11.56
1.365	20	29	42	1.682	0.838	20	27	9.32	0.810	9.0	20	33	48	4	11.55
1.360	19	37	26	1.689	0.835	19	37	9.27	0.806	9.0	20	29	46	4	11.44
1.357	19	35	50	1.694	0.832	21	31	9.21	0.801	8.0	19	37	48	4	11.39
1.354	20	27	44	1.701	0.829	19	39	9.19	0.799	9.2	19	33	54	4	11.34
1.339	19	27	40	1.702	0.828	20	25	9.18	0.798	9.2	21	35	54	4	11.29

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.12 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 4,200.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	22183.4
Exposure: MWd/MTU (GWd)	4409.7 (610.19)		
Delta E: MWd/MTU, (GWd)	209.7 (29.02)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-31.53		
Flow: Mlb/hr	88.56 (86.40 %)		
		Axial Profile	Edit Radial Power
		N (PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.160 4.527	13 0.457 0.672 15 8
		24 0.424 12.226	14 0.365 0.673 27 4
		23 0.532 15.593	15 0.450 0.721 33 58
		22 0.601 17.816	16 1.092 1.272 29 44
		21 0.645 19.280	17 1.110 1.263 21 32
		20 0.677 20.420	18 0.980 1.301 29 48
		19 0.695 21.144	19 1.279 1.373 37 30
		18 0.718 21.935	20 1.232 1.399 31 46
		17 0.744 22.656	21 1.129 1.273 31 54
		16 0.790 22.924	
		15 0.869 23.028	
		14 0.922 23.852	
		13 0.978 24.626	
		12 1.044 25.607	
		11 1.104 26.163	
		10 1.239 25.388	
		9 1.342 26.306	
		8 1.437 27.094	
		7 1.548 27.978	
		6 1.659 28.691	
		5 1.748 28.990*	
		4 1.765* 28.251	
		3 1.669 26.124	
		2 1.316 20.211	
		Bottom 1 0.374 6.083	
Control Rod Density: %	4.14		
k-effective:	0.99922		
Void Fraction:	0.513		
Core Delta-P: psia	20.322	% AXIAL TILT -35.248 -13.809	
Core Plate Delta-P: psia	15.768	AVG BOT 8ft/12ft 1.1959 1.0753	
Coolant Temp: Deg-F	548.4		
In Channel Flow: Mlb/hr	77.46	Active Channel Flow: Mlb/hr	74.57
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.3	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.399	20	31	46	1.615	0.873	20	29	46	9.62	0.837	9.8	19	35	50	4	11.81	0.869	12.7	20	29	50	4
1.383	20	33	48	1.648	0.855	20	29	50	9.55	0.831	9.7	20	31	50	4	11.78	0.866	12.7	19	35	50	4
1.381	20	31	50	1.649	0.855	20	27	48	9.48	0.824	9.8	19	37	52	4	11.77	0.865	12.7	20	27	52	4
1.373	19	37	30	1.668	0.845	20	29	42	9.47	0.824	9.6	20	33	52	4	11.68	0.859	12.5	20	29	46	4
1.371	19	39	28	1.670	0.845	19	35	50	9.41	0.818	9.5	20	33	48	4	11.58	0.851	12.5	19	23	52	4
1.369	20	29	42	1.673	0.843	20	27	52	9.40	0.818	9.6	19	39	50	4	11.57	0.851	12.4	19	21	50	4
1.363	19	37	26	1.680	0.839	19	37	30	9.37	0.815	9.5	20	29	46	4	11.49	0.845	12.3	20	27	48	4
1.361	19	35	50	1.690	0.834	21	31	54	9.26	0.806	8.5	19	37	48	4	11.44	0.841	12.1	20	25	46	4
1.358	20	27	44	1.692	0.833	19	39	28	9.25	0.805	9.7	19	33	54	4	11.38	0.837	12.4	21	25	8	4
1.342	19	27	40	1.694	0.832	20	25	46	9.24	0.803	9.7	21	35	54	4	11.32	0.832	12.5	21	31	8	4

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.13 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 4,409.7 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	22184.2
Exposure: MWd/MTU (GWd)	4410.4 (610.29)		
Delta E: MWd/MTU, (GWd)	0.7 (0.10)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-27.44		
Flow: Mlb/hr	100.76 (98.30 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.166 4.527 13 0.462 0.676 7 16
		24	0.444 12.226 14 0.369 0.676 27 4
		23	0.555 15.593 15 0.456 0.725 33 58
		22	0.622 17.817 16 1.096 1.337 29 30
		21	0.660 19.280 17 1.104 1.321 31 26
		20	0.681 20.421 18 0.981 1.235 29 48
		19	0.696 21.145 19 1.301 1.430 33 26
		18	0.718 21.936 20 1.192 1.452 33 30
		17	0.743 22.657 21 1.152 1.275 31 54
		16	0.788 22.924
		15	0.867 23.028
		14	0.921 23.853
		13	0.977 24.627
		12	1.045 25.607
		11	1.107 26.164
		10	1.244 25.389
		9	1.351 26.307
		8	1.448 27.095
		7	1.559 27.979
		6	1.667 28.693
		5	1.748* 28.992*
		4	1.744 28.252
		3	1.625 26.125
		2	1.267 20.212
		Bottom 1	0.358 6.084
Control Rod Density: %	5.14		
k-effective:	0.99915		
Void Fraction:	0.492		
Core Delta-P: psia	24.569	% AXIAL TILT	-34.570 -13.809
Core Plate Delta-P: psia	20.007	AVG BOT 8ft/12ft	1.1908 1.0753
Coolant Temp: Deg-F	548.6		
In Channel Flow: Mlb/hr	88.36	Active Channel Flow: Mlb/hr	85.17
Total Bypass Flow (%):	12.3	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.452	20	33	30	1.652	0.854	20	31	9.45	0.822	9.8	19	37	52	4	11.59
1.451	20	31	28	1.674	0.842	20	27	9.44	0.821	9.8	19	35	50	4	11.57
1.430	19	33	26	1.698	0.831	19	27	9.39	0.816	9.6	20	33	52	4	11.57
1.430	19	35	28	1.699	0.830	19	35	9.30	0.809	9.6	19	39	50	4	11.55
1.386	19	31	24	1.803	0.782	21	31	9.27	0.806	9.7	20	31	50	4	11.48
1.383	19	23	32	1.810	0.779	19	23	9.27	0.806	9.2	19	9	24	4	11.46
1.354	19	35	24	1.810	0.779	20	29	9.25	0.805	9.7	19	33	54	4	11.39
1.350	19	37	26	1.811	0.779	19	31	9.24	0.804	9.7	21	35	54	4	11.38
1.345	20	31	50	1.814	0.777	20	27	9.21	0.801	9.8	21	31	54	4	11.35
1.340	19	35	50	1.823	0.774	19	35	9.20	0.800	9.2	19	25	34	4	11.35

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.14 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 4,410.4 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	22673.7
Exposure: MWd/MTU (GWd)	4900.0 (678.03)		
Delta E: MWd/MTU, (GWd)	489.6 (67.74)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.19		
Flow: Mlb/hr	98.30 (95.90 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.166 4.615 13 0.458 0.672 7 16
		24	0.443 12.464 14 0.365 0.672 27 4
		23	0.554 15.891 15 0.452 0.721 33 58
		22	0.621 18.152 16 1.094 1.328 29 30
		21	0.659 19.636 17 1.101 1.315 31 26
		20	0.680 20.788 18 0.976 1.234 29 48
		19	0.696 21.521 19 1.308 1.435 33 26
		18	0.717 22.323 20 1.199 1.457 33 30
		17	0.742 23.058 21 1.154 1.280 31 54
		16	0.785 23.339
		15	0.862 23.457
		14	0.915 24.308
		13	0.970 25.110
		12	1.038 26.124
		11	1.098 26.710
		10	1.233 25.943
		9	1.339 26.902
		8	1.437 27.732
		7	1.551 28.666
		6	1.664 29.429
		5	1.752 29.765*
		4	1.763* 29.028
		3	1.654 26.850
		2	1.294 20.778
		Bottom 1	0.367 6.261
Control Rod Density: %	5.14		
k-effective:	0.99908		
Void Fraction:	0.496		
Core Delta-P: psia	23.688	% AXIAL TILT	-34.751 -14.108
Core Plate Delta-P: psia	19.128	AVG BOT 8ft/12ft	1.1913 1.0766
Coolant Temp: Deg-F	548.6		
In Channel Flow: Mlb/hr	86.16	Active Channel Flow: Mlb/hr	83.02
Total Bypass Flow (%):	12.4	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.457	20	33	30	1.657	0.851	20	31	9.62	0.836	10.8	20	33	52	4	11.68
1.453	20	31	28	1.658	0.851	20	27	9.61	0.836	11.0	19	35	50	4	11.67
1.435	19	33	26	1.680	0.839	19	35	9.60	0.835	11.0	19	37	52	4	11.67
1.435	19	35	28	1.681	0.839	19	27	9.50	0.826	10.9	20	31	50	4	11.52
1.391	19	31	24	1.783	0.791	20	29	9.44	0.821	10.7	19	39	50	4	11.50
1.389	19	23	32	1.787	0.789	20	27	9.42	0.820	10.8	19	33	54	4	11.48
1.360	19	35	24	1.787	0.789	19	23	9.40	0.817	10.8	21	35	54	4	11.44
1.357	19	37	26	1.788	0.789	19	31	9.39	0.817	10.4	19	9	24	4	11.42
1.356	20	31	50	1.789	0.788	21	31	9.35	0.813	10.9	21	31	54	4	11.40
1.349	19	35	50	1.797	0.785	19	35	9.32	0.811	9.8	19	11	26	4	11.36

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.15 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 4,900.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU										23173.7			
Exposure: MWd/MTU (Gwd)	5400.0	(747.22)													
Delta E: MWd/MTU, (Gwd)	500.0	(69.19)													
Power: MWt	3952.0	(100.00 %)													
Core Pressure: psia	1050.0														
Inlet Subcooling: Btu/lbm	-28.97														
Flow: Mlb/hr	95.84	(93.50 %)													
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
59				--	--	--	--	--	--	--					59
55				--	--	--	--	--	--	--					55
51			--	--	--	--	--	--	--	--					51
47		--	--	--	--	--	--	--	--	--					47
43	--	--	--	--	14	--	8	--	8	--	14	--	--	--	43
39	--	--	--	--	--	--	--	--	--	--	--	--	--	--	39
35	--	--	--	--	8	--	--	--	--	8	--	--	--	--	35
31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	31
27	--	--	--	--	8	--	--	--	--	8	--	--	--	--	27
23	--	--	--	--	--	--	--	--	--	--	--	--	--	--	23
19	--	--	--	--	14	--	8	--	8	--	14	--	--	--	19
15	--	--	--	--	--	--	--	--	--	--	--	--	--	--	15
11			--	--	--	--	--	--	--	--	--	--	--	--	11
7			--	--	--	--	--	--	--	--	--	--	--	--	7
3				--	--	--	--	--	--	--	--	--	--	--	3
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
Control Rod Density: %	5.14														
k-effective:	0.99899														
Void Fraction:	0.501														
Core Delta-P: psia	22.831											% AXIAL TILT -35.129 -14.406			
Core Plate Delta-P: psia	18.271											AVG BOT 8ft/12ft 1.1929 1.0779			
Coolant Temp: Deg-F	548.5														
In Channel Flow: Mlb/hr	83.95											Active Channel Flow: Mlb/hr 80.87			
Total Bypass Flow (%):	12.4											(of total core flow)			
Total Water Rod Flow (%):	3.2											(of total core flow)			
Source Convergence	0.00007														

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	Value	Margin
1.464	20	33	30	1.635	0.862	20	27	9.82	0.854	12.0	20	33	52	11.71	0.861
1.460	20	31	28	1.636	0.862	20	31	9.76	0.848	12.2	19	35	50	11.71	0.861
1.442	19	35	28	1.658	0.850	19	35	9.75	0.848	12.2	19	37	52	11.68	0.859
1.442	19	33	26	1.659	0.850	19	27	9.70	0.843	12.1	20	31	50	11.51	0.847
1.398	19	31	24	1.758	0.802	20	29	9.58	0.833	12.0	19	33	54	11.51	0.846
1.396	19	23	32	1.761	0.801	20	27	9.56	0.832	11.9	19	39	50	11.50	0.846
1.367	19	35	24	1.762	0.800	19	23	9.55	0.831	11.6	19	9	24	11.50	0.846
1.364	20	31	50	1.763	0.800	19	31	9.54	0.830	12.0	21	35	54	11.50	0.845
1.364	19	37	26	1.772	0.796	19	35	9.49	0.825	11.0	19	11	26	11.45	0.842
1.357	19	35	50	1.776	0.794	21	31	9.48	0.824	12.1	21	31	54	11.44	0.841

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.16 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 5,400.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	23673.7
Exposure: MWd/MTU (GWd)	5900.0 (816.41)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.75		
Flow: Mlb/hr	93.48 (91.20 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.166 4.795 13 0.450 0.664 7 16
		24	0.437 12.947 14 0.357 0.664 27 4
		23	0.547 16.494 15 0.443 0.711 33 58
		22	0.614 18.833 16 1.088 1.318 29 30
		21	0.653 20.359 17 1.095 1.306 29 26
		20	0.675 21.536 18 0.967 1.228 29 48
		19	0.691 22.285 19 1.320 1.449 35 28
		18	0.713 23.112 20 1.213 1.472 33 30
		17	0.737 23.873 21 1.159 1.288 31 54
		16	0.778 24.182
		15	0.852 24.326
		14	0.903 25.230
		13	0.958 26.087
		12	1.024 27.169
		11	1.083 27.814
		10	1.214 27.059
		9	1.317 28.100
		8	1.417 29.020
		7	1.535 30.059
		6	1.656 30.928
		5	1.761 31.352*
		4	1.800* 30.639
		3	1.721 28.376
		2	1.359 21.978
		Bottom 1	0.388 6.638
Control Rod Density: %	5.14		
k-effective:	0.99893		
Void Fraction:	0.505		
Core Delta-P: psia	22.019	% AXIAL TILT	-35.394 -14.699
Core Plate Delta-P: psia	17.461	AVG BOT 8ft/12ft	1.1939 1.0792
Coolant Temp: Deg-F	548.5		
In Channel Flow: Mlb/hr	81.84	Active Channel Flow: Mlb/hr	78.82
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	Value	Margin	Exp.	FT
1.472	20	33	30	1.611	0.875	20	33	9.97	0.867	13.3	20	11.66	0.857	16.9	20
1.467	20	31	28	1.612	0.875	20	31	9.86	0.858	13.5	19	11.65	0.856	16.5	20
1.449	19	35	28	1.635	0.862	19	35	9.85	0.857	13.4	19	11.57	0.851	17.0	19
1.449	19	33	26	1.636	0.862	19	27	9.84	0.855	13.3	20	11.55	0.849	10.8	20
1.405	19	31	24	1.734	0.813	20	29	9.69	0.842	13.2	19	11.52	0.847	16.7	21
1.403	19	23	32	1.736	0.812	19	23	9.68	0.842	12.8	19	11.52	0.847	15.7	19
1.374	19	35	24	1.737	0.812	19	31	9.65	0.839	13.1	19	11.47	0.844	15.7	20
1.371	20	31	50	1.737	0.812	20	27	9.65	0.839	12.2	20	11.46	0.842	16.5	19
1.371	19	37	26	1.749	0.806	19	35	9.63	0.838	12.2	19	11.44	0.842	15.4	20
1.363	19	35	50	1.762	0.800	21	31	9.63	0.837	13.2	21	11.44	0.841	15.5	20

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.17 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 5,900.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	24173.7
Exposure: MWd/MTU (GWd)	6400.0 (885.59)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.62		
Flow: Mlb/hr	91.02 (88.80 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.166 4.885 13 0.447 0.660 7 16
		24	0.436 13.186 14 0.354 0.659 27 4
		23	0.545 16.793 15 0.440 0.706 33 58
		22	0.612 19.171 16 1.086 1.314 29 30
		21	0.652 20.719 17 1.093 1.303 29 26
		20	0.675 21.908 18 0.962 1.225 29 48
		19	0.692 22.667 19 1.327 1.457 35 28
		18	0.714 23.505 20 1.219 1.480 33 30
		17	0.737 24.279 21 1.161 1.291 31 54
		16	0.777 24.601
		15	0.850 24.757
		14	0.901 25.687
		13	0.955 26.571
		12	1.020 27.687
		11	1.079 28.362
		10	1.207 27.611
		9	1.308 28.693
		8	1.406 29.658
		7	1.525 30.750
		6	1.647 31.674
		5	1.758 32.147*
		4	1.810* 31.454
		3	1.746 29.160
		2	1.387 22.598
		Bottom 1	0.397 6.834
Control Rod Density: %	5.14		
k-effective:	0.99887		
Void Fraction:	0.509		
Core Delta-P: psia	21.180	% AXIAL TILT	-35.490 -14.984
Core Plate Delta-P: psia	16.623	AVG BOT 8ft/12ft	1.1943 1.0805
Coolant Temp: Deg-F	548.4		
In Channel Flow: Mlb/hr	79.64	Active Channel Flow: Mlb/hr	76.69
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.480	20	33	30	1.586	0.889	20	33	30	10.09	0.877	13.9	20	33	52	3	11.67	0.858	17.9	20	33	52	4
1.475	20	31	28	1.587	0.889	20	31	28	9.94	0.864	14.7	19	35	50	4	11.66	0.858	18.4	20	31	50	4
1.457	19	35	28	1.607	0.877	19	35	28	9.92	0.863	14.7	19	37	52	4	11.56	0.850	12.3	20	31	28	4
1.456	19	33	26	1.608	0.877	19	27	36	9.92	0.863	14.6	20	31	50	4	11.51	0.846	18.1	21	25	8	4
1.412	19	31	24	1.708	0.826	19	23	32	9.80	0.852	13.6	19	33	54	3	11.49	0.845	17.8	19	25	50	4
1.410	19	23	32	1.708	0.825	19	31	24	9.79	0.852	13.4	20	9	28	4	11.46	0.843	16.9	20	9	34	4
1.380	19	35	24	1.710	0.825	20	29	50	9.78	0.850	14.0	19	9	24	4	11.45	0.842	18.0	19	23	10	4
1.378	20	31	50	1.711	0.824	20	27	52	9.74	0.847	13.4	19	11	26	4	11.44	0.841	16.9	19	33	54	3
1.378	19	37	26	1.724	0.818	19	35	50	9.72	0.845	14.3	19	39	50	4	11.41	0.839	17.2	19	11	36	4
1.369	19	35	50	1.737	0.812	19	35	24	9.71	0.845	13.9	21	35	54	3	11.38	0.837	17.3	21	7	26	4

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.18 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 6,400.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	24673.6
Exposure: MWd/MTU (GWd)	6900.0 (954.78)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-31.49		
Flow: Mlb/hr	88.66 (86.50 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.166 4.976	13 0.443 0.657 7 16
		24 0.435 13.425	14 0.351 0.655 27 4
		23 0.544 17.092	15 0.436 0.701 33 58
		22 0.612 19.509	16 1.083 1.309 29 30
		21 0.653 21.079	17 1.090 1.300 29 26
		20 0.677 22.281	18 0.958 1.221 29 48
		19 0.694 23.049	19 1.332 1.463 35 28
		18 0.716 23.900	20 1.226 1.488 33 30
		17 0.739 24.686	21 1.163 1.293 31 54
		16 0.779 25.020	
		15 0.851 25.188	
		14 0.901 26.143	
		13 0.954 27.055	
		12 1.019 28.204	
		11 1.076 28.907	
		10 1.201 28.161	
		9 1.299 29.282	
		8 1.395 30.290	
		7 1.512 31.435	
		6 1.636 32.415	
		5 1.750 32.938*	
		4 1.813* 32.272	
		3 1.763 29.953	
		2 1.409 23.230	
		Bottom 1 0.404 7.033	
Control Rod Density: %	5.14	% AXIAL TILT -35.386 -15.257	
k-effective:	0.99884	AVG BOT 8ft/12ft 1.1937 1.0817	
Void Fraction:	0.513		
Core Delta-P: psia	20.383		
Core Plate Delta-P: psia	15.827		
Coolant Temp: Deg-F	548.4		
In Channel Flow: Mlb/hr	77.55	Active Channel Flow: Mlb/hr	74.65
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.3	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.488	20	33	30	1.562	0.903	20	31	28	10.21	0.888	15.2	20	33	52	3	11.69	0.860	18.5	20	33	52	3
1.483	20	31	28	1.563	0.902	20	33	30	10.04	0.873	15.0	19	37	52	3	11.57	0.851	18.9	20	31	50	3
1.463	19	35	28	1.577	0.894	19	35	28	9.98	0.868	15.1	20	31	50	3	11.53	0.848	18.8	21	25	8	3
1.463	19	33	26	1.577	0.894	19	27	36	9.97	0.867	15.0	19	35	50	3	11.49	0.845	18.3	19	33	54	3
1.419	19	31	24	1.680	0.839	19	29	24	9.93	0.864	14.8	19	33	54	3	11.49	0.845	13.8	20	31	28	4
1.417	19	23	32	1.680	0.839	19	23	32	9.89	0.860	14.7	20	9	28	4	11.49	0.845	18.3	20	9	34	4
1.387	19	35	24	1.688	0.835	20	29	50	9.87	0.858	14.2	19	9	24	3	11.49	0.845	18.7	19	23	10	3
1.384	19	37	26	1.688	0.835	20	27	52	9.82	0.854	15.1	21	35	54	3	11.44	0.841	18.3	19	25	50	3
1.382	20	31	50	1.701	0.829	19	35	50	9.82	0.854	14.6	19	11	26	4	11.38	0.837	18.2	21	29	54	3
1.373	19	35	50	1.705	0.827	19	35	24	9.74	0.847	15.6	19	39	50	4	11.38	0.837	17.8	21	7	26	3

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.19 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 6,900.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	24884.3
Exposure: MWd/MTU (GWd)	7110.7 (983.93)		
Delta E: MWd/MTU, (GWd)	210.7 (29.15)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-31.69		
Flow: Mlb/hr	88.15 (86.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.167 5.014 13 0.442 0.655 7 16
		24	0.436 13.526 14 0.349 0.654 27 4
		23	0.545 17.217 15 0.435 0.699 33 58
		22	0.614 19.652 16 1.082 1.308 29 30
		21	0.655 21.231 17 1.089 1.299 29 26
		20	0.679 22.438 18 0.956 1.219 29 48
		19	0.697 23.210 19 1.335 1.466 33 26
		18	0.719 24.066 20 1.228 1.491 33 30
		17	0.742 24.858 21 1.164 1.293 31 54
		16	0.781 25.197
		15	0.853 25.370
		14	0.902 26.336
		13	0.955 27.259
		12	1.020 28.421
		11	1.076 29.137
		10	1.199 28.391
		9	1.296 29.529
		8	1.391 30.555
		7	1.507 31.723
		6	1.630 32.726
		5	1.745 33.271*
		4	1.810* 32.617
		3	1.764 30.288
		2	1.413 23.499
		Bottom 1	0.405 7.118
Control Rod Density: %	5.14		
k-effective:	0.99893		
Void Fraction:	0.513		
Core Delta-P: psia	20.208	% AXIAL TILT	-35.207 -15.367
Core Plate Delta-P: psia	15.652	AVG BOT 8ft/12ft	1.1927 1.0822
Coolant Temp: Deg-F	548.4		
In Channel Flow: Mlb/hr	77.09	Active Channel Flow: Mlb/hr	74.21
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.3	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.491	20	33	30	1.556	0.906	20	31	28	10.21	0.888	15.7	20	33	52	3	11.65	0.856	19.2	20	33	52	3
1.486	20	31	28	1.558	0.905	20	33	30	10.06	0.875	15.5	19	37	52	3	11.50	0.845	19.5	20	31	50	3
1.466	19	33	26	1.568	0.899	19	35	28	9.97	0.867	15.5	19	35	50	3	11.49	0.845	19.5	21	25	8	3
1.466	19	35	28	1.568	0.899	19	27	36	9.97	0.867	15.6	20	31	50	3	11.49	0.845	17.8	20	9	34	3
1.422	19	31	24	1.670	0.844	19	29	38	9.94	0.865	15.3	19	33	54	3	11.47	0.844	18.9	19	33	8	3
1.420	19	23	32	1.673	0.843	19	23	32	9.94	0.864	14.3	20	9	28	3	11.47	0.843	19.3	19	23	10	3
1.390	19	35	24	1.683	0.838	20	27	52	9.92	0.863	14.7	19	9	24	3	11.42	0.840	14.4	20	31	28	4
1.387	19	37	26	1.684	0.837	20	29	50	9.83	0.855	15.2	19	11	26	4	11.40	0.838	18.9	19	25	50	3
1.383	20	31	50	1.696	0.831	19	35	24	9.83	0.855	15.7	21	35	54	3	11.39	0.837	18.4	21	7	26	3
1.375	19	35	50	1.697	0.831	19	35	50	9.75	0.848	15.1	19	39	50	3	11.38	0.837	18.3	19	9	24	3

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.20 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 7,110.7 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	24891.3
Exposure: MWd/MTU (GWd)	7117.7 (984.90)		
Delta E: MWd/MTU, (GWd)	7.0 (0.97)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.93		
Flow: Mlb/hr	95.94 (93.60 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.154 5.015 13 0.441 0.665 7 16
		24	0.405 13.529 14 0.343 0.629 27 4
		23	0.504 17.221 15 0.428 0.684 45 8
		22	0.563 19.656 16 1.069 1.268 33 24
		21	0.591 21.236 17 1.098 1.289 31 22
		20	0.616 22.443 18 0.957 1.236 43 18
		19	0.638 23.216 19 1.327 1.457 31 24
		18	0.670 24.072 20 1.251 1.410 29 42
		17	0.709 24.864 21 1.152 1.300 43 12
		16	0.760 25.203
		15	0.843 25.376
		14	0.903 26.342
		13	0.964 27.266
		12	1.037 28.429
		11	1.100 29.145
		10	1.231 28.399
		9	1.334 29.537
		8	1.434 30.564
		7	1.554 31.732
		6	1.681 32.736
		5	1.796 33.282*
		4	1.857* 32.628
		3	1.803 30.300
		2	1.440 23.508
		Bottom 1	0.413 7.121
			% AXIAL TILT -38.787 -15.371
			AVG BOT 8ft/12ft 1.2165 1.0822
Control Rod Density: %	5.59		
k-effective:	0.99882		
Void Fraction:	0.505		
Core Delta-P: psia	23.008		
Core Plate Delta-P: psia	18.447		
Coolant Temp: Deg-F	548.6		
In Channel Flow: Mlb/hr	83.97	Active Channel Flow: Mlb/hr	80.87
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.457	19	31	24	1.648	0.856	19	29	10.10	0.878	14.9	19	27	40	4	11.76
1.455	19	33	22	1.650	0.855	19	33	10.07	0.875	15.6	19	41	14	4	11.70
1.444	19	35	24	1.662	0.848	19	35	10.05	0.874	14.7	20	43	16	4	11.64
1.415	19	33	26	1.718	0.821	20	19	10.02	0.871	14.0	19	31	24	4	11.63
1.410	20	29	42	1.738	0.811	20	35	9.98	0.868	15.6	19	25	38	4	11.60
1.407	20	41	30	1.742	0.809	20	43	9.94	0.865	15.7	19	11	22	4	11.57
1.404	19	37	26	1.747	0.807	20	29	9.94	0.864	14.7	20	15	18	4	11.54
1.398	20	37	22	1.749	0.806	19	41	9.93	0.863	15.5	19	13	20	4	11.52
1.397	20	25	42	1.750	0.806	19	33	9.88	0.859	16.1	19	39	50	4	11.51
1.396	19	21	28	1.751	0.805	20	37	9.83	0.855	14.4	20	29	42	4	11.51

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.21 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 7,117.7 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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Cycle:	21	Core Average Exposure: MWd/MTU	25273.6
Exposure: MWd/MTU (GWd)	7500.0 (1037.80)		
Delta E: MWd/MTU, (GWd)	382.3 (52.90)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.68		
Flow: Mlb/hr	93.68 (91.40 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.155 5.079 13 0.439 0.663 7 16
		24	0.407 13.699 14 0.341 0.627 27 4
		23	0.507 17.433 15 0.426 0.682 45 8
		22	0.566 19.894 16 1.068 1.266 33 24
		21	0.595 21.486 17 1.095 1.286 31 22
		20	0.621 22.704 18 0.954 1.232 43 18
		19	0.644 23.486 19 1.331 1.462 31 24
		18	0.676 24.356 20 1.255 1.413 31 42
		17	0.715 25.164 21 1.154 1.301 43 12
		16	0.766 25.518
		15	0.848 25.704
		14	0.907 26.693
		13	0.968 27.640
		12	1.039 28.831
		11	1.100 29.570
		10	1.228 28.828
		9	1.328 29.996
		8	1.425 31.057
		7	1.542 32.267
		6	1.667 33.314
		5	1.782 33.900*
		4	1.847* 33.268
		3	1.804 30.923
		2	1.447 24.006
		Bottom 1	0.416 7.279
Control Rod Density: %	5.59		
k-effective:	0.99864		
Void Fraction:	0.508		
Core Delta-P: psia	22.199	% AXIAL TILT	-38.364 -15.619
Core Plate Delta-P: psia	17.639	AVG BOT 8ft/12ft	1.2144 1.0834
Coolant Temp: Deg-F	548.5		
In Channel Flow: Mlb/hr	81.97	Active Channel Flow: Mlb/hr	78.93
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.462	19	31	24	1.627	0.866	19	29	10.05	0.874	15.8	19	27	40	4	11.65
1.458	19	33	22	1.632	0.864	19	33	10.02	0.871	15.5	19	41	14	3	11.58
1.448	19	35	24	1.644	0.858	19	35	10.00	0.870	15.7	20	43	16	4	11.55
1.419	19	33	26	1.697	0.831	20	19	10.00	0.869	15.0	19	31	24	4	11.50
1.413	20	31	42	1.716	0.822	20	35	9.93	0.863	16.5	19	25	38	4	11.47
1.412	20	41	30	1.723	0.818	20	43	9.92	0.863	15.6	19	11	22	3	11.44
1.408	19	37	26	1.727	0.817	19	33	9.89	0.860	15.7	20	15	18	4	11.43
1.402	20	37	22	1.727	0.816	20	29	9.89	0.860	16.4	19	13	20	4	11.41
1.400	20	25	42	1.731	0.815	19	41	9.81	0.853	15.0	20	19	30	4	11.40
1.400	19	21	28	1.732	0.814	20	37	9.81	0.853	16.1	19	39	12	3	11.38

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.22 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 7,500.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	25773.5
Exposure: MWd/MTU (GWd)	8000.0 (1106.99)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.25		
Flow: Mlb/hr	92.05 (89.80 %)		
		Axial Profile	Edit Radial Power
		N (PRA)	Power Exposure Zone Avg. Max. IR JR
		Top	25 0.159 5.165 13 0.437 0.661 7 16
			24 0.414 13.924 14 0.339 0.623 27 4
			23 0.516 17.714 15 0.423 0.679 45 8
			22 0.576 20.209 16 1.066 1.263 33 24
			21 0.607 21.817 17 1.093 1.282 31 22
			20 0.633 23.050 18 0.951 1.229 43 18
			19 0.657 23.845 19 1.334 1.467 31 24
			18 0.690 24.732 20 1.260 1.418 41 30
			17 0.729 25.562 21 1.156 1.303 43 50
			16 0.779 25.934
			15 0.861 26.137
			14 0.919 27.156
			13 0.978 28.134
			12 1.047 29.360
			11 1.105 30.129
			10 1.229 29.389
			9 1.323 30.595
			8 1.415 31.698
			7 1.527 32.959
			6 1.645 34.061
			5 1.754 34.698*
			4 1.816* 34.096
			3 1.778 31.732
			2 1.432 24.657
		Bottom	1 0.412 7.486
Control Rod Density: %	5.59		
k-effective:	0.99865		
Void Fraction:	0.508		
Core Delta-P: psia	21.591	% AXIAL TILT	-37.238 -15.915
Core Plate Delta-P: psia	17.032	AVG BOT 8ft/12ft	1.2089 1.0848
Coolant Temp: Deg-F	548.5		
In Channel Flow: Mlb/hr	80.53	Active Channel Flow: Mlb/hr	77.54
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.3	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.467	19	31	24	1.613	0.874	19	29	9.89	0.860	17.1	19	33	22	4	11.42
1.463	19	33	22	1.620	0.870	19	33	9.88	0.860	15.9	20	43	16	3	11.34
1.451	19	35	24	1.634	0.863	19	35	9.87	0.858	16.2	19	31	24	4	11.30
1.424	19	33	26	1.683	0.838	20	19	9.86	0.858	16.7	19	41	14	3	11.25
1.418	20	41	30	1.701	0.829	20	35	9.81	0.853	16.8	19	11	22	3	11.21
1.418	20	31	42	1.709	0.825	20	43	9.77	0.849	15.9	20	15	18	3	11.18
1.412	19	37	26	1.710	0.825	19	33	9.76	0.849	16.5	19	13	20	3	11.14
1.407	20	23	40	1.714	0.822	20	29	9.74	0.847	17.7	19	25	38	4	11.11
1.405	20	25	42	1.718	0.821	19	41	9.71	0.844	16.9	19	9	24	3	11.11
1.405	19	21	28	1.718	0.821	20	37	9.69	0.843	16.2	20	41	32	4	11.08

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.23 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 8,000.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	26273.4
Exposure: MWd/MTU (GWd)	8500.0 (1176.18)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.66		
Flow: Mlb/hr	90.92 (88.70 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.163 5.252	13 0.435 0.660 7 16
		24 0.424 14.153	14 0.337 0.621 27 4
		23 0.529 18.000	15 0.421 0.677 45 8
		22 0.592 20.531	16 1.065 1.260 33 24
		21 0.624 22.157	17 1.091 1.279 31 22
		20 0.652 23.404	18 0.948 1.227 43 18
		19 0.677 24.213	19 1.337 1.472 31 24
		18 0.711 25.119	20 1.264 1.422 41 30
		17 0.750 25.970	21 1.157 1.304 43 50
		16 0.799 26.359	
		15 0.881 26.578	
		14 0.938 27.626	
		13 0.996 28.634	
		12 1.063 29.894	
		11 1.117 30.691	
		10 1.236 29.951	
		9 1.324 31.192	
		8 1.408 32.335	
		7 1.511 33.645	
		6 1.617 34.798	
		5 1.712 35.480*	
		4 1.763* 34.904	
		3 1.723 32.523	
		2 1.391 25.295	
		Bottom 1 0.400 7.688	
Control Rod Density: %	5.59		
k-effective:	0.99869		
Void Fraction:	0.505		
Core Delta-P: psia	21.144	% AXIAL TILT -35.504 -16.172	
Core Plate Delta-P: psia	16.585	AVG BOT 8ft/12ft 1.2004 1.0860	
Coolant Temp: Deg-F	548.4		
In Channel Flow: Mlb/hr	79.56	Active Channel Flow: Mlb/hr	76.61
Total Bypass Flow (%):	12.5	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.472	19	31	24	1.602	0.880	19	29	38	9.59	0.834	17.4	19	31	24	4	11.05	0.812	19.6	20	41	18	4
1.466	19	33	22	1.607	0.877	19	33	22	9.58	0.833	17.1	20	43	16	3	10.94	0.804	19.7	20	25	42	4
1.453	19	35	24	1.623	0.869	19	35	24	9.57	0.832	18.3	19	33	22	4	10.90	0.802	19.2	20	17	34	4
1.427	19	33	26	1.675	0.842	20	19	32	9.52	0.828	17.9	19	41	14	3	10.88	0.800	20.8	19	31	24	4
1.422	20	41	30	1.690	0.834	20	35	20	9.49	0.825	18.0	19	11	22	3	10.71	0.797	22.5	20	17	16	4
1.421	20	31	42	1.699	0.830	19	33	26	9.48	0.824	17.1	20	15	18	3	10.70	0.796	22.6	20	15	48	4
1.415	19	37	26	1.701	0.829	20	43	16	9.45	0.822	17.8	19	13	20	3	10.75	0.795	21.7	19	33	40	4
1.411	20	23	40	1.707	0.826	19	21	34	9.45	0.822	15.8	20	19	18	4	10.68	0.794	22.5	20	47	16	4
1.410	20	25	42	1.710	0.825	20	29	42	9.43	0.820	17.4	20	41	32	4	10.65	0.793	22.5	20	15	18	4
1.409	19	21	28	1.711	0.824	19	23	36	9.42	0.820	18.1	19	9	24	3	10.78	0.792	18.6	20	39	42	4

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.24 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 8,500.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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Cycle:	21	Core Average Exposure: MWd/MTU										26773.4			
Exposure: MWd/MTU (Gwd)	9000.0	(1245.36)													
Delta E: MWd/MTU, (Gwd)	500.0	(69.19)													
Power: MWt	3952.0	(100.00 %)													
Core Pressure: psia	1050.0														
Inlet Subcooling: Btu/lbm	-30.92														
Flow: Mlb/hr	90.20	(88.00 %)													
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
59				--	--	--	--	--	--	--					59
55			--	--	--	--	--	--	--	--					55
51		--	--	--	--	--	--	--	--	--					51
47	--	--	--	--	--	6	--	6	--	--	--	--	--		47
43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	43
39	--	--	--	--	8	--	--	--	--	8	--	--	--	--	39
35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	35
31	--	--	6	--	--	--	6	--	6	--	--	6	--	--	31
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27
23	--	--	--	--	8	--	--	--	--	8	--	--	--	--	23
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19
15	--	--	--	--	--	6	--	6	--	--	--	--	--	--	15
11		--	--	--	--	--	--	--	--	--	--	--	--	--	11
7			--	--	--	--	--	--	--	--	--	--	--	--	7
3				--	--	--	--	--	--	--	--	--	--	--	3
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
Control Rod Density: %	5.59														
k-effective:	0.99879														
Void Fraction:	0.500														
Core Delta-P: psia	20.816	% AXIAL TILT -33.126 -16.380													
Core Plate Delta-P: psia	16.259	AVG BOT 8ft/12ft 1.1889 1.0870													
Coolant Temp: Deg-F	548.3														
In Channel Flow: Mlb/hr	78.97	Active Channel Flow: Mlb/hr										76.06			
Total Bypass Flow (%):	12.4	(of total core flow)													
Total Water Rod Flow (%):	3.2	(of total core flow)													
Source Convergence	0.00009														

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.474	19	31	24	1.587	0.889	19	29	38	9.16	0.796	18.6	19	31	24	4	10.53	0.774	21.0	20	41	18	4
1.467	19	33	22	1.595	0.884	19	33	22	9.11	0.793	19.5	19	33	22	4	10.41	0.765	20.5	20	17	34	4
1.454	19	35	24	1.612	0.875	19	35	24	9.11	0.792	19.3	20	43	16	4	10.24	0.765	23.0	19	33	40	4
1.429	19	33	26	1.675	0.842	20	19	32	9.11	0.792	17.0	20	19	18	4	10.40	0.764	21.0	20	25	42	4
1.426	20	41	30	1.682	0.838	19	27	36	9.06	0.788	20.2	19	41	14	4	10.21	0.763	23.0	20	17	16	4
1.422	20	31	42	1.685	0.837	20	35	20	9.05	0.787	20.2	19	49	40	4	10.29	0.763	22.1	19	31	24	4
1.416	19	37	26	1.692	0.833	19	39	28	9.04	0.786	18.3	19	39	16	4	10.14	0.763	23.9	20	15	48	4
1.414	20	37	22	1.695	0.832	19	37	26	9.02	0.785	19.3	20	15	18	4	10.15	0.762	23.6	19	49	40	4
1.414	20	25	42	1.701	0.829	20	43	16	9.02	0.784	18.6	20	41	32	4	7.62	0.762	53.8	18	15	16	4
1.412	19	21	28	1.704	0.828	20	31	42	9.02	0.784	20.0	19	47	42	4	10.12	0.761	23.8	20	47	16	4

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.25 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 9,000.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU				27273.4			
Exposure: MWd/MTU (Gwd)	9500.0 (1314.55)								
Delta E: MWd/MTU, (Gwd)	500.0 (69.19)								
Power: MWt	3952.0 (100.00 %)								
Core Pressure: psia	1050.0								
Inlet Subcooling: Btu/lbm	-31.38								
Flow: Mlb/hr	88.97 (86.80 %)								
		Axial Profile		Edit	Radial Power				
		N(PRA)	Power	Exposure	Zone	Avg.	Max.	IR	JR
		Top 25	0.176	5.436	13	0.433	0.658	7	16
		24	0.456	14.636	14	0.334	0.617	27	4
		23	0.571	18.602	15	0.419	0.675	45	8
		22	0.640	21.210	16	1.063	1.254	33	24
		21	0.676	22.873	17	1.088	1.273	31	22
		20	0.708	24.154	18	0.945	1.223	43	18
		19	0.736	24.992	19	1.340	1.476	31	24
		18	0.772	25.936	20	1.271	1.427	41	30
		17	0.811	26.830	21	1.160	1.305	43	50
		16	0.859	27.252					
		15	0.941	27.500					
		14	0.995	28.605					
		13	1.049	29.669					
		12	1.110	30.995					
		11	1.156	31.841					
		10	1.263	31.090					
		9	1.335	32.392					
		8	1.398	33.602					
		7	1.473	34.993					
		6	1.541	36.225					
		5	1.593	36.974*					
		4	1.600*	36.426					
		3	1.540	34.001					
		2	1.242	26.488					
		Bottom 1	0.356	8.066					
		% AXIAL TILT -30.336 -16.531							
		AVG BOT 8ft/12ft			1.1755	1.0878			
Control Rod Density: %	5.59								
k-effective:	0.99872								
Void Fraction:	0.494								
Core Delta-P: psia	20.307								
Core Plate Delta-P: psia	15.750								
Coolant Temp: Deg-F	548.1								
In Channel Flow: Mlb/hr	77.93	Active Channel Flow: Mlb/hr			75.07				
Total Bypass Flow (%):	12.4	(of total core flow)							
Total Water Rod Flow (%):	3.2	(of total core flow)							
Source Convergence	0.00010								

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.476	19	31	24	1.570	0.898	19	29	38	8.66	0.753	18.1	20	19	18	4	7.21	0.742	55.0	18	15	16	5
1.467	19	33	40	1.577	0.894	19	33	22	8.64	0.752	19.7	19	31	24	4	7.13	0.738	55.2	18	43	48	5
1.455	19	25	38	1.594	0.884	19	35	24	8.62	0.749	20.4	20	43	16	4	7.14	0.737	55.1	18	47	18	5
1.430	19	33	26	1.657	0.851	20	19	32	8.58	0.747	21.3	19	49	40	4	9.91	0.736	22.2	20	41	18	4
1.427	20	41	30	1.658	0.850	19	27	36	8.59	0.747	20.6	19	33	22	4	9.63	0.730	24.9	19	49	40	4
1.423	20	31	42	1.664	0.847	19	39	28	8.57	0.746	21.3	19	41	14	4	9.65	0.729	24.3	19	33	40	4
1.417	19	37	26	1.669	0.845	19	23	36	8.56	0.746	21.4	19	9	24	4	9.59	0.729	25.1	19	47	42	4
1.417	20	35	42	1.680	0.839	20	37	22	8.57	0.745	19.4	19	21	16	4	9.66	0.726	23.8	19	39	16	4
1.416	20	23	40	1.682	0.838	20	35	20	8.57	0.745	17.8	20	43	34	4	9.57	0.726	24.9	19	41	48	4
1.414	19	21	28	1.687	0.836	20	29	42	8.56	0.745	19.5	19	47	24	4	9.81	0.726	21.8	20	17	34	4

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.26 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 9,500.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	27392.2
Exposure: MWd/MTU (GWd)	9618.7 (1330.97)		
Delta E: MWd/MTU, (GWd)	118.7 (16.42)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-31.45		
Flow: Mlb/hr	88.76 (86.60 %)		
		Axial Profile	Edit Radial Power
		N (PRA)	Power Exposure Zone Avg. Max. IR JR
		Top	25 0.178 5.459 13 0.433 0.658 7 16
			24 0.460 14.695 14 0.333 0.616 27 4
			23 0.576 18.677 15 0.418 0.675 45 8
			22 0.646 21.294 16 1.062 1.254 33 24
			21 0.683 22.962 17 1.088 1.272 31 22
			20 0.715 24.247 18 0.944 1.223 43 18
			19 0.743 25.088 19 1.340 1.476 31 24
			18 0.779 26.037 20 1.272 1.428 41 30
			17 0.819 26.936 21 1.160 1.305 43 50
			16 0.867 27.363
			15 0.948 27.614
			14 1.002 28.725
			13 1.055 29.796
			12 1.116 31.129
			11 1.160 31.980
			10 1.266 31.227
			9 1.337 32.536
			8 1.397 33.752
			7 1.468 35.150
			6 1.532 36.390
			5 1.579 37.144*
			4 1.580* 36.596
			3 1.518 34.165
			2 1.224 26.620
		Bottom	1 0.351 8.108
Control Rod Density: %	5.59		
k-effective:	0.99875		
Void Fraction:	0.493		
Core Delta-P: psia	20.218	% AXIAL TILT	-29.700 -16.558
Core Plate Delta-P: psia	15.661	AVG BOT 8ft/12ft	1.1724 1.0880
Coolant Temp: Deg-F	548.1		
In Channel Flow: Mlb/hr	77.76	Active Channel Flow: Mlb/hr	74.91
Total Bypass Flow (%):	12.4	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.476	19	31	24	1.565	0.901	19	29	38	8.56	0.745	18.3	20	19	18	4	7.14	0.740	55.2	18	15	16	5
1.468	19	33	40	1.572	0.897	19	33	22	8.53	0.742	20.0	19	31	24	4	7.06	0.735	55.4	18	43	48	5
1.455	19	35	24	1.590	0.887	19	35	24	8.51	0.740	20.7	20	43	16	4	7.08	0.735	55.3	18	47	18	5
1.430	19	33	26	1.652	0.854	20	19	32	8.48	0.740	21.5	19	49	40	4	9.78	0.728	22.5	20	41	18	4
1.428	20	41	30	1.654	0.853	19	27	36	8.46	0.738	21.7	19	9	24	4	9.51	0.723	25.1	19	49	40	4
1.423	20	31	42	1.659	0.850	19	39	28	8.46	0.738	21.5	19	41	14	4	9.47	0.722	25.4	19	47	42	4
1.418	20	35	42	1.665	0.847	19	37	26	8.48	0.737	20.9	19	33	22	4	9.52	0.721	24.6	19	33	40	4
1.417	19	37	26	1.675	0.842	20	37	22	8.47	0.737	19.7	19	39	16	4	7.21	0.720	53.8	18	17	18	5
1.416	20	23	40	1.678	0.840	20	35	20	8.47	0.736	18.0	20	43	34	4	9.55	0.719	24.1	19	39	16	4
1.414	19	21	28	1.682	0.838	20	29	42	8.46	0.736	19.8	19	47	24	4	9.45	0.718	25.2	19	41	48	4

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.27 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 9,618.7 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	27393.0
Exposure: MWd/MTU (GWd)	9619.6 (1331.10)		
Delta E: MWd/MTU, (GWd)	0.9 (0.12)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.82		
Flow: Mlb/hr	93.28 (91.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
2 6 10 14 18 22 26 30 34 38 42 46 50 54 58		Top 25 0.165 5.459	13 0.410 0.615 7 16
59		24 0.428 14.696	14 0.326 0.639 27 4
55		23 0.538 18.677	15 0.406 0.684 33 58
51		22 0.609 21.295	16 1.068 1.227 33 42
47		21 0.652 22.963	17 1.133 1.251 29 40
43		20 0.691 24.248	18 0.895 1.194 35 52
39		19 0.725 25.089	19 1.354 1.453 31 24
35		18 0.767 26.038	20 1.273 1.416 31 42
31		17 0.812 26.937	21 1.151 1.295 35 54
27		16 0.865 27.363	
23		15 0.952 27.615	
19		14 1.010 28.726	
15		13 1.068 29.797	
11		12 1.132 31.130	
7		11 1.179 31.982	
3		10 1.287 31.228	
		9 1.359 32.537	
		8 1.419 33.753	
		7 1.490 35.151	
		6 1.552 36.391	
		5 1.595* 37.146*	
		4 1.592 36.598	
		3 1.527 34.167	
		2 1.231 26.621	
		Bottom 1 0.354 8.108	
Control Rod Density: %	6.33		
k-effective:	0.99853		
Void Fraction:	0.485		
Core Delta-P: psia	21.797	% AXIAL TILT -31.347 -16.558	
Core Plate Delta-P: psia	17.236	AVG BOT 8ft/12ft 1.1846 1.0880	
Coolant Temp: Deg-F	548.2		
In Channel Flow: Mlb/hr	81.76	Active Channel Flow: Mlb/hr	78.78
Total Bypass Flow (%):	12.3	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.453	19	31	24	1.631	0.865	19	29	8.99	0.782	19.8	19	47	24	4	7.22	0.764	56.0	18	25	10	5
1.452	19	23	30	1.635	0.862	19	37	8.90	0.774	19.5	19	45	40	4	7.46	0.760	54.6	18	9	26	4
1.423	19	33	40	1.675	0.842	19	37	8.87	0.772	17.8	20	43	38	4	9.95	0.759	25.6	19	9	24	4
1.422	19	35	28	1.676	0.841	19	13	8.83	0.771	21.7	19	9	24	4	9.97	0.758	25.1	21	7	26	4
1.422	19	33	26	1.680	0.839	19	21	8.85	0.770	17.8	20	45	36	4	10.21	0.754	21.6	20	17	24	4
1.421	19	37	48	1.681	0.839	19	33	8.82	0.767	20.9	19	49	26	4	9.92	0.752	24.9	19	49	26	4
1.419	19	21	28	1.684	0.837	19	45	8.81	0.766	20.3	19	23	14	4	10.02	0.752	23.5	19	47	24	4
1.418	19	13	24	1.688	0.835	20	35	8.79	0.765	20.4	20	51	28	4	10.15	0.751	21.8	20	15	26	4
1.416	20	31	42	1.689	0.835	20	17	8.78	0.763	19.7	19	39	16	4	9.86	0.749	25.1	20	9	34	4
1.414	19	15	22	1.690	0.834	20	27	8.75	0.761	17.9	20	23	18	4	9.90	0.748	24.5	19	7	34	4

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.28 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 9,619.6 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	27773.4
Exposure: MWd/MTU (GWd)	10000.0 (1383.74)		
Delta E: MWd/MTU, (GWd)	380.4 (52.64)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.79		
Flow: Mlb/hr	93.38 (91.10 %)		
		Axial Profile	Edit Radial Power
		N (PRA)	Power Exposure Zone Avg. Max. IR JR
2 6 10 14 18 22 26 30 34 38 42 46 50 54 58		Top 25	0.171 5.528 13 0.409 0.615 7 16
59		24	0.444 14.878 14 0.325 0.638 27 4
55		23	0.558 18.906 15 0.406 0.682 33 58
51		22	0.632 21.555 16 1.067 1.226 33 42
47		21	0.678 23.242 17 1.132 1.249 29 40
43		20	0.719 24.543 18 0.895 1.193 35 52
39		19	0.754 25.400 19 1.354 1.454 31 24
35		18	0.797 26.366 20 1.275 1.416 31 42
31		17	0.843 27.284 21 1.152 1.295 35 54
27		16	0.896 27.725
23		15	0.982 27.988
19		14	1.040 29.121
15		13	1.095 30.214
11		12	1.157 31.571
7		11	1.200 32.440
3		10	1.304 31.678
		9	1.368 33.005
		8	1.417 34.240
		7	1.473 35.660
		6	1.516 36.918
		5	1.536* 37.683*
		4	1.510 37.131
		3	1.431 34.675
		2	1.150 27.030
		Bottom 1	0.330 8.238
Control Rod Density: %	6.33		
k-effective:	0.99865		
Void Fraction:	0.478		
Core Delta-P: psia	21.740	% AXIAL TILT	-28.769 -16.644
Core Plate Delta-P: psia	17.179	AVG BOT 8ft/12ft	1.1722 1.0885
Coolant Temp: Deg-F	548.1		
In Channel Flow: Mlb/hr	81.90	Active Channel Flow: Mlb/hr	78.94
Total Bypass Flow (%):	12.3	(of total core flow)	
Total Water Rod Flow (%):	3.2	(of total core flow)	
Source Convergence	0.00007		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.454	19	31	24	1.628	0.866	19	29	38	8.55	0.743	20.6	19	47	24	4	6.94	0.748	56.7	18	25	10	5
1.452	19	23	30	1.633	0.863	19	37	30	8.42	0.738	22.4	19	51	24	4	7.17	0.745	55.3	18	9	26	5
1.423	19	33	40	1.672	0.844	19	37	48	8.46	0.736	20.4	19	45	40	4	9.47	0.728	26.5	19	9	24	4
1.422	19	33	26	1.672	0.844	19	33	40	8.44	0.734	18.7	20	43	38	4	9.50	0.727	26.1	21	7	26	4
1.422	19	35	28	1.674	0.842	19	13	38	8.43	0.733	18.7	20	45	36	4	9.43	0.721	25.9	19	49	26	4
1.420	19	37	48	1.677	0.841	19	21	46	8.38	0.731	21.7	19	49	26	4	9.53	0.720	24.5	19	47	24	4
1.419	19	21	28	1.682	0.838	19	39	34	8.36	0.728	21.3	20	9	34	4	9.43	0.718	25.4	19	7	34	4
1.418	19	13	24	1.683	0.838	19	45	22	8.32	0.727	21.8	21	7	36	4	9.65	0.718	22.5	20	17	24	4
1.416	20	31	42	1.694	0.833	20	35	20	8.35	0.726	21.1	19	23	14	4	7.07	0.716	54.3	17	49	24	5
1.415	19	15	22	1.694	0.832	19	35	28	8.34	0.725	20.5	19	39	16	4	9.59	0.715	22.7	20	15	26	4

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.29 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 10,000.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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Cycle:	21	Core Average Exposure: MWd/MTU										28273.4			
Exposure: MWd/MTU (GWd)	10500.0	(1452.92)													
Delta E: MWd/MTU, (GWd)	500.0	(69.19)													
Power: MWt	3952.0	(100.00 %)													
Core Pressure: psia	1050.0														
Inlet Subcooling: Btu/lbm	-30.07														
Flow: Mlb/hr	92.56	(90.30 %)													
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
59				--	--	--	--	--	--	--					59
55				--	--	--	--	--	--	--					55
51			--	--	--	--	--	--	--	--					51
47	--	--	8	--	--	--	6	--	--	--	8	--	--		47
43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	43
39	--	--	--	--	--	0	--	--	0	--	--	--	--	--	39
35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	35
31	--	--	6	--	--	--	6	--	--	--	6	--	--	--	31
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27
23	--	--	--	--	--	0	--	--	0	--	--	--	--	--	23
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19
15	--	--	8	--	--	--	6	--	--	--	8	--	--		15
11			--	--	--	--	--	--	--	--	--	--	--		11
7			--	--	--	--	--	--	--	--	--	--	--		7
3				--	--	--	--	--	--	--					3
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
Control Rod Density: %	6.33														
k-effective:	0.99859														
Void Fraction:	0.470														
Core Delta-P: psia	21.338	% AXIAL TILT -25.302 -16.699													
Core Plate Delta-P: psia	16.778	AVG BOT 8ft/12ft 1.1556 1.0889													
Coolant Temp: Deg-F	547.9														
In Channel Flow: Mlb/hr	81.24	Active Channel Flow: Mlb/hr										78.32			
Total Bypass Flow (%):	12.2	(of total core flow)													
Total Water Rod Flow (%):	3.1	(of total core flow)													
Source Convergence	0.00006														

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.453	19	31	24	1.621	0.870	19	29	38	7.98	0.695	21.2	19	47	24	5	6.57	0.725	57.6	18	25	10	5
1.451	19	23	30	1.627	0.867	19	37	30	7.87	0.694	23.4	19	51	24	4	6.82	0.725	56.2	18	9	26	5
1.422	19	33	40	1.655	0.852	19	33	40	7.86	0.687	22.1	19	49	26	5	6.72	0.696	55.2	17	49	24	5
1.421	19	33	26	1.661	0.849	19	37	48	7.90	0.687	21.0	19	15	22	5	6.59	0.686	55.4	17	23	50	5
1.420	19	25	28	1.663	0.848	19	13	38	7.86	0.685	21.6	19	37	14	5	8.84	0.686	27.7	19	9	24	4
1.420	19	37	48	1.664	0.847	19	39	34	7.83	0.685	22.0	20	9	34	5	8.87	0.686	27.2	21	7	26	4
1.418	19	13	24	1.666	0.847	19	21	46	7.80	0.685	22.8	21	7	36	4	6.55	0.684	55.5	17	9	32	5
1.418	19	21	28	1.672	0.844	19	45	22	7.87	0.684	19.9	20	45	36	5	6.38	0.681	56.4	17	41	50	5
1.415	20	31	42	1.681	0.839	19	35	28	7.87	0.684	19.9	20	17	24	5	6.26	0.681	57.1	16	33	50	5
1.415	19	15	22	1.684	0.838	19	27	36	7.83	0.681	21.1	19	39	16	5	6.33	0.681	56.6	17	11	20	5

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.30 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 10,500.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU										28773.2			
Exposure: MWd/MTU (Gwd)	11000.0	(1522.11)													
Delta E: MWd/MTU, (Gwd)	500.0	(69.19)													
Power: MWt	3952.0	(100.00 %)													
Core Pressure: psia	1050.0														
Inlet Subcooling: Btu/lbm	-30.18														
Flow: Mlb/hr	92.25	(90.00 %)													
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
59				--	--	--	--	--	--	--					59
55			--	--	--	--	--	--	--	--					55
51		--	--	--	--	--	--	--	--	--					51
47	--	--	8	--	--	--	6	--	--	--	8	--	--		47
43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	43
39	--	--	--	--	--	0	--	--	0	--	--	--	--	--	39
35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	35
31	--	--	6	--	--	--	6	--	--	--	6	--	--	--	31
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27
23	--	--	--	--	--	0	--	--	0	--	--	--	--	--	23
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19
15	--	--	8	--	--	--	6	--	--	--	8	--	--		15
11		--	--	--	--	--	--	--	--	--	--	--	--		11
7			--	--	--	--	--	--	--	--	--	--	--		7
3				--	--	--	--	--	--	--	--	--	--		3
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
Control Rod Density: %	6.33														
k-effective:	0.99863														
Void Fraction:	0.461														
Core Delta-P: psia	21.116											% AXIAL TILT -21.752 -16.690			
Core Plate Delta-P: psia	16.556											AVG BOT 8ft/12ft 1.1384 1.0890			
Coolant Temp: Deg-F	547.7														
In Channel Flow: Mlb/hr	81.03											Active Channel Flow: Mlb/hr 78.15			
Total Bypass Flow (%):	12.2											(of total core flow)			
Total Water Rod Flow (%):	3.1											(of total core flow)			
Source Convergence	0.00007														

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.452	19	31	24	1.616	0.872	19	29	38	7.55	0.661	22.2	19	47	24	5	6.46	0.702	57.0	18	9	26	5
1.450	19	23	30	1.622	0.870	19	37	30	7.50	0.661	23.5	19	9	24	5	6.48	0.701	56.8	18	25	10	6
1.421	19	33	40	1.645	0.857	19	33	40	7.53	0.655	16.6	19	29	38	11	6.36	0.673	56.0	17	49	24	5
1.420	19	33	26	1.655	0.852	19	39	34	7.44	0.655	23.1	19	49	26	5	6.46	0.668	55.1	17	23	50	6
1.419	19	25	28	1.660	0.849	19	37	48	7.44	0.654	23.0	20	9	34	5	6.21	0.667	56.6	16	33	50	6
1.419	19	37	48	1.660	0.849	19	13	38	7.47	0.653	22.0	19	15	22	5	6.26	0.663	56.0	17	41	50	6
1.418	19	13	24	1.664	0.847	19	21	46	7.51	0.653	16.5	19	23	30	11	6.20	0.662	56.3	17	9	32	5
1.417	19	21	28	1.669	0.845	19	45	22	7.50	0.653	21.3	19	23	48	6	6.15	0.662	56.7	17	31	26	6
1.415	19	15	22	1.670	0.844	19	35	28	7.35	0.650	23.9	19	23	10	5	6.38	0.660	55.1	17	39	48	6
1.414	19	39	46	1.673	0.843	19	27	36	7.39	0.649	22.8	21	7	36	5	6.16	0.660	56.5	17	25	32	6

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.31 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 11,000.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	29273.3
Exposure: MWd/MTU (GWd)	11500.0 (1591.30)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.18		
Flow: Mlb/hr	92.25 (90.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.198 5.829 13 0.409 0.617 7 16
		24	0.512 15.662 14 0.323 0.635 27 4
		23	0.646 19.894 15 0.404 0.679 33 58
		22	0.733 22.682 16 1.063 1.218 33 42
		21	0.788 24.452 17 1.125 1.236 29 40
		20	0.837 25.828 18 0.897 1.191 35 52
		19	0.878 26.747 19 1.355 1.450 31 24
		18	0.925 27.789 20 1.278 1.412 31 42
		17	0.970 28.783 21 1.160 1.299 35 54
		16	1.018 29.271
		15	1.104 29.573
		14	1.154 30.789
		13	1.200 31.960
		12	1.251 33.404
		11	1.276 34.323
		10	1.356 33.500
		9	1.387 34.873
		8	1.388* 36.143
		7	1.383 37.597
		6	1.354 38.864
		5	1.291 39.599*
		4	1.191 38.961
		3	1.072 36.370
		2	0.847 28.382
		Bottom 1	0.242 8.666
Control Rod Density: %	6.33		
k-effective:	0.99877		
Void Fraction:	0.451		
Core Delta-P: psia	20.995	% AXIAL TILT	-17.970 -16.616
Core Plate Delta-P: psia	16.436	AVG BOT 8ft/12ft	1.1198 1.0888
Coolant Temp: Deg-F	547.5		
In Channel Flow: Mlb/hr	81.10	Active Channel Flow: Mlb/hr	78.25
Total Bypass Flow (%):	12.1	(of total core flow)	
Total Water Rod Flow (%):	3.1	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.450	19	31	24	1.610	0.876	19	29	38	7.65	0.665	17.6	19	29	38	11	6.22	0.688	57.6	18	25	10	6
1.448	19	23	30	1.615	0.873	19	37	30	7.63	0.663	17.5	19	23	30	11	6.37	0.682	56.5	18	9	26	6
1.419	19	37	48	1.637	0.861	19	33	40	7.53	0.655	18.0	19	33	40	11	8.89	0.660	22.1	19	31	24	11
1.419	19	33	40	1.647	0.856	19	39	34	7.53	0.655	16.8	19	37	48	11	6.94	0.659	49.9	17	31	40	11
1.419	19	13	24	1.650	0.855	19	37	48	7.49	0.652	18.2	19	33	26	11	6.28	0.659	55.7	17	49	24	6
1.418	19	33	26	1.656	0.852	19	13	38	7.49	0.652	17.8	20	31	42	11	8.85	0.656	21.9	19	23	32	11
1.417	19	25	28	1.659	0.850	19	21	46	7.49	0.651	18.2	19	25	34	11	6.21	0.655	55.9	17	23	50	6
1.415	19	15	22	1.663	0.848	19	15	22	7.49	0.651	17.8	19	21	28	11	6.90	0.655	49.9	17	39	32	11
1.415	19	21	28	1.665	0.847	19	35	28	7.46	0.648	16.6	19	39	46	11	8.79	0.655	22.6	19	33	40	11
1.415	19	39	46	1.667	0.846	19	27	36	7.44	0.647	16.2	20	35	46	11	5.94	0.652	57.4	16	33	50	6

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.32 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 11,500.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	29773.2
Exposure: MWd/MTU (GWd)	12000.0 (1660.49)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.18		
Flow: Mlb/hr	92.25 (90.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.209 5.939	13 0.409 0.617 7 16
		24 0.538 15.950	14 0.322 0.634 27 4
		23 0.679 20.257	15 0.404 0.678 3 34
		22 0.771 23.097	16 1.061 1.214 33 42
		21 0.830 24.898	17 1.123 1.230 31 40
		20 0.881 26.301	18 0.898 1.192 35 52
		19 0.923 27.244	19 1.355 1.446 31 24
		18 0.971 28.312	20 1.279 1.409 31 42
		17 1.016 29.331	21 1.164 1.303 35 54
		16 1.061 29.831	
		15 1.145 30.143	
		14 1.191 31.383	
		13 1.233 32.576	
		12 1.278 34.045	
		11 1.294 34.973	
		10 1.365 34.121	
		9 1.384* 35.498	
		8 1.368 36.765	
		7 1.344 38.213	
		6 1.293 39.462	
		5 1.206 40.163*	
		4 1.087 39.475	
		3 0.961 36.830	
		2 0.754 28.744	
		Bottom 1 0.216 8.780	
Control Rod Density: %	6.33		
k-effective:	0.99888		
Void Fraction:	0.441		
Core Delta-P: psia	20.876	% AXIAL TILT -14.041 -16.478	
Core Plate Delta-P: psia	16.316	AVG BOT 8ft/12ft 1.1001 1.0883	
Coolant Temp: Deg-F	547.3		
In Channel Flow: Mlb/hr	81.17	Active Channel Flow: Mlb/hr	78.34
Total Bypass Flow (%):	12.0	(of total core flow)	
Total Water Rod Flow (%):	3.1	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.446	19	31	24	1.608	0.877	19	29	38	7.71	0.670	18.6	19	31	24	11	5.95	0.672	58.4	18	25	10	6
1.444	19	23	30	1.613	0.874	19	37	30	7.70	0.669	18.5	19	23	32	11	9.00	0.670	22.7	19	31	24	12
1.419	19	37	48	1.627	0.867	19	33	40	7.65	0.665	17.8	19	37	48	11	6.11	0.668	57.2	18	9	26	6
1.419	19	13	24	1.636	0.862	19	39	34	7.59	0.660	19.0	19	27	40	11	6.96	0.667	50.8	17	31	40	11
1.416	19	33	40	1.640	0.860	19	37	48	7.58	0.659	17.5	19	39	46	11	8.96	0.666	22.4	19	23	32	12
1.415	19	15	22	1.645	0.857	19	13	38	7.57	0.658	17.3	19	13	24	11	8.91	0.666	23.1	19	33	40	12
1.414	19	33	26	1.650	0.855	19	21	46	7.56	0.657	18.8	19	21	28	11	6.93	0.664	50.7	17	39	32	11
1.414	19	39	46	1.653	0.853	19	15	22	7.56	0.657	18.7	20	31	42	11	8.85	0.660	22.8	19	39	34	12
1.414	19	25	28	1.660	0.850	19	33	26	7.55	0.657	18.5	19	35	50	11	8.86	0.656	21.9	19	23	48	11
1.411	19	21	28	1.660	0.849	19	25	34	7.55	0.656	17.2	20	35	46	11	8.82	0.655	22.2	20	31	42	12

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.33 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 12,000.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	29899.9
Exposure: MWd/MTU (GWd)	12126.7 (1678.02)		
Delta E: MWd/MTU, (GWd)	126.7 (17.53)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.18		
Flow: Mlb/hr	92.25 (90.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.211 5.968	13 0.409 0.618 7 16
		24 0.544 16.025	14 0.322 0.633 27 4
		23 0.687 20.352	15 0.404 0.678 3 34
		22 0.781 23.205	16 1.060 1.212 33 42
		21 0.840 25.015	17 1.122 1.229 31 40
		20 0.892 26.425	18 0.898 1.192 35 52
		19 0.934 27.374	19 1.355 1.445 31 24
		18 0.982 28.448	20 1.279 1.408 31 42
		17 1.027 29.474	21 1.165 1.303 35 54
		16 1.071 29.977	
		15 1.154 30.290	
		14 1.199 31.537	
		13 1.239 32.735	
		12 1.283 34.209	
		11 1.297 35.140	
		10 1.366 34.279	
		9 1.381* 35.656	
		8 1.362 36.921	
		7 1.334 38.366	
		6 1.278 39.609	
		5 1.188 40.300*	
		4 1.065 39.598	
		3 0.939 36.938	
		2 0.735 28.829	
		Bottom 1 0.211 8.807	
			% AXIAL TILT -13.108 -16.433
			AVG BOT 8ft/12ft 1.0953 1.0881
Control Rod Density: %	6.33		
k-effective:	0.99896		
Void Fraction:	0.438		
Core Delta-P: psia	20.849		
Core Plate Delta-P: psia	16.289		
Coolant Temp: Deg-F	547.3		
In Channel Flow: Mlb/hr	81.19	Active Channel Flow: Mlb/hr	78.36
Total Bypass Flow (%):	12.0	(of total core flow)	
Total Water Rod Flow (%):	3.1	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.445	19	31	24	1.608	0.877	19	29	38	7.71	0.670	18.8	19	31	24	11	8.99	0.671	22.9	19	31	24	12
1.443	19	23	30	1.613	0.874	19	37	30	7.70	0.669	18.7	19	23	32	11	5.89	0.668	58.6	18	25	10	6
1.419	19	37	48	1.625	0.868	19	33	40	7.67	0.667	18.0	19	37	48	11	6.95	0.668	51.0	17	31	40	11
1.419	19	13	24	1.635	0.862	19	39	34	7.60	0.660	17.8	19	39	46	11	8.95	0.667	22.7	19	23	32	12
1.415	19	33	40	1.638	0.861	19	37	48	7.59	0.660	19.2	19	27	40	11	8.90	0.667	23.3	19	33	40	12
1.415	19	15	22	1.643	0.858	19	13	38	7.59	0.660	17.5	19	13	24	11	6.05	0.665	57.4	18	9	26	6
1.414	19	39	46	1.648	0.856	19	21	46	7.57	0.658	18.7	19	35	50	11	6.92	0.664	51.0	17	39	32	11
1.414	19	33	26	1.651	0.854	19	15	22	7.56	0.658	17.4	20	35	46	11	8.85	0.661	23.1	19	39	34	12
1.413	19	25	28	1.658	0.850	19	33	26	7.56	0.657	17.5	19	15	22	11	8.86	0.657	22.1	19	23	48	11
1.411	19	21	28	1.659	0.850	19	25	34	7.56	0.657	19.0	19	21	28	11	8.82	0.656	22.5	20	31	42	12

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.34 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 12,126.7 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	29900.4
Exposure: MWd/MTU (GWd)	12127.3 (1678.10)		
Delta E: MWd/MTU, (GWd)	0.6 (0.08)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.25		
Flow: Mlb/hr	92.05 (89.80 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.206 5.968	13 0.431 0.662 7 16
		24 0.530 16.025	14 0.328 0.585 27 4
		23 0.670 20.352	15 0.416 0.675 45 8
		22 0.760 23.206	16 1.054 1.238 23 28
		21 0.817 25.015	17 1.073 1.251 21 32
		20 0.875 26.426	18 0.948 1.212 45 16
		19 0.922 27.375	19 1.344 1.472 23 30
		18 0.973 28.449	20 1.274 1.424 19 32
		17 1.021 29.474	21 1.181 1.327 11 18
		16 1.067 29.977	
		15 1.151 30.291	
		14 1.198 31.537	
		13 1.239 32.736	
		12 1.285 34.210	
		11 1.300 35.140	
		10 1.370 34.279	
		9 1.387* 35.657	
		8 1.370 36.922	
		7 1.345 38.367	
		6 1.292 39.609	
		5 1.205 40.301*	
		4 1.086 39.599	
		3 0.961 36.939	
		2 0.754 28.829	
		Bottom 1 0.216 8.807	
Control Rod Density: %	5.95		
k-effective:	0.99906		
Void Fraction:	0.443		
Core Delta-P: psia	20.809	% AXIAL TILT -14.228 -16.433	
Core Plate Delta-P: psia	16.251	AVG BOT 8ft/12ft 1.1027 1.0881	
Coolant Temp: Deg-F	547.4		
In Channel Flow: Mlb/hr	80.98	Active Channel Flow: Mlb/hr	78.16
Total Bypass Flow (%):	12.0	(of total core flow)	
Total Water Rod Flow (%):	3.1	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR						LHGR								
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.472	19	23	30	1.572	0.897	19	37	30	7.79	0.678	18.7	19	23	30	11	9.12	0.679	22.7	19	23	32	12
1.462	19	21	28	1.575	0.895	19	39	34	7.77	0.675	19.0	19	21	28	11	9.04	0.676	23.1	19	39	34	12
1.448	19	23	26	1.599	0.882	19	23	26	7.72	0.671	19.2	19	23	26	11	7.01	0.673	51.0	17	39	32	11
1.425	19	25	28	1.634	0.863	19	25	34	7.62	0.663	19.0	20	31	42	11	6.87	0.670	52.5	16	37	28	11
1.424	20	19	32	1.650	0.854	20	21	38	7.61	0.662	17.4	20	21	24	11	8.91	0.668	23.4	19	23	26	12
1.421	20	21	24	1.661	0.849	19	25	42	7.56	0.657	18.6	20	19	32	11	9.03	0.667	21.6	20	39	24	12
1.420	20	19	26	1.661	0.849	20	29	24	7.54	0.656	17.4	20	19	26	11	6.86	0.666	52.1	17	39	26	11
1.417	20	31	42	1.666	0.846	20	41	26	7.54	0.655	19.4	19	25	34	11	8.83	0.662	23.4	19	25	34	12
1.409	19	35	24	1.668	0.845	19	33	40	7.53	0.655	19.3	19	25	38	11	6.16	0.660	56.5	18	15	16	6
1.403	19	33	40	1.668	0.845	20	41	22	7.52	0.654	17.8	20	15	18	11	8.93	0.659	21.6	20	41	26	12

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.35 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 12,127.3 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU				30273.2			
Exposure: MWd/MTU (GWd)	12500.0 (1729.67)								
Delta E: MWd/MTU, (GWd)	372.7 (51.57)								
Power: MWt	3952.0 (100.00 %)								
Core Pressure: psia	1050.0								
Inlet Subcooling: Btu/lbm	-30.18								
Flow: Mlb/hr	92.25 (90.00 %)								
		Axial Profile				Edit Radial Power			
		N (PRA)	Power	Exposure	Zone	Avg.	Max.	IR	JR
		Top 25	0.214	6.053	13	0.431	0.662	7	16
		24	0.551	16.246	14	0.327	0.585	27	4
		23	0.697	20.632	15	0.415	0.674	45	8
		22	0.791	23.525	16	1.053	1.233	23	28
		21	0.850	25.358	17	1.072	1.246	21	30
		20	0.910	26.793	18	0.948	1.210	45	16
		19	0.959	27.761	19	1.345	1.470	23	30
		18	1.010	28.857	20	1.274	1.422	19	32
		17	1.057	29.902	21	1.184	1.328	11	18
		16	1.100	30.413					
		15	1.182	30.732					
		14	1.225	31.995					
		13	1.262	33.208					
		12	1.301	34.698					
		11	1.309	35.633					
		10	1.373	34.746					
		9	1.380*	36.123					
		8	1.351	37.380					
		7	1.312	38.814					
		6	1.243	40.036					
		5	1.141	40.696*					
		4	1.011	39.952					
		3	0.883	37.249					
		2	0.690	29.073					
		Bottom 1	0.198	8.884					
Control Rod Density: %	5.95								
k-effective:	0.99909								
Void Fraction:	0.435								
Core Delta-P: psia	20.788	% AXIAL TILT				-11.140 -16.293			
Core Plate Delta-P: psia	16.230	AVG BOT 8ft/12ft				1.0869 1.0876			
Coolant Temp: Deg-F	547.2								
In Channel Flow: Mlb/hr	81.22	Active Channel Flow: Mlb/hr				78.41			
Total Bypass Flow (%):	12.0	(of total core flow)							
Total Water Rod Flow (%):	3.0	(of total core flow)							
Source Convergence	0.00010								

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.470	19	23	30	1.569	0.899	19	23	32	7.79	0.678	19.4	19	23	32	11	9.13	0.686	23.6	19	23	32	12
1.459	19	21	28	1.571	0.897	19	39	34	7.77	0.676	19.7	19	21	28	11	9.05	0.681	23.9	19	39	34	12
1.445	19	23	26	1.596	0.883	19	23	26	7.72	0.672	19.0	19	23	26	12	7.10	0.680	50.8	17	39	32	12
1.423	19	25	28	1.628	0.866	19	25	34	7.63	0.664	18.1	20	21	24	11	6.96	0.677	52.3	16	37	28	12
1.422	20	19	32	1.651	0.854	20	39	24	7.63	0.663	18.7	20	31	42	12	9.06	0.674	22.4	20	39	24	12
1.418	20	19	26	1.655	0.852	19	25	24	7.58	0.659	18.5	20	15	18	11	8.92	0.673	24.3	19	23	26	12
1.418	20	21	24	1.658	0.850	20	41	26	7.58	0.659	18.1	20	19	26	11	6.94	0.672	51.8	17	39	26	12
1.414	20	31	42	1.663	0.848	19	33	40	7.57	0.659	19.4	20	19	32	11	8.85	0.668	24.2	19	25	34	12
1.407	19	25	24	1.666	0.846	20	29	42	7.56	0.657	19.1	19	25	34	12	8.97	0.667	22.4	20	41	26	12
1.401	19	33	40	1.668	0.846	20	41	22	7.54	0.656	17.9	20	17	20	11	8.89	0.664	23.0	20	41	32	12

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.36 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 12,500.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	30773.2
Exposure: MWd/MTU (GWd)	13000.0 (1798.86)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.93		
Flow: Mlb/hr	92.97 (90.70 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.226 6.173 13 0.430 0.662 7 16
		24	0.581 16.557 14 0.326 0.585 27 4
		23	0.736 21.024 15 0.414 0.673 45 8
		22	0.835 23.973 16 1.051 1.226 23 28
		21	0.898 25.840 17 1.070 1.239 21 30
		20	0.960 27.309 18 0.948 1.209 45 16
		19	1.010 28.304 19 1.345 1.464 23 30
		18	1.062 29.428 20 1.274 1.418 19 32
		17	1.106 30.498 21 1.189 1.332 11 18
		16	1.145 31.018
		15	1.223 31.341
		14	1.260 32.625
		13	1.289 33.855
		12	1.320 35.363
		11	1.315 36.297
		10	1.369* 35.371
		9	1.364 36.742
		8	1.321 37.983
		7	1.264 39.396
		6	1.176 40.582
		5	1.056 41.191*
		4	0.914 40.387
		3	0.785 37.626
		2	0.610 29.366
		Bottom 1	0.175 8.977
		% AXIAL TILT	-6.864 -16.049
		AVG BOT 8ft/12ft	1.0648 1.0866
Control Rod Density: %	5.95		
k-effective:	0.99922		
Void Fraction:	0.423		
Core Delta-P: psia	20.908		
Core Plate Delta-P: psia	16.350		
Coolant Temp: Deg-F	547.0		
In Channel Flow: Mlb/hr	81.93	Active Channel Flow: Mlb/hr	79.13
Total Bypass Flow (%):	11.9	(of total core flow)	
Total Water Rod Flow (%):	3.0	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.464	19	23	30	1.571	0.897	19	23	32	7.84	0.682	19.5	19	23	30	12	9.11	0.690	24.7	19	23	32	12
1.454	19	21	28	1.574	0.896	19	39	34	7.82	0.680	19.7	19	21	28	12	7.11	0.688	51.7	17	39	32	12
1.440	19	23	26	1.598	0.882	19	23	26	7.77	0.676	19.9	19	23	26	12	6.97	0.687	53.2	16	37	28	12
1.418	20	19	32	1.632	0.864	19	25	34	7.69	0.668	19.7	20	31	42	12	9.03	0.686	25.1	19	39	34	12
1.418	19	25	28	1.648	0.855	19	25	24	7.65	0.665	18.1	20	21	24	12	6.96	0.680	52.7	17	39	26	12
1.415	20	19	26	1.649	0.855	20	39	24	7.63	0.663	19.4	20	19	32	12	9.05	0.679	23.6	20	39	24	12
1.413	20	21	24	1.654	0.852	20	41	26	7.63	0.663	19.5	20	15	18	11	8.89	0.677	25.4	19	23	26	12
1.410	20	31	42	1.658	0.851	19	33	40	7.60	0.661	18.2	20	19	26	12	8.98	0.674	23.5	20	41	26	12
1.402	19	25	24	1.667	0.846	20	19	32	7.60	0.661	20.1	19	25	34	12	8.82	0.671	25.4	19	25	34	12
1.397	19	33	40	1.668	0.845	19	47	20	7.59	0.660	18.8	20	17	20	11	6.99	0.671	50.9	16	23	24	12

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.37 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 13,000.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	31273.2
Exposure: MWd/MTU (GWd)	13500.0 (1868.05)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.65		
Flow: Mlb/hr	93.79 (91.50 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.239 6.299	13 0.430 0.663 7 16
		24 0.613 16.884	14 0.326 0.585 27 4
		23 0.777 21.439	15 0.414 0.674 45 8
		22 0.882 24.447	16 1.049 1.218 23 28
		21 0.948 26.349	17 1.068 1.232 21 30
		20 1.013 27.853	18 0.949 1.208 45 16
		19 1.063 28.876	19 1.345 1.458 23 30
		18 1.114 30.028	20 1.274 1.414 19 32
		17 1.156 31.122	21 1.194 1.337 11 18
		16 1.189 31.646	
		15 1.262 31.971	
		14 1.291 33.271	
		13 1.311 34.513	
		12 1.332 36.035	
		11 1.314 36.963	
		10 1.358* 35.994	
		9 1.341 37.353	
		8 1.284 38.571	
		7 1.211 39.954	
		6 1.106 41.097	
		5 0.973 41.649*	
		4 0.825 40.779	
		3 0.700 37.962	
		2 0.542 29.627	
		Bottom 1 0.156 9.059	
Control Rod Density: %	5.95	% AXIAL TILT	-2.518 -15.743
k-effective:	0.99930	AVG BOT 8ft/12ft	1.0417 1.0853
Void Fraction:	0.411		
Core Delta-P: psia	21.065		
Core Plate Delta-P: psia	16.507		
Coolant Temp: Deg-F	546.8		
In Channel Flow: Mlb/hr	82.73	Active Channel Flow: Mlb/hr	79.94
Total Bypass Flow (%):	11.8	(of total core flow)	
Total Water Rod Flow (%):	3.0	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.458	19	23	30	1.576	0.894	19	37	7.83	0.681	20.5	19	23	32	12	6.94
1.448	19	21	28	1.577	0.894	19	39	7.81	0.679	20.7	19	21	28	12	7.08
1.434	19	23	26	1.597	0.883	19	23	7.75	0.674	20.9	19	23	26	12	9.02
1.414	20	19	32	1.635	0.862	19	25	7.69	0.669	19.4	20	15	18	12	6.94
1.412	19	25	28	1.645	0.857	19	25	7.68	0.668	20.7	20	31	42	12	8.94
1.411	20	19	26	1.651	0.854	20	39	7.68	0.668	19.1	20	21	24	12	8.98
1.408	20	21	24	1.654	0.852	19	33	7.64	0.665	19.2	20	19	26	12	6.67
1.405	20	31	42	1.655	0.852	20	41	7.64	0.664	20.3	20	19	32	12	8.85
1.397	20	45	18	1.661	0.849	19	47	7.64	0.664	18.8	20	17	20	12	8.93
1.397	19	25	24	1.671	0.844	20	19	7.61	0.662	19.5	20	43	16	12	6.97

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.38 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 13,500.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: Mwd/MTU	31773.1
Exposure: Mwd/MTU (GWd)	14000.0 (1937.23)		
Delta E: Mwd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.10		
Flow: Mlb/hr	95.43 (93.10 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.252 6.433	13 0.430 0.663 7 16
		24 0.648 17.230	14 0.325 0.585 27 4
		23 0.822 21.877	15 0.414 0.674 45 8
		22 0.933 24.948	16 1.046 1.209 23 28
		21 1.001 26.886	17 1.065 1.222 21 30
		20 1.069 28.427	18 0.950 1.208 45 16
		19 1.119 29.477	19 1.345 1.450 23 32
		18 1.169 30.658	20 1.274 1.408 41 30
		17 1.207 31.774	21 1.201 1.343 11 18
		16 1.233 32.299	
		15 1.300 32.620	
		14 1.320 33.933	
		13 1.329 35.182	
		12 1.338 36.711	
		11 1.307 37.626	
		10 1.340* 36.609	
		9 1.313 37.952	
		8 1.242 39.141	
		7 1.154 40.488	
		6 1.034 41.580	
		5 0.891 42.070*	
		4 0.741 41.133	
		3 0.621 38.260	
		2 0.479 29.858	
		Bottom 1 0.138 9.133	
		% AXIAL TILT	2.021 -15.375
		AVG BOT 8ft/12ft	1.0170 1.0837
Control Rod Density: %	5.95		
k-effective:	0.99948		
Void Fraction:	0.398		
Core Delta-P: psia	21.497		
Core Plate Delta-P: psia	16.939		
Coolant Temp: Deg-F	546.6		
In Channel Flow: Mlb/hr	84.27	Active Channel Flow: Mlb/hr	81.46
Total Bypass Flow (%):	11.7	(of total core flow)	
Total Water Rod Flow (%):	2.9	(of total core flow)	
Source Convergence	0.00006		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.450	19	23	32	1.586	0.889	19	39	34	7.95	0.691	17.5	19	23	30	17	6.86	0.706	55.0	16	37	28	12
1.441	19	21	28	1.588	0.888	19	23	32	7.87	0.685	17.7	19	21	28	17	7.38	0.699	49.7	17	39	32	16
1.426	19	23	26	1.605	0.878	19	23	26	7.85	0.682	17.8	19	23	26	17	6.88	0.698	54.4	17	39	26	12
1.408	20	41	30	1.644	0.858	19	25	34	7.77	0.676	18.0	19	25	28	17	9.12	0.689	24.4	19	23	32	14
1.406	20	19	26	1.653	0.853	19	25	24	7.74	0.673	20.4	20	15	18	12	6.60	0.686	55.4	16	33	24	12
1.404	19	25	28	1.661	0.849	19	33	40	7.68	0.668	19.8	20	17	20	12	9.05	0.685	24.7	19	39	34	14
1.401	20	21	24	1.662	0.848	20	39	24	7.67	0.667	20.5	19	13	20	12	6.77	0.685	54.3	16	29	44	12
1.399	20	45	18	1.662	0.848	19	47	42	7.67	0.667	20.4	20	43	16	12	7.31	0.683	48.3	17	25	32	16
1.399	20	31	42	1.664	0.847	20	41	26	7.67	0.667	17.8	20	31	42	16	6.98	0.682	52.7	17	15	42	12
1.392	19	13	20	1.674	0.842	20	19	32	7.66	0.666	17.7	19	25	24	17	6.84	0.681	53.6	16	23	24	12

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.39 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 14,000.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	32273.0
Exposure: MWd/MTU (GWd)	14500.0 (2006.42)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.47		
Flow: Mlb/hr	97.38 (95.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.267 6.573 13 0.430 0.665 7 16
		24	0.686 17.596 14 0.324 0.586 27 4
		23	0.870 22.341 15 0.413 0.675 45 8
		22	0.988 25.478 16 1.042 1.197 23 28
		21	1.058 27.454 17 1.062 1.211 21 30
		20	1.127 29.033 18 0.951 1.209 45 16
		19	1.176 30.110 19 1.345 1.439 23 32
		18	1.224 31.318 20 1.273 1.401 41 30
		17	1.258 32.454 21 1.208 1.349 11 18
		16	1.276 32.975
		15	1.336 33.289
		14	1.346* 34.609
		13	1.342 35.859
		12	1.338 37.389
		11	1.292 38.284
		10	1.316 37.215
		9	1.279 38.537
		8	1.195 39.691
		7	1.093 40.995
		6	0.962 42.031
		5	0.811 42.454*
		4	0.663 41.450
		3	0.551 38.525
		2	0.424 30.062
		Bottom 1	0.122 9.197
			% AXIAL TILT 6.623 -14.947
			AVG BOT 8ft/12ft 0.9913 1.0818
Control Rod Density: %	5.95		
k-effective:	0.99955		
Void Fraction:	0.385		
Core Delta-P: psia	22.040		
Core Plate Delta-P: psia	17.480		
Coolant Temp: Deg-F	546.5		
In Channel Flow: Mlb/hr	86.08	Active Channel Flow: Mlb/hr	83.25
Total Bypass Flow (%):	11.6	(of total core flow)	
Total Water Rod Flow (%):	2.9	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.439	19	23	32	1.601	0.881	19	39	34	8.22	0.714	18.5	19	23	30	17	7.51	0.719	50.7	17	39	32	16
1.432	19	21	28	1.604	0.879	19	23	32	8.14	0.708	18.7	19	21	28	17	7.37	0.716	52.2	16	23	28	16
1.417	19	23	26	1.621	0.870	19	23	26	8.10	0.705	18.8	19	23	26	17	7.34	0.707	51.4	17	39	26	16
1.401	20	41	30	1.659	0.850	19	25	34	8.01	0.696	19.0	19	25	28	17	7.44	0.701	49.2	17	25	32	16
1.401	20	45	18	1.667	0.846	19	47	42	7.92	0.689	18.7	19	25	24	17	7.44	0.699	48.9	17	25	26	16
1.400	20	41	26	1.667	0.846	19	25	24	7.89	0.686	18.1	20	31	42	17	9.30	0.698	23.6	19	23	32	16
1.395	19	13	20	1.670	0.844	20	39	24	7.89	0.686	18.6	19	33	40	17	7.30	0.695	50.1	16	23	24	16
1.394	20	21	24	1.672	0.843	21	49	18	7.83	0.681	18.0	20	19	32	17	9.22	0.694	23.9	19	39	34	16
1.394	19	25	28	1.672	0.843	20	41	26	7.78	0.677	17.6	20	21	24	16	7.25	0.693	50.4	17	31	40	16
1.391	20	31	42	1.674	0.842	19	33	40	7.75	0.676	21.4	20	15	18	12	6.96	0.693	53.6	17	15	42	12

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.40 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 14,500.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: Mwd/MTU	32407.7
Exposure: Mwd/MTU (GWd)	14634.7 (2025.06)		
Delta E: Mwd/MTU, (GWd)	134.7 (18.65)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.25		
Flow: Mlb/hr	98.09 (95.70 %)		
		Axial Profile	Edit Radial Power
		N (PRA)	Power Exposure Zone Avg. Max. IR JR
		Top 25	0.270 6.613 13 0.430 0.665 7 16
		24	0.697 17.698 14 0.324 0.586 27 4
		23	0.884 22.471 15 0.413 0.676 45 8
		22	1.003 25.626 16 1.041 1.194 23 28
		21	1.074 27.613 17 1.061 1.208 21 30
		20	1.143 29.202 18 0.951 1.210 45 16
		19	1.191 30.286 19 1.345 1.436 23 32
		18	1.238 31.501 20 1.273 1.401 45 18
		17	1.270 32.642 21 1.210 1.351 11 18
		16	1.286 33.161
		15	1.344 33.472
		14	1.351* 34.793
		13	1.344 36.043
		12	1.336 37.572
		11	1.287 38.460
		10	1.308 37.376
		9	1.269 38.692
		8	1.182 39.835
		7	1.077 41.127
		6	0.943 42.146
		5	0.792 42.552*
		4	0.645 41.530
		3	0.535 38.591
		2	0.412 30.113
		Bottom 1	0.118 9.214
		% AXIAL TILT	7.802 -14.822
		AVG BOT 8ft/12ft	0.9845 1.0812
Control Rod Density: %	5.95		
k-effective:	0.99964		
Void Fraction:	0.382		
Core Delta-P: psia	22.255		
Core Plate Delta-P: psia	17.695		
Coolant Temp: Deg-F	546.4		
In Channel Flow: Mlb/hr	86.74	Active Channel Flow: Mlb/hr	83.90
Total Bypass Flow (%):	11.6	(of total core flow)	
Total Water Rod Flow (%):	2.9	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.436	19	23	32	1.608	0.877	19	39	8.27	0.719	18.8	19	23	30	17	7.53
1.429	19	21	28	1.611	0.875	19	23	8.20	0.713	18.9	19	21	28	17	7.39
1.413	19	23	26	1.628	0.866	19	23	8.16	0.709	19.1	19	23	26	17	7.36
1.401	20	45	18	1.666	0.846	19	25	8.05	0.700	19.3	19	25	28	17	7.45
1.399	20	41	30	1.668	0.845	19	47	7.97	0.693	19.0	19	25	24	17	7.46
1.399	20	41	26	1.671	0.844	21	49	7.96	0.692	18.4	20	31	42	17	9.31
1.396	19	13	20	1.674	0.842	19	25	7.95	0.691	18.8	19	33	40	17	7.32
1.392	20	21	24	1.675	0.842	20	39	7.89	0.686	18.3	20	19	30	17	7.22
1.390	19	25	28	1.677	0.841	20	41	7.84	0.682	17.3	20	21	24	17	7.28
1.389	20	31	42	1.680	0.839	19	33	6.76	0.680	45.3	16	23	28	17	9.23

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.41 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 14,634.7 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	32408.7
Exposure: MWd/MTU (GWd)	14635.7 (2025.20)		
Delta E: MWd/MTU, (GWd)	1.0 (0.14)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.48		
Flow: Mlb/hr	94.30 (92.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.256 6.613 13 0.442 0.676 7 16
		24	0.657 17.699 14 0.336 0.641 27 4
		23	0.839 22.472 15 0.428 0.690 45 8
		22	0.968 25.627 16 0.994 1.204 11 28
		21	1.063 27.614 17 1.052 1.216 41 16
		20	1.144 29.203 18 0.992 1.255 17 18
		19	1.190 30.287 19 1.295 1.431 13 20
		18	1.236 31.502 20 1.270 1.442 43 16
		17	1.269 32.643 21 1.257 1.376 11 18
		16	1.287 33.163
		15	1.347 33.473
		14	1.355* 34.794
		13	1.348 36.044
		12	1.340 37.573
		11	1.292 38.461
		10	1.312 37.377
		9	1.269 38.693
		8	1.181 39.837
		7	1.079 41.128
		6	0.953 42.147
		5	0.813 42.552*
		4	0.673 41.530
		3	0.564 38.591
		2	0.437 30.113
		Bottom 1	0.126 9.214
			% AXIAL TILT 6.650 -14.821
			AVG BOT 8ft/12ft 0.9927 1.0812
Control Rod Density: %	6.04		
k-effective:	0.99968		
Void Fraction:	0.390		
Core Delta-P: psia	21.001		
Core Plate Delta-P: psia	16.442		
Coolant Temp: Deg-F	546.3		
In Channel Flow: Mlb/hr	83.33	Active Channel Flow: Mlb/hr	80.58
Total Bypass Flow (%):	11.6	(of total core flow)	
Total Water Rod Flow (%):	2.9	(of total core flow)	
Source Convergence	0.00004		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.442	20	43	16	1.590	0.887	19	41	48	8.01	0.696	16.7	20	31	50	16	6.98	0.729	55.5	16	33	50	12
1.442	20	45	18	1.594	0.884	19	47	42	7.97	0.695	21.6	20	43	16	12	7.09	0.720	54.4	17	41	46	12
1.441	20	41	18	1.599	0.882	19	9	24	7.97	0.695	21.6	20	15	18	12	7.14	0.714	53.8	17	15	42	12
1.438	20	43	20	1.604	0.879	19	23	10	7.98	0.694	17.3	20	41	18	16	7.67	0.713	47.7	18	17	18	17
1.431	19	13	20	1.605	0.878	21	49	18	7.96	0.692	17.5	20	43	20	16	7.00	0.708	54.2	16	11	28	12
1.431	19	41	48	1.606	0.878	21	17	50	7.96	0.692	17.9	19	35	50	16	7.65	0.703	46.7	18	31	48	17
1.427	19	11	26	1.607	0.878	19	39	50	7.94	0.691	18.0	19	41	48	16	9.27	0.703	24.9	20	31	50	13
1.427	20	11	30	1.608	0.877	19	39	16	7.90	0.690	21.8	19	13	20	12	7.05	0.703	53.7	17	39	14	12
1.423	20	31	50	1.612	0.875	19	49	40	7.92	0.690	21.3	19	11	26	12	7.17	0.700	52.6	17	31	10	12
1.422	19	39	46	1.613	0.874	20	29	50	7.92	0.689	20.2	20	11	30	12	7.05	0.699	53.4	17	13	22	12

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.42 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 14,635.7 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	32772.9
Exposure: MWd/MTU (GWd)	15000.0 (2075.61)		
Delta E: MWd/MTU, (GWd)	364.3 (50.41)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-28.70		
Flow: Mlb/hr	96.66 (94.30 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.267 6.717	13 0.441 0.676 7 16
		24 0.687 17.967	14 0.335 0.639 27 4
		23 0.877 22.815	15 0.427 0.690 45 8
		22 1.011 26.024	16 0.993 1.202 11 28
		21 1.109 28.050	17 1.051 1.213 41 16
		20 1.191 29.672	18 0.991 1.252 17 18
		19 1.235 30.775	19 1.297 1.431 13 20
		18 1.278 32.007	20 1.269 1.442 43 16
		17 1.307 33.161	21 1.261 1.379 11 18
		16 1.318 33.674	
		15 1.372* 33.975	
		14 1.371 35.298	
		13 1.354 36.543	
		12 1.336 38.067	
		11 1.277 38.935	
		10 1.290 37.810	
		9 1.239 39.106	
		8 1.143 40.219	
		7 1.032 41.475	
		6 0.900 42.452	
		5 0.756 42.810*	
		4 0.619 41.743	
		3 0.516 38.769	
		2 0.399 30.251	
		Bottom 1 0.115 9.257	
Control Rod Density: %	6.04		
k-effective:	0.99970		
Void Fraction:	0.379		
Core Delta-P: psia	21.706	% AXIAL TILT	10.163 -14.474
Core Plate Delta-P: psia	17.147	AVG BOT 8ft/12ft	0.9726 1.0796
Coolant Temp: Deg-F	546.2		
In Channel Flow: Mlb/hr	85.50	Active Channel Flow: Mlb/hr	82.70
Total Bypass Flow (%):	11.5	(of total core flow)	
Total Water Rod Flow (%):	2.9	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.442	20	43	16	1.606	0.915	19	41	8.21	0.714	17.4	20	31	50	16	7.88
1.441	20	45	18	1.608	0.914	19	47	8.21	0.714	18.0	19	35	50	17	6.93
1.438	20	41	18	1.608	0.914	19	9	8.19	0.712	18.5	20	43	46	16	7.59
1.435	20	43	20	1.610	0.913	21	49	8.19	0.712	18.2	19	41	48	17	7.85
1.431	19	13	20	1.610	0.913	21	17	8.17	0.711	18.0	20	41	18	16	7.58
1.430	19	41	48	1.613	0.911	19	23	8.17	0.711	18.5	20	45	18	16	7.68
1.427	19	11	26	1.622	0.906	19	39	8.15	0.709	18.3	20	43	20	16	7.62
1.427	20	11	30	1.626	0.904	19	49	8.13	0.707	18.5	19	39	46	17	7.63
1.422	20	31	50	1.626	0.904	19	39	8.12	0.706	18.1	19	13	20	17	7.49
1.420	19	39	46	1.629	0.902	20	47	8.11	0.705	18.5	19	37	48	17	6.98

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.43 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 15,000.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	33272.9
Exposure: MWd/MTU (GWd)	15500.0 (2144.79)		
Delta E: MWd/MTU, (GWd)	500.0 (69.19)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-27.53		
Flow: Mlb/hr	100.45 (98.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.283 6.866	13 0.441 0.677 7 16
		24 0.730 18.356	14 0.334 0.639 27 4
		23 0.932 23.311	15 0.426 0.691 45 8
		22 1.073 26.599	16 0.990 1.202 11 28
		21 1.174 28.680	17 1.048 1.209 41 16
		20 1.256 30.347	18 0.992 1.249 17 18
		19 1.296 31.473	19 1.297 1.432 13 20
		18 1.334 32.728	20 1.268 1.442 43 16
		17 1.355 33.895	21 1.270 1.386 11 18
		16 1.356 34.395	
		15 1.402* 34.678	
		14 1.388 35.997	
		13 1.356 37.230	
		12 1.324 38.741	
		11 1.253 39.576	
		10 1.256 38.390	
		9 1.197 39.656	
		8 1.090 40.723	
		7 0.969 41.927	
		6 0.830 42.842	
		5 0.684 43.136*	
		4 0.552 42.007	
		3 0.456 38.989	
		2 0.352 30.420	
		Bottom 1 0.102 9.311	
		% AXIAL TILT	14.858 -13.948
		AVG BOT 8ft/12ft	0.9448 1.0771
Control Rod Density: %	6.04		
k-effective:	0.99963		
Void Fraction:	0.363		
Core Delta-P: psia	22.889		
Core Plate Delta-P: psia	18.328		
Coolant Temp: Deg-F	546.2		
In Channel Flow: Mlb/hr	88.97	Active Channel Flow: Mlb/hr	86.11
Total Bypass Flow (%):	11.4	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00007		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.442	20	43	16	1.617	0.909	21	49	18	8.54	0.743	19.1	19	35	50	17	8.12	0.768	49.4	18	17	18	17
1.441	20	45	18	1.618	0.909	21	17	50	8.51	0.740	17.6	20	31	50	17	8.11	0.758	48.4	18	31	48	17
1.434	20	41	18	1.620	0.907	19	41	48	8.50	0.740	19.2	19	41	48	17	7.79	0.752	51.6	16	33	50	16
1.432	19	13	20	1.623	0.906	19	47	20	8.46	0.735	18.9	20	43	46	17	7.76	0.752	51.8	17	41	46	16
1.431	20	17	20	1.625	0.905	19	9	24	8.43	0.733	19.2	19	13	20	17	7.99	0.750	48.7	18	25	10	17
1.431	19	41	48	1.629	0.902	19	23	10	8.43	0.733	18.9	19	39	50	17	7.75	0.749	51.6	17	15	42	16
1.429	19	11	26	1.633	0.900	21	41	52	8.43	0.733	18.9	20	45	18	17	7.98	0.749	48.6	18	15	16	17
1.429	20	11	30	1.635	0.899	21	51	20	8.42	0.732	18.7	20	41	18	17	7.97	0.746	48.5	18	47	18	17
1.422	20	31	50	1.635	0.899	19	39	50	8.40	0.731	19.6	19	37	48	17	7.89	0.746	49.5	17	29	52	16
1.419	20	9	28	1.637	0.898	21	7	26	8.40	0.730	19.6	19	39	46	17	7.82	0.745	50.2	17	37	50	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.44 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 15,500.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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Cycle:	21	Core Average Exposure: MWd/MTU	33472.9
Exposure: MWd/MTU (GWd)	15700.0 (2172.47)		
Delta E: MWd/MTU, (GWd)	200.0 (27.67)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-26.94		
Flow: Mlb/hr	102.50 (100.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.290 6.928 13 0.440 0.678 7 16
		24	0.749 18.518 14 0.333 0.639 27 4
		23	0.956 23.518 15 0.426 0.692 45 8
		22	1.099 26.839 16 0.988 1.202 11 28
		21	1.200 28.942 17 1.046 1.209 31 52
		20	1.282 30.627 18 0.993 1.247 17 18
		19	1.320 31.761 19 1.297 1.433 13 20
		18	1.354 33.024 20 1.267 1.442 43 16
		17	1.371 34.196 21 1.274 1.389 11 18
		16	1.369 34.689
		15	1.411* 34.963
		14	1.392 36.279
		13	1.355 37.505
		12	1.317 39.009
		11	1.242 39.828
		10	1.242 38.618
		9	1.179 39.870
		8	1.068 40.918
		7	0.944 42.100
		6	0.803 42.990
		5	0.658 43.257*
		4	0.528 42.105
		3	0.436 39.069
		2	0.336 30.483
		Bottom 1	0.097 9.331
		% AXIAL TILT	16.663 -13.722
		AVG BOT 8ft/12ft	0.9336 1.0761
Control Rod Density: %	6.04		
k-effective:	0.99967		
Void Fraction:	0.357		
Core Delta-P: psia	23.561		
Core Plate Delta-P: psia	18.999		
Coolant Temp: Deg-F	546.2		
In Channel Flow: Mlb/hr	90.83	Active Channel Flow: Mlb/hr	87.94
Total Bypass Flow (%):	11.4	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00007		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR					LHGR				
Value	FT	IR	JR	Value	Margin	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K	Value
1.442	20	43	16	1.620	0.907	21	49	18	8.66	0.753	19.5	19	35	50	17	8.20	0.779
1.441	20	45	18	1.621	0.907	21	17	50	8.64	0.751	18.1	20	31	50	17	8.19	0.770
1.433	19	13	20	1.629	0.902	19	41	48	8.61	0.749	19.6	19	41	48	17	8.10	0.764
1.433	20	41	18	1.632	0.901	19	47	20	8.56	0.744	19.3	20	43	16	17	7.85	0.761
1.431	19	41	48	1.634	0.900	19	9	24	8.55	0.744	19.4	19	39	50	17	8.08	0.761
1.431	19	11	26	1.636	0.899	19	23	10	8.54	0.743	19.6	19	13	20	17	7.81	0.760
1.431	20	11	30	1.636	0.899	21	7	26	8.54	0.742	19.3	20	45	18	17	8.07	0.759
1.430	20	17	20	1.637	0.898	21	41	52	8.52	0.741	18.4	20	33	52	17	7.80	0.757
1.423	20	9	28	1.638	0.897	21	51	20	8.51	0.740	19.1	20	41	18	17	8.09	0.757
1.422	20	31	50	1.641	0.896	21	25	8	8.50	0.739	20.0	19	37	48	17	7.96	0.756

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.45 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 15,700.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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Cycle:	21	Core Average Exposure: MWd/MTU	33473.9
Exposure: MWd/MTU (GWd)	15701.0 (2172.61)		
Delta E: MWd/MTU, (GWd)	1.0 (0.14)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.86		
Flow: Mlb/hr	93.17 (90.90 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.269 6.929 13 0.428 0.658 7 16
		24	0.689 18.519 14 0.324 0.621 27 4
		23	0.880 23.519 15 0.414 0.672 45 8
		22	1.018 26.840 16 1.015 1.167 11 28
		21	1.123 28.943 17 1.059 1.175 41 16
		20	1.215 30.629 18 0.963 1.214 17 18
		19	1.276 31.763 19 1.340 1.390 13 20
		18	1.328 33.026 20 1.271 1.407 29 28
		17	1.358 34.197 21 1.233 1.345 11 18
		16	1.366 34.690
		15	1.413* 34.965
		14	1.398 36.280
		13	1.364 37.506
		12	1.328 39.010
		11	1.256 39.830
		10	1.262 38.620
		9	1.208 39.871
		8	1.110 40.919
		7	0.998 42.101
		6	0.864 42.991
		5	0.719 43.258*
		4	0.585 42.105
		3	0.487 39.070
		2	0.378 30.483
		Bottom 1	0.109 9.331
		% AXIAL TILT	12.812 -13.721
		AVG BOT 8ft/12ft	0.9610 1.0760
Control Rod Density: %	4.32		
k-effective:	0.99970		
Void Fraction:	0.378		
Core Delta-P: psia	20.505		
Core Plate Delta-P: psia	15.951		
Coolant Temp: Deg-F	545.9		
In Channel Flow: Mlb/hr	82.39	Active Channel Flow: Mlb/hr	79.69
Total Bypass Flow (%):	11.6	(of total core flow)	
Total Water Rod Flow (%):	2.9	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.407	20	29	28	1.625	0.905	19	41	48	8.36	0.727	18.5	20	31	28	17	7.89	0.749	49.8	18	17	18	17
1.401	20	41	18	1.626	0.904	21	49	18	8.31	0.723	19.5	19	35	50	17	7.88	0.740	48.8	18	31	48	17
1.399	20	43	16	1.627	0.904	21	17	50	8.29	0.721	18.1	20	31	50	17	7.53	0.733	52.2	17	41	46	16
1.399	20	15	18	1.627	0.903	19	47	20	8.27	0.719	19.7	20	27	30	17	7.55	0.732	52.0	16	33	50	16
1.398	20	17	20	1.633	0.900	19	9	24	8.27	0.719	19.6	19	41	48	17	7.76	0.731	49.1	18	25	10	17
1.391	20	33	30	1.636	0.898	19	23	10	8.24	0.717	20.4	19	27	26	17	7.61	0.731	51.0	17	31	26	16
1.390	19	13	20	1.641	0.896	19	39	50	8.23	0.715	19.1	20	41	18	17	7.53	0.730	52.0	17	15	42	16
1.389	20	11	30	1.641	0.896	21	41	52	8.23	0.715	19.3	20	43	16	17	7.74	0.729	49.1	18	15	16	17
1.388	19	41	48	1.642	0.895	19	39	16	8.21	0.714	20.7	19	25	28	17	7.39	0.727	53.2	16	33	28	16
1.388	19	11	26	1.642	0.895	21	51	20	8.20	0.713	19.6	19	13	20	17	7.73	0.727	48.9	18	47	18	17

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.46 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 15,701.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	33972.8
Exposure: MWd/MTU (GWd)	16200.0 (2241.66)		
Delta E: MWd/MTU, (GWd)	499.0 (69.05)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-27.44		
Flow: Mlb/hr	100.76 (98.30 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.288 7.079	13 0.428 0.661 7 16
		24 0.741 18.910	14 0.323 0.623 27 4
		23 0.946 24.018	15 0.414 0.675 45 8
		22 1.090 27.420	16 1.009 1.171 11 28
		21 1.196 29.581	17 1.055 1.176 31 52
		20 1.286 31.317	18 0.968 1.214 17 18
		19 1.340 32.483	19 1.337 1.395 13 20
		18 1.383 33.772	20 1.267 1.404 43 16
		17 1.402 34.957	21 1.247 1.357 11 18
		16 1.398 35.434	
		15 1.437* 35.685	
		14 1.409 36.990	
		13 1.361 38.195	
		12 1.313 39.678	
		11 1.230 40.458	
		10 1.229 39.186	
		9 1.166 40.406	
		8 1.056 41.407	
		7 0.931 42.535	
		6 0.788 43.363	
		5 0.643 43.564*	
		4 0.515 42.353	
		3 0.426 39.276	
		2 0.330 30.642	
		Bottom 1 0.096 9.383	
Control Rod Density: %	4.32		
k-effective:	0.99974		
Void Fraction:	0.357		
Core Delta-P: psia	22.943	% AXIAL TILT	17.742 -13.177
Core Plate Delta-P: psia	18.387	AVG BOT 8ft/12ft	0.9304 1.0735
Coolant Temp: Deg-F	546.0		
In Channel Flow: Mlb/hr	89.27	Active Channel Flow: Mlb/hr	86.41
Total Bypass Flow (%):	11.4	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR						LHGR								
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.404	20	43	16	1.643	0.895	21	49	18	8.62	0.750	19.1	20	31	50	17	8.14	0.780	50.8	18	17	18	17
1.403	20	15	18	1.643	0.895	21	17	50	8.61	0.749	20.6	19	35	50	17	8.14	0.772	49.8	18	31	48	17
1.399	20	41	18	1.656	0.888	21	7	26	8.56	0.744	20.7	19	41	48	17	8.09	0.770	50.1	18	25	10	17
1.396	20	11	30	1.658	0.886	19	9	24	8.52	0.741	19.4	20	33	52	17	8.05	0.766	50.0	18	15	16	17
1.396	20	17	20	1.659	0.886	19	23	10	8.52	0.741	20.4	19	39	50	17	8.03	0.762	49.9	18	47	18	17
1.395	19	13	20	1.661	0.885	21	25	8	8.51	0.740	20.3	20	43	16	17	8.05	0.761	49.4	18	17	48	17
1.394	19	11	26	1.662	0.884	21	41	10	8.50	0.739	20.7	19	13	20	17	7.72	0.759	53.1	16	33	50	16
1.393	19	41	14	1.663	0.884	19	41	14	8.49	0.738	20.4	20	15	18	17	7.70	0.758	53.2	17	41	46	16
1.389	20	9	28	1.664	0.883	21	51	20	8.48	0.738	20.1	19	11	26	17	8.03	0.757	49.2	18	9	26	17
1.386	20	31	50	1.665	0.883	19	47	20	8.46	0.736	20.2	20	41	18	17	7.88	0.755	50.7	17	31	10	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.47 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 16,200.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	34072.8
Exposure: MWd/MTU (GWd)	16300.0 (2255.49)		
Delta E: MWd/MTU, (GWd)	100.0 (13.84)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-26.94		
Flow: Mlb/hr	102.50 (100.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.291 7.111 13 0.428 0.662 7 16
		24	0.751 18.992 14 0.323 0.623 27 4
		23	0.959 24.123 15 0.414 0.675 45 8
		22	1.105 27.541 16 1.007 1.171 11 28
		21	1.210 29.714 17 1.054 1.177 31 52
		20	1.300 31.460 18 0.969 1.214 17 18
		19	1.352 32.632 19 1.336 1.396 13 20
		18	1.393 33.925 20 1.267 1.404 43 16
		17	1.409 35.112 21 1.250 1.360 11 18
		16	1.403 35.584
		15	1.440* 35.831
		14	1.410 37.133
		13	1.359 38.333
		12	1.309 39.811
		11	1.225 40.582
		10	1.222 39.298
		9	1.158 40.511
		8	1.045 41.501
		7	0.919 42.619
		6	0.775 43.434
		5	0.629 43.622*
		4	0.503 42.399
		3	0.416 39.314
		2	0.322 30.672
		Bottom 1	0.093 9.392
		% AXIAL TILT	18.638 -13.061
		AVG BOT 8ft/12ft	0.9246 1.0730
Control Rod Density: %	4.32		
k-effective:	0.99986		
Void Fraction:	0.353		
Core Delta-P: psia	23.528		
Core Plate Delta-P: psia	18.972		
Coolant Temp: Deg-F	546.1		
In Channel Flow: Mlb/hr	90.85	Active Channel Flow: Mlb/hr	87.96
Total Bypass Flow (%):	11.4	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.404	20	43	16	1.646	0.893	21	17	50	8.67	0.754	19.4	20	31	50	17	8.17	0.785	51.0	18	17	18	17
1.404	20	15	18	1.647	0.893	21	49	18	8.66	0.753	20.8	19	35	50	17	8.17	0.777	50.0	18	31	48	17
1.398	20	41	18	1.660	0.886	21	7	26	8.60	0.748	20.9	19	41	48	17	8.14	0.777	50.3	18	25	10	17
1.397	20	11	30	1.664	0.883	21	25	8	8.58	0.746	19.6	20	33	52	17	8.10	0.772	50.2	18	15	16	17
1.396	19	13	20	1.665	0.883	21	41	10	8.56	0.745	20.6	19	39	50	17	8.07	0.768	50.1	18	47	18	17
1.395	19	11	26	1.665	0.883	19	23	10	8.55	0.744	20.6	20	43	16	17	8.09	0.766	49.6	18	17	48	17
1.395	20	17	20	1.666	0.883	19	9	24	8.54	0.743	20.9	19	13	20	17	7.74	0.765	53.3	16	33	50	16
1.394	19	41	14	1.668	0.881	21	9	42	8.53	0.742	20.3	19	11	26	17	7.72	0.763	53.4	17	41	46	16
1.391	20	9	28	1.671	0.879	19	41	14	8.53	0.742	20.6	20	15	18	17	8.08	0.763	49.4	18	9	26	17
1.387	20	31	50	1.672	0.879	21	7	32	8.50	0.739	19.8	19	37	52	17	7.92	0.759	50.9	17	31	10	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.48 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 16,300.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	34073.7
Exposure: MWd/MTU (GWd)	16301.0 (2255.63)		
Delta E: MWd/MTU, (GWd)	1.0 (0.14)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-30.22		
Flow: Mlb/hr	92.15 (89.90 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.325 7.111 13 0.423 0.652 7 16
		24	0.834 18.993 14 0.320 0.615 27 4
		23	1.055 24.124 15 0.409 0.665 45 8
		22	1.194 27.542 16 1.024 1.164 11 28
		21	1.268 29.715 17 1.061 1.171 39 18
		20	1.332 31.461 18 0.955 1.203 17 18
		19	1.364 32.633 19 1.335 1.381 11 26
		18	1.387 33.927 20 1.284 1.391 41 18
		17	1.390 35.113 21 1.225 1.332 11 18
		16	1.375 35.586
		15	1.402* 35.833
		14	1.367 37.134
		13	1.314 38.334
		12	1.264 39.812
		11	1.183 40.583
		10	1.182 39.299
		9	1.123 40.512
		8	1.019 41.502
		7	0.901 42.620
		6	0.764 43.434
		5	0.624 43.622*
		4	0.501 42.400
		3	0.416 39.314
		2	0.322 30.672
		Bottom 1	0.093 9.392
		% AXIAL TILT	20.680 -13.060
		AVG BOT 8ft/12ft	0.9029 1.0730
Control Rod Density: %	3.78		
k-effective:	0.99980		
Void Fraction:	0.361		
Core Delta-P: psia	19.976		
Core Plate Delta-P: psia	15.424		
Coolant Temp: Deg-F	545.5		
In Channel Flow: Mlb/hr	81.59	Active Channel Flow: Mlb/hr	78.96
Total Bypass Flow (%):	11.5	(of total core flow)	
Total Water Rod Flow (%):	2.9	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.391	20	41	18	1.595	0.922	21	49	18	8.54	0.742	19.4	20	31	50	17	8.03	0.771	51.0	18	17	18	17
1.388	20	17	20	1.595	0.921	21	17	50	8.51	0.740	20.8	19	35	50	17	8.06	0.766	50.0	18	31	48	17
1.386	20	11	30	1.596	0.921	19	41	48	8.45	0.734	19.2	20	29	28	18	7.96	0.760	50.3	18	25	10	17
1.384	20	43	16	1.599	0.919	19	9	24	8.44	0.734	20.9	19	41	48	17	7.91	0.754	50.3	18	15	16	17
1.383	20	15	18	1.600	0.919	19	23	10	8.41	0.731	19.6	20	33	52	17	7.89	0.750	50.1	18	47	18	17
1.383	20	31	28	1.602	0.918	19	47	42	8.39	0.730	20.6	19	39	50	17	7.91	0.749	49.6	18	17	48	17
1.381	19	11	26	1.608	0.914	19	39	50	8.39	0.730	20.6	20	43	16	17	7.90	0.747	49.4	18	9	26	17
1.377	20	31	50	1.609	0.914	19	49	26	8.39	0.729	20.4	20	41	18	17	7.55	0.746	53.3	16	33	50	16
1.376	19	13	20	1.609	0.914	19	25	50	8.38	0.729	20.3	19	11	26	17	7.91	0.745	49.1	18	47	32	17
1.375	19	39	16	1.615	0.910	19	49	40	8.38	0.728	20.9	19	13	20	17	7.53	0.745	53.4	17	41	46	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.49 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 16,301.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	34572.8
Exposure: MWd/MTU (GWd)	16800.0 (2324.68)		
Delta E: MWd/MTU, (GWd)	499.0 (69.05)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-27.41		
Flow: Mlb/hr	100.86 (98.40 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.346 7.293 13 0.423 0.654 7 16
		24	0.892 19.465 14 0.318 0.617 27 4
		23	1.126 24.721 15 0.409 0.668 45 8
		22	1.271 28.221 16 1.019 1.166 49 34
		21	1.341 30.433 17 1.057 1.168 31 52
		20	1.399 32.213 18 0.959 1.202 17 18
		19	1.420 33.399 19 1.332 1.386 11 26
		18	1.432* 34.703 20 1.281 1.390 11 30
		17	1.422 35.887 21 1.238 1.343 11 18
		16	1.396 36.331
		15	1.417 36.546
		14	1.370 37.827
		13	1.306 38.997
		12	1.246 40.447
		11	1.158 41.175
		10	1.150 39.830
		9	1.081 41.009
		8	0.965 41.950
		7	0.836 43.011
		6	0.694 43.763
		5	0.557 43.888*
		4	0.444 42.613
		3	0.366 39.490
		2	0.283 30.809
		Bottom 1	0.082 9.436
		% AXIAL TILT	25.191 -12.421
		AVG BOT 8ft/12ft	0.8732 1.0697
Control Rod Density: %	3.78		
k-effective:	0.99969		
Void Fraction:	0.340		
Core Delta-P: psia	22.773		
Core Plate Delta-P: psia	18.219		
Coolant Temp: Deg-F	545.7		
In Channel Flow: Mlb/hr	89.48	Active Channel Flow: Mlb/hr	86.67
Total Bypass Flow (%):	11.3	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00005		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.390	20	11	30	1.622	0.907	21	17	8.79	0.764	19.4	20	31	50	18	8.20
1.387	20	41	18	1.622	0.906	21	49	8.72	0.762	21.9	19	35	50	17	8.23
1.386	20	43	16	1.633	0.900	21	7	8.64	0.755	22.0	19	41	14	17	8.24
1.386	20	15	18	1.634	0.900	19	23	8.68	0.754	19.5	20	33	52	18	8.15
1.386	19	11	26	1.634	0.900	21	25	8.62	0.752	21.7	19	39	50	17	8.12
1.383	20	17	20	1.635	0.899	21	31	8.60	0.750	21.4	19	11	26	17	8.16
1.382	20	31	50	1.637	0.898	19	9	8.57	0.750	21.9	19	13	20	17	8.14
1.379	20	9	28	1.637	0.898	21	7	8.58	0.749	21.6	20	43	16	17	7.68
1.379	19	13	20	1.637	0.898	21	41	8.59	0.747	20.8	19	37	52	17	7.63
1.378	19	41	14	1.641	0.896	21	9	8.56	0.747	21.6	20	15	18	17	8.10

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.50 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 16,800.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	34573.8
Exposure: MWd/MTU (GWd)	16801.0 (2324.82)		
Delta E: MWd/MTU, (GWd)	1.0 (0.14)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.07		
Flow: Mlb/hr	95.53 (93.20 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.352 7.293 13 0.420 0.649 7 16
		24	0.904 19.466 14 0.316 0.613 27 4
		23	1.145 24.722 15 0.406 0.662 45 8
		22	1.300 28.222 16 1.026 1.163 49 34
		21	1.386 30.435 17 1.061 1.168 39 18
		20	1.426 32.214 18 0.953 1.197 17 18
		19	1.433 33.401 19 1.332 1.379 11 26
		18	1.435* 34.704 20 1.290 1.385 11 30
		17	1.417 35.889 21 1.226 1.330 11 18
		16	1.386 36.333
		15	1.401 36.547
		14	1.352 37.828
		13	1.287 38.998
		12	1.227 40.448
		11	1.140 41.176
		10	1.134 39.831
		9	1.068 41.009
		8	0.956 41.950
		7	0.830 43.012
		6	0.691 43.763
		5	0.556 43.889*
		4	0.443 42.613
		3	0.366 39.491
		2	0.284 30.809
		Bottom 1	0.082 9.436
Control Rod Density: %	3.60		
k-effective:	0.99979		
Void Fraction:	0.344		
Core Delta-P: psia	20.953	% AXIAL TILT	25.986 -12.420
Core Plate Delta-P: psia	16.401	AVG BOT 8ft/12ft	0.8643 1.0697
Coolant Temp: Deg-F	545.4		
In Channel Flow: Mlb/hr	84.70	Active Channel Flow: Mlb/hr	82.02
Total Bypass Flow (%):	11.3	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR						LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.385	20	11	30	1.598	0.920	21	17	50	8.79	0.765	19.4	20	31	50	18	8.44	0.794	49.0	18	31	48	18
1.384	20	41	18	1.598	0.920	21	49	18	8.75	0.761	20.8	19	35	50	18	8.14	0.790	52.1	18	17	18	17
1.380	20	17	20	1.605	0.916	19	23	10	8.63	0.751	19.5	20	33	52	18	8.15	0.785	51.3	18	25	10	17
1.379	19	11	26	1.608	0.914	19	9	24	8.62	0.749	19.7	20	29	28	19	8.06	0.776	51.3	18	15	16	17
1.377	20	31	12	1.609	0.914	21	31	8	8.57	0.749	22.0	19	41	14	17	8.03	0.771	51.1	18	47	18	17
1.377	20	43	16	1.609	0.914	21	7	26	8.59	0.748	21.4	19	27	26	19	8.08	0.771	50.4	18	9	26	17
1.376	20	15	18	1.610	0.913	21	25	8	8.58	0.747	21.3	19	37	48	18	8.05	0.770	50.6	18	17	48	17
1.371	19	39	16	1.611	0.913	19	41	48	8.59	0.747	20.6	19	39	50	18	8.09	0.770	50.1	18	47	32	17
1.369	19	13	20	1.611	0.912	21	7	32	8.58	0.746	17.4	20	33	44	21	7.60	0.769	54.3	16	33	50	16
1.369	20	9	28	1.615	0.910	19	25	50	8.56	0.746	21.3	19	39	16	18	7.55	0.765	54.3	17	41	46	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.51 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 16,801.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	34915.5
Exposure: MWd/MTU (GWd)	17142.8 (2372.11)		
Delta E: MWd/MTU, (GWd)	341.8 (47.29)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-26.82		
Flow: Mlb/hr	102.91 (100.40 %)		
		Axial Profile	Edit Radial Power
		N (PRA)	Power Exposure Zone Avg. Max. IR JR
		Top 25	0.366 7.427 13 0.420 0.650 7 16
		24	0.946 19.812 14 0.315 0.614 27 4
		23	1.196 25.160 15 0.406 0.664 45 8
		22	1.355 28.723 16 1.023 1.164 49 34
		21	1.438 30.967 17 1.058 1.164 21 18
		20	1.472* 32.761 18 0.955 1.195 17 18
		19	1.469 33.948 19 1.330 1.382 11 26
		18	1.461 35.250 20 1.288 1.388 49 32
		17	1.435 36.427 21 1.235 1.338 11 18
		16	1.396 36.845
		15	1.408 37.034
		14	1.352 38.296
		13	1.279 39.443
		12	1.213 40.871
		11	1.122 41.567
		10	1.109 40.181
		9	1.037 41.334
		8	0.918 42.239
		7	0.786 43.261
		6	0.646 43.969
		5	0.515 44.054*
		4	0.408 42.745
		3	0.337 39.599
		2	0.261 30.893
		Bottom 1	0.076 9.463
			% AXIAL TILT 28.951 -11.948
			AVG BOT 8ft/12ft 0.8441 1.0672
Control Rod Density: %	3.60		
k-effective:	0.99967		
Void Fraction:	0.328		
Core Delta-P: psia	23.387		
Core Plate Delta-P: psia	18.833		
Coolant Temp: Deg-F	545.6		
In Channel Flow: Mlb/hr	91.38	Active Channel Flow: Mlb/hr	88.54
Total Bypass Flow (%):	11.2	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR						LHGR								
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.388	20	49	32	1.622	0.906	21	17	50	8.98	0.781	20.1	20	31	50	18	8.60	0.815	49.7	18	31	48	18
1.382	19	11	26	1.623	0.906	21	49	18	8.92	0.778	21.5	19	35	50	18	8.31	0.807	52.0	18	25	10	17
1.382	20	29	12	1.625	0.905	21	25	8	8.86	0.771	18.1	20	33	44	21	8.24	0.806	52.8	18	17	18	17
1.381	20	19	18	1.626	0.904	21	31	8	8.85	0.770	20.3	20	33	52	18	8.21	0.796	51.9	18	15	16	17
1.378	20	17	16	1.626	0.904	21	7	26	8.81	0.766	18.3	20	35	42	21	8.24	0.792	51.1	18	9	26	17
1.378	20	15	18	1.632	0.901	21	7	32	8.78	0.766	21.7	19	41	48	18	8.17	0.791	51.8	18	47	18	17
1.377	20	17	20	1.636	0.898	19	23	10	7.88	0.765	39.6	18	31	48	20	8.20	0.790	51.3	18	17	48	17
1.376	20	9	28	1.638	0.897	21	41	10	8.77	0.764	21.3	19	39	50	18	8.38	0.790	49.1	18	47	32	18
1.372	19	41	14	1.642	0.895	19	9	24	8.77	0.763	19.8	20	33	48	19	7.66	0.788	54.9	16	33	50	16
1.372	19	13	20	1.642	0.895	21	9	42	8.72	0.763	22.0	19	37	48	18	7.60	0.783	55.0	17	41	46	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.52 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 17,142.8 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: Mwd/MTU	34916.1
Exposure: Mwd/MTU (GWd)	17143.4 (2372.20)		
Delta E: Mwd/MTU, (GWd)	0.6 (0.09)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.68		
Flow: Mlb/hr	93.68 (91.40 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.351 7.427 13 0.415 0.641 7 16
		24	0.900 19.813 14 0.312 0.608 27 4
		23	1.138 25.161 15 0.401 0.654 45 8
		22	1.296 28.724 16 1.030 1.174 27 12
		21	1.388 30.968 17 1.063 1.190 21 18
		20	1.440 32.762 18 0.947 1.210 29 14
		19	1.447* 33.949 19 1.288 1.392 21 16
		18	1.445 35.251 20 1.337 1.398 29 12
		17	1.424 36.428 21 1.217 1.318 11 18
		16	1.391 36.846
		15	1.404 37.035
		14	1.350 38.297
		13	1.280 39.444
		12	1.216 40.872
		11	1.127 41.568
		10	1.120 40.182
		9	1.055 41.335
		8	0.946 42.240
		7	0.825 43.262
		6	0.691 43.970
		5	0.561 44.054*
		4	0.451 42.745
		3	0.375 39.600
		2	0.293 30.893
		Bottom 1	0.085 9.463
Control Rod Density: %	2.66		
k-effective:	0.99953		
Void Fraction:	0.345		
Core Delta-P: psia	20.352	% AXIAL TILT	26.265 -11.947
Core Plate Delta-P: psia	15.802	AVG BOT 8ft/12ft	0.8624 1.0672
Coolant Temp: Deg-F	545.3		
In Channel Flow: Mlb/hr	83.04	Active Channel Flow: Mlb/hr	80.41
Total Bypass Flow (%):	11.4	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.398	20	29	12	1.591	0.924	19	25	9.02	0.784	19.5	20	19	32	21	8.64
1.395	20	27	14	1.594	0.922	19	39	8.93	0.777	20.1	20	31	50	18	8.14
1.392	20	47	34	1.596	0.921	21	31	8.85	0.772	21.5	19	35	50	18	8.17
1.392	19	21	16	1.597	0.920	20	31	8.87	0.771	20.8	20	33	14	18	7.69
1.392	20	19	18	1.597	0.920	21	49	7.76	0.770	43.1	18	29	14	18	8.33
1.389	20	17	20	1.598	0.920	21	25	8.75	0.765	21.9	19	37	14	18	7.65
1.389	19	15	22	1.598	0.920	19	37	8.77	0.763	20.8	20	29	16	18	7.48
1.389	20	45	26	1.598	0.920	21	17	8.69	0.761	22.1	19	39	16	18	8.48
1.388	20	23	18	1.599	0.920	19	49	8.72	0.758	20.8	20	35	16	18	7.59
1.387	19	47	24	1.600	0.919	19	47	7.71	0.758	41.7	16	17	32	21	8.09

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.53 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 17,143.4 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	35222.8
Exposure: MWd/MTU (GWd)	17450.0 (2414.62)		
Delta E: MWd/MTU, (GWd)	306.6 (42.42)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-27.05		
Flow: Mlb/hr	102.09 (99.60 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.364 7.546 13 0.414 0.642 7 16
		24	0.939 20.122 14 0.310 0.608 27 4
		23	1.186 25.552 15 0.400 0.655 45 8
		22	1.349 29.171 16 1.026 1.176 27 12
		21	1.437 31.446 17 1.061 1.186 21 18
		20	1.483* 33.256 18 0.949 1.208 29 14
		19	1.480 34.444 19 1.288 1.390 21 16
		18	1.469 35.744 20 1.335 1.400 29 12
		17	1.440 36.912 21 1.226 1.326 11 18
		16	1.401 37.308
		15	1.410 37.472
		14	1.350 38.717
		13	1.274 39.841
		12	1.205 41.248
		11	1.111 41.916
		10	1.099 40.492
		9	1.028 41.623
		8	0.911 42.497
		7	0.784 43.484
		6	0.648 44.155
		5	0.521 44.204*
		4	0.417 42.865
		3	0.346 39.700
		2	0.270 30.971
		Bottom 1	0.079 9.488
Control Rod Density: %	2.66	% AXIAL TILT	29.035 -11.530
k-effective:	0.99955	AVG BOT 8ft/12ft	0.8435 1.0651
Void Fraction:	0.329		
Core Delta-P: psia	23.109		
Core Plate Delta-P: psia	18.557		
Coolant Temp: Deg-F	545.6		
In Channel Flow: Mlb/hr	90.63	Active Channel Flow: Mlb/hr	87.82
Total Bypass Flow (%):	11.2	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00006		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.400	20	29	12	1.624	0.905	21	25	8	9.21	0.801	20.2	20	19	32	21	8.77	0.837	50.4	18	31	48	18
1.393	20	27	14	1.625	0.904	21	31	8	9.10	0.791	20.7	20	31	12	18	8.23	0.814	53.4	18	17	18	17
1.391	20	47	34	1.629	0.902	21	7	26	9.01	0.788	22.1	19	35	12	18	8.32	0.813	52.7	18	25	10	17
1.390	19	21	16	1.631	0.901	21	17	50	9.00	0.784	21.5	20	33	14	18	7.74	0.808	55.5	16	33	50	16
1.389	20	49	32	1.631	0.901	21	49	18	7.87	0.783	43.7	18	29	14	18	8.47	0.803	49.7	18	47	32	18
1.389	20	19	18	1.636	0.898	21	7	32	8.88	0.779	22.6	19	37	14	18	8.67	0.800	47.1	16	17	32	21
1.387	19	47	24	1.642	0.895	19	23	10	7.88	0.777	42.3	16	17	32	21	7.68	0.800	55.4	16	25	48	16
1.386	19	49	26	1.642	0.895	19	25	50	8.91	0.775	20.5	20	29	16	19	8.24	0.797	51.7	18	9	26	17
1.386	19	15	22	1.642	0.895	20	31	50	8.81	0.773	22.7	19	21	16	18	8.15	0.795	52.6	18	15	16	17
1.386	19	23	14	1.647	0.893	19	39	16	8.87	0.772	21.0	20	33	52	18	7.51	0.794	56.0	16	23	16	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.54 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 17,450.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	35223.8
Exposure: MWd/MTU (GWd)	17451.0 (2414.76)		
Delta E: MWd/MTU, (GWd)	1.0 (0.14)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-29.20		
Flow: Mlb/hr	95.12 (92.80 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.352 7.546 13 0.407 0.631 7 16
		24	0.903 20.123 14 0.305 0.596 27 4
		23	1.141 25.553 15 0.393 0.643 45 8
		22	1.303 29.172 16 1.046 1.202 45 34
		21	1.399 31.447 17 1.063 1.199 43 26
		20	1.461 33.258 18 0.935 1.227 47 32
		19	1.464* 34.445 19 1.291 1.386 47 24
		18	1.458 35.746 20 1.353 1.424 45 32
		17	1.433 36.914 21 1.203 1.301 7 32
		16	1.397 37.309
		15	1.407 37.473
		14	1.349 38.718
		13	1.274 39.842
		12	1.206 41.249
		11	1.115 41.917
		10	1.106 40.493
		9	1.041 41.624
		8	0.933 42.498
		7	0.814 43.485
		6	0.682 44.156
		5	0.556 44.204*
		4	0.449 42.865
		3	0.376 39.700
		2	0.294 30.971
		Bottom 1	0.086 9.488
Control Rod Density: %	1.71		
k-effective:	0.99963		
Void Fraction:	0.342		
Core Delta-P: psia	20.813	% AXIAL TILT	27.008 -11.529
Core Plate Delta-P: psia	16.265	AVG BOT 8ft/12ft	0.8572 1.0650
Coolant Temp: Deg-F	545.3		
In Channel Flow: Mlb/hr	84.33	Active Channel Flow: Mlb/hr	81.67
Total Bypass Flow (%):	11.3	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00007		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.424	20	45	32	1.590	0.925	20	15	32	9.28	0.807	20.6	19	27	22	21	8.60	0.821	50.4	18	31	48	18
1.424	20	47	34	1.592	0.923	20	47	34	9.17	0.797	20.8	19	25	24	21	8.65	0.815	49.1	16	33	24	21
1.422	20	43	28	1.595	0.922	20	15	26	7.76	0.775	44.2	16	27	24	21	8.39	0.810	51.5	18	47	32	17
1.421	20	45	36	1.597	0.920	20	17	34	8.90	0.774	20.7	20	31	12	18	8.75	0.809	47.1	17	25	40	21
1.402	20	49	32	1.608	0.914	20	49	32	8.83	0.770	21.5	20	33	14	18	8.05	0.797	53.4	18	17	18	17
1.395	20	17	24	1.613	0.911	19	49	26	8.80	0.770	22.1	19	35	12	18	8.10	0.791	52.7	18	25	10	17
1.392	20	41	26	1.614	0.911	19	47	24	7.72	0.769	43.7	18	29	14	18	7.55	0.789	55.5	16	33	50	16
1.386	19	47	24	1.619	0.908	21	7	26	8.81	0.767	21.3	20	13	28	17	7.42	0.788	56.2	16	15	24	16
1.385	19	49	26	1.619	0.908	20	17	24	8.82	0.767	20.5	20	29	16	19	7.81	0.784	54.0	16	47	26	16
1.381	19	15	22	1.622	0.907	21	7	32	8.77	0.766	21.9	20	45	30	17	7.51	0.783	55.4	16	25	48	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.55 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 17,451.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	35472.6
Exposure: MWd/MTU (GWd)	17700.0 (2449.22)		
Delta E: MWd/MTU, (GWd)	249.0 (34.46)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-26.94		
Flow: Mlb/hr	102.50 (100.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.363 7.643 13 0.407 0.632 7 16
		24	0.935 20.374 14 0.304 0.597 27 4
		23	1.181 25.870 15 0.392 0.644 45 8
		22	1.345 29.536 16 1.043 1.197 45 34
		21	1.438 31.837 17 1.061 1.192 43 26
		20	1.494* 33.664 18 0.937 1.224 47 32
		19	1.489 34.851 19 1.290 1.386 49 26
		18	1.475 36.149 20 1.350 1.421 47 34
		17	1.444 37.309 21 1.211 1.309 7 26
		16	1.403 37.685
		15	1.411 37.829
		14	1.348 39.059
		13	1.269 40.163
		12	1.198 41.552
		11	1.104 42.197
		10	1.091 40.743
		9	1.021 41.856
		8	0.906 42.705
		7	0.782 43.664
		6	0.649 44.305
		5	0.524 44.326*
		4	0.422 42.963
		3	0.352 39.782
		2	0.275 31.035
		Bottom 1	0.081 9.509
Control Rod Density: %	1.71		
k-effective:	0.99957		
Void Fraction:	0.328		
Core Delta-P: psia	23.257	% AXIAL TILT	29.165 -11.192
Core Plate Delta-P: psia	18.708	AVG BOT 8ft/12ft	0.8423 1.0633
Coolant Temp: Deg-F	545.6		
In Channel Flow: Mlb/hr	91.00	Active Channel Flow: Mlb/hr	88.17
Total Bypass Flow (%):	11.2	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.421	20	47	34	1.638	0.897	20	47	9.42	0.820	21.2	19	27	22	21	8.71
1.418	20	45	32	1.642	0.895	20	15	9.30	0.810	21.4	19	25	24	21	8.76
1.416	20	45	36	1.645	0.894	21	25	7.84	0.786	44.7	16	27	24	21	8.88
1.413	20	43	28	1.646	0.893	20	15	9.02	0.786	21.3	20	31	12	18	8.45
1.402	20	49	32	1.646	0.893	21	7	7.94	0.783	42.3	18	29	14	19	8.12
1.389	20	17	24	1.648	0.892	21	31	8.92	0.783	22.6	19	35	12	18	8.43
1.386	19	49	26	1.649	0.892	20	17	8.93	0.781	22.0	20	27	14	18	7.59
1.385	19	47	24	1.651	0.891	20	49	7.91	0.778	41.8	17	25	22	21	7.43
1.383	20	41	26	1.651	0.890	21	7	8.94	0.778	21.0	20	29	16	19	8.18
1.379	19	15	22	1.656	0.888	19	49	8.92	0.776	19.6	20	27	18	20	7.82

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.56 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 17,700.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU										35473.7			
Exposure: MWd/MTU (GWd)	17701.0	(2449.35)													
Delta E: MWd/MTU, (GWd)	1.0	(0.14)													
Power: MWt	3952.0	(100.00 %)													
Core Pressure: psia	1050.0														
Inlet Subcooling: Btu/lbm	-29.68														
Flow: Mlb/hr	93.68	(91.40 %)													
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
59				--	--	--	--	--	--	--					59
55				--	--	--	--	--	--	--					55
51			--	--	--	--	--	--	--	--					51
47		--	--	--	--	--	--	--	--	--					47
43	--	--	--	--	--	--	--	--	--	--					43
39	--	--	--	--	--	--	--	--	--	--					39
35	--	--	--	--	--	--	--	--	--	--					35
31	--	--	--	--	--	--	--	--	--	--					31
27	--	--	--	--	--	--	--	--	--	--					27
23	--	--	--	--	--	--	--	--	--	--					23
19	--	--	--	--	--	--	--	--	--	--					19
15	--	--	--	--	--	--	--	--	--	--					15
11		--	--	--	--	--	--	--	--	--					11
7			--	--	--	--	--	--	--	--					7
3				--	--	--	--	--	--	--					3
2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
Control Rod Density: %	0.00														
k-effective:	0.99961														
Void Fraction:	0.348														
Core Delta-P: psia	20.412											% AXIAL TILT			
Core Plate Delta-P: psia	15.869											24.820 -11.191			
Coolant Temp: Deg-F	545.3											AVG BOT 8ft/12ft			
In Channel Flow: Mlb/hr	83.00											0.8741 1.0633			
Total Bypass Flow (%):	11.4														
Total Water Rod Flow (%):	2.8														
Source Convergence	0.00006														
										Active Channel Flow: Mlb/hr					
										80.35					
										(of total core flow)					
										(of total core flow)					

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.398	20	25	20	1.618	0.909	20	33	18	8.73	0.759	21.0	20	27	18	18	8.40	0.806	50.9	18	31	48	18
1.396	20	23	18	1.618	0.908	20	23	18	8.68	0.759	22.0	20	29	16	18	7.87	0.788	53.9	18	17	18	17
1.395	20	43	28	1.620	0.908	20	25	42	8.66	0.757	22.0	20	33	14	18	8.12	0.788	52.0	18	47	32	17
1.394	20	27	18	1.627	0.903	20	39	42	8.69	0.757	21.3	20	31	12	18	7.48	0.787	55.8	16	33	16	16
1.392	20	21	20	1.628	0.903	20	17	34	7.58	0.757	44.2	18	29	14	18	7.18	0.787	57.3	16	33	24	16
1.388	20	45	32	1.632	0.901	20	31	16	8.59	0.754	22.7	19	35	12	18	7.28	0.785	56.8	16	29	18	16
1.387	20	45	36	1.632	0.901	20	15	32	8.67	0.754	21.0	20	25	20	18	7.44	0.785	55.9	16	25	48	16
1.386	20	41	26	1.634	0.900	20	15	26	8.60	0.752	22.0	20	25	16	18	7.30	0.782	56.5	16	23	16	16
1.385	20	47	34	1.635	0.899	20	47	34	8.63	0.751	21.1	20	23	18	18	7.39	0.782	56.0	16	33	50	16
1.377	20	29	16	1.636	0.899	20	23	40	8.49	0.748	23.4	19	27	22	18	7.91	0.779	53.2	18	25	10	17

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.57 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 17,701.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	35880.1
Exposure: MWd/MTU (GWd)	18107.4 (2505.59)		
Delta E: MWd/MTU, (GWd)	406.4 (56.23)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1050.0		
Inlet Subcooling: Btu/lbm	-25.55		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N (PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.357 7.797 13 0.395 0.617 7 16
		24	0.924 20.774 14 0.295 0.583 27 4
		23	1.164 26.374 15 0.381 0.630 45 8
		22	1.326 30.115 16 1.057 1.167 45 34
		21	1.417 32.459 17 1.070 1.175 25 18
		20	1.477 34.314 18 0.918 1.191 47 32
		19	1.485* 35.508 19 1.320 1.356 21 16
		18	1.478 36.806 20 1.352 1.389 23 18
		17	1.450 37.956 21 1.190 1.284 7 26
		16	1.412 38.303
		15	1.422 38.415
		14	1.357 39.619
		13	1.275 40.691
		12	1.201 42.051
		11	1.106 42.657
		10	1.093 41.153
		9	1.022 42.238
		8	0.907 43.047
		7	0.783 43.963
		6	0.652 44.557*
		5	0.530 44.532
		4	0.430 43.131
		3	0.361 39.924
		2	0.284 31.147
		Bottom 1	0.084 9.545
		% AXIAL TILT	28.733 -10.667
		AVG BOT 8ft/12ft	0.8474 1.0605
Control Rod Density: %	0.00		
k-effective:	0.99972		
Void Fraction:	0.323		
Core Delta-P: psia	25.109		
Core Plate Delta-P: psia	20.566		
Coolant Temp: Deg-F	545.8		
In Channel Flow: Mlb/hr	95.59	Active Channel Flow: Mlb/hr	92.64
Total Bypass Flow (%):	11.2	(of total core flow)	
Total Water Rod Flow (%):	2.7	(of total core flow)	
Source Convergence	0.00007		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.389	20	23	18	1.694	0.868	21	25	8.90	0.779	22.2	20	31	12	18	8.35
1.385	20	43	28	1.699	0.865	21	31	8.80	0.776	23.5	19	25	12	18	8.01
1.384	20	25	20	1.703	0.863	21	7	7.83	0.776	43.1	18	29	14	19	8.12
1.384	20	47	34	1.705	0.862	20	33	8.82	0.776	22.9	20	27	14	18	8.42
1.384	20	21	20	1.708	0.861	20	23	8.81	0.774	22.9	20	29	16	18	7.51
1.383	20	27	18	1.712	0.859	21	7	8.82	0.771	21.9	20	27	18	18	7.47
1.383	20	45	32	1.712	0.859	20	25	8.68	0.767	24.0	19	23	14	18	7.49
1.382	20	45	36	1.713	0.858	20	31	8.73	0.767	22.9	20	25	16	18	7.34
1.373	20	41	26	1.714	0.858	21	17	8.75	0.765	21.9	20	23	18	18	7.26
1.370	20	29	16	1.715	0.857	20	47	8.74	0.764	21.9	20	25	20	18	7.26

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.58 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 18,107.4 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	35887.8
Exposure: MWd/MTU (GWd)	18115.0 (2506.64)		
Delta E: MWd/MTU, (GWd)	7.6 (1.05)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1044.4		
Inlet Subcooling: Btu/lbm	-36.06		
Flow: Mlb/hr	95.74 (93.40 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.342 7.800 13 0.400 0.627 7 16
		24	0.884 20.781 14 0.298 0.592 27 4
		23	1.114 26.384 15 0.386 0.640 45 8
		22	1.271 30.126 16 1.056 1.162 45 34
		21	1.360 32.470 17 1.069 1.170 25 18
		20	1.420 34.326 18 0.923 1.186 47 32
		19	1.431* 35.521 19 1.315 1.350 21 16
		18	1.428 36.818 20 1.346 1.381 23 18
		17	1.407 37.968 21 1.194 1.284 7 26
		16	1.378 38.314
		15	1.396 38.425
		14	1.344 39.630
		13	1.275 40.701
		12	1.216 42.061
		11	1.137 42.665
		10	1.143 41.161
		9	1.087 42.245
		8	0.975 43.053
		7	0.846 43.968
		6	0.706 44.561*
		5	0.575 44.536
		4	0.468 43.134
		3	0.395 39.926
		2	0.311 31.149
		Bottom 1	0.091 9.546
Control Rod Density: %	0.00		
k-effective:	0.99978		
Void Fraction:	0.321		
Core Delta-P: psia	20.701	% AXIAL TILT	24.541 -10.658
Core Plate Delta-P: psia	16.124	AVG BOT 8ft/12ft	0.8726 1.0605
Coolant Temp: Deg-F	542.6		
In Channel Flow: Mlb/hr	85.01	Active Channel Flow: Mlb/hr	82.38
Total Bypass Flow (%):	11.2	(of total core flow)	
Total Water Rod Flow (%):	2.8	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.381	20	23	18	1.674	0.878	21	25	8.54	0.748	22.2	20	31	12	18	8.05
1.377	20	47	34	1.679	0.875	20	33	8.45	0.745	23.5	19	25	12	18	7.73
1.377	20	43	28	1.681	0.874	20	23	7.42	0.745	45.0	18	29	14	18	7.85
1.376	20	21	20	1.681	0.874	21	31	8.46	0.744	22.9	20	27	14	18	7.27
1.376	20	25	20	1.681	0.874	21	7	8.44	0.741	22.9	20	29	16	18	7.29
1.375	20	45	36	1.687	0.871	20	25	8.45	0.739	21.9	20	27	18	18	7.28
1.375	20	27	18	1.688	0.871	20	47	8.32	0.736	24.0	19	23	14	18	7.96
1.374	20	45	32	1.689	0.870	20	31	8.36	0.735	22.9	20	25	16	18	7.13
1.365	20	41	26	1.691	0.870	20	15	8.38	0.732	22.0	20	23	18	18	7.05
1.362	20	31	16	1.691	0.869	20	17	8.35	0.731	22.3	20	33	10	18	7.04

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.59 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 18,115.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	36192.7
Exposure: MWd/MTU (GWd)	18420.0 (2548.84)		
Delta E: MWd/MTU, (GWd)	305.0 (42.20)		
Power: MWt	3952.0 (100.00 %)		
Core Pressure: psia	1044.4		
Inlet Subcooling: Btu/lbm	-31.83		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.358 7.916 13 0.398 0.626 7 16
		24	0.931 21.085 14 0.295 0.591 27 4
		23	1.171 26.766 15 0.384 0.640 45 8
		22	1.331 30.564 16 1.052 1.159 45 34
		21	1.416 32.937 17 1.067 1.165 25 18
		20	1.468 34.812 18 0.926 1.185 47 32
		19	1.468* 36.008 19 1.315 1.350 49 36
		18	1.457 37.303 20 1.344 1.377 23 18
		17	1.428 38.445 21 1.204 1.295 7 26
		16	1.393 38.770
		15	1.409 38.859
		14	1.351 40.046
		13	1.276 41.095
		12	1.213 42.436
		11	1.126 43.015
		10	1.124 41.477
		9	1.055 42.540
		8	0.929 43.315
		7	0.790 44.194
		6	0.648 44.748*
		5	0.522 44.687
		4	0.422 43.257
		3	0.354 40.029
		2	0.279 31.231
		Bottom 1	0.082 9.572
		% AXIAL TILT	27.970 -10.277
		AVG BOT 8ft/12ft	0.8505 1.0585
Control Rod Density: %	0.00		
k-effective:	1.00002		
Void Fraction:	0.300		
Core Delta-P: psia	24.684		
Core Plate Delta-P: psia	20.109		
Coolant Temp: Deg-F	543.2		
In Channel Flow: Mlb/hr	95.76	Active Channel Flow: Mlb/hr	92.88
Total Bypass Flow (%):	11.0	(of total core flow)	
Total Water Rod Flow (%):	2.7	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR								LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K	
1.377	20	23	18	1.710	0.860	21	25	8	8.73	0.767	22.9	20	31	12	18	8.20	0.832	54.4	18	31	48	17	
1.377	20	47	34	1.719	0.855	21	31	8	8.70	0.765	23.0	19	25	12	19	8.04	0.821	54.6	18	25	10	17	
1.372	20	45	36	1.722	0.854	21	7	26	7.69	0.765	43.7	18	29	14	19	7.88	0.819	55.3	18	17	18	17	
1.372	20	21	20	1.734	0.848	21	7	32	8.68	0.761	22.5	20	27	14	19	7.37	0.808	57.3	16	33	50	16	
1.371	20	45	32	1.736	0.847	21	17	50	8.57	0.756	23.6	20	29	16	18	8.11	0.804	53.5	18	47	32	17	
1.371	20	43	34	1.740	0.845	21	49	18	8.55	0.754	23.5	19	23	14	19	7.34	0.804	57.3	16	25	14	16	
1.369	20	25	20	1.744	0.843	21	41	10	8.57	0.754	22.9	20	33	10	18	7.36	0.803	57.2	16	33	16	16	
1.369	20	27	18	1.749	0.841	20	23	18	8.57	0.752	22.6	20	27	18	18	7.21	0.799	57.8	16	23	16	16	
1.363	20	49	32	1.749	0.840	20	33	18	8.50	0.750	23.5	20	25	16	18	7.86	0.799	54.5	18	15	16	17	
1.359	20	31	16	1.752	0.839	20	47	34	8.46	0.748	24.0	19	11	26	18	7.94	0.797	54.0	18	9	26	17	

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.60 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 18,420.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	36272.6
Exposure: MWd/MTU (GWd)	18500.0 (2559.91)		
Delta E: MWd/MTU, (GWd)	80.0 (11.07)		
Power: MWt	3889.3 (98.41 %)		
Core Pressure: psia	1043.1		
Inlet Subcooling: Btu/lbm	-31.25		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.361 7.947 13 0.398 0.627 7 16
		24	0.942 21.167 14 0.295 0.591 27 4
		23	1.184 26.869 15 0.384 0.640 45 8
		22	1.345 30.682 16 1.051 1.158 45 34
		21	1.428 33.063 17 1.066 1.164 25 18
		20	1.479* 34.942 18 0.927 1.185 47 32
		19	1.476 36.138 19 1.315 1.351 49 36
		18	1.462 37.432 20 1.343 1.376 47 34
		17	1.431 38.571 21 1.206 1.297 7 26
		16	1.394 38.890
		15	1.409 38.973
		14	1.350 40.156
		13	1.274 41.199
		12	1.209 42.534
		11	1.121 43.106
		10	1.117 41.558
		9	1.046 42.616
		8	0.919 43.382
		7	0.779 44.250
		6	0.639 44.794*
		5	0.514 44.724
		4	0.415 43.287
		3	0.349 40.055
		2	0.275 31.251
		Bottom 1	0.081 9.579
			% AXIAL TILT 28.645 -10.174
			AVG BOT 8ft/12ft 0.8457 1.0580
Control Rod Density: %	0.00		
k-effective:	0.99998		
Void Fraction:	0.297		
Core Delta-P: psia	24.620		
Core Plate Delta-P: psia	20.047		
Coolant Temp: Deg-F	543.1		
In Channel Flow: Mlb/hr	95.80	Active Channel Flow: Mlb/hr	92.93
Total Bypass Flow (%):	11.0	(of total core flow)	
Total Water Rod Flow (%):	2.7	(of total core flow)	
Source Convergence	0.00010		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR					APLHGR							LHGR						
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.376	20	47	34	1.729	0.850	21	25	8	8.69	0.760	21.9	20	31	12	19	8.08	0.824	54.6	18	31	48	17
1.376	20	23	18	1.739	0.845	21	31	8	8.62	0.758	23.1	19	25	12	19	7.94	0.814	54.8	18	25	10	17
1.371	20	45	36	1.742	0.844	21	7	26	7.60	0.757	43.9	18	29	14	19	7.77	0.811	55.5	18	17	18	17
1.370	20	21	20	1.755	0.837	21	7	32	8.58	0.753	22.7	20	27	14	19	7.26	0.799	57.5	16	33	50	16
1.370	20	45	32	1.757	0.836	21	17	50	8.51	0.748	22.8	20	29	16	19	8.00	0.796	53.6	18	47	32	17
1.369	20	43	34	1.761	0.835	21	49	18	8.46	0.747	23.7	19	23	14	19	7.23	0.794	57.4	16	25	14	16
1.368	20	25	20	1.764	0.833	21	41	10	8.48	0.746	23.1	20	33	10	18	7.24	0.793	57.3	16	33	16	16
1.368	20	27	18	1.774	0.829	20	23	18	8.45	0.742	22.8	20	27	18	18	7.76	0.792	54.6	18	15	16	17
1.364	20	49	32	1.774	0.828	21	9	42	8.44	0.741	22.7	20	25	16	19	7.84	0.790	54.1	18	9	26	17
1.358	20	31	16	1.775	0.828	20	33	18	7.37	0.740	45.1	16	27	12	19	7.09	0.790	57.9	16	23	16	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.61 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 18,500.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	36577.0
Exposure: MWd/MTU (GWd)	18804.4 (2602.03)		
Delta E: MWd/MTU, (GWd)	304.4 (42.12)		
Power: MWt	3597.1 (91.02 %)		
Core Pressure: psia	1037.1		
Inlet Subcooling: Btu/lbm	-28.61		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.378 8.069 13 0.398 0.627 7 16
		24	0.990 21.489 14 0.294 0.591 27 4
		23	1.242 27.274 15 0.383 0.641 45 8
		22	1.406 31.144 16 1.048 1.155 45 34
		21	1.482 33.551 17 1.064 1.159 25 18
		20	1.523* 35.446 18 0.929 1.184 47 32
		19	1.508 36.639 19 1.314 1.354 49 36
		18	1.484 37.927 20 1.340 1.376 47 34
		17	1.445 39.054 21 1.215 1.307 7 26
		16	1.400 39.348
		15	1.411 39.408
		14	1.345 40.571
		13	1.263 41.590
		12	1.194 42.905
		11	1.099 43.448
		10	1.088 41.865
		9	1.009 42.898
		8	0.875 43.629
		7	0.735 44.459
		6	0.598 44.964*
		5	0.480 44.861
		4	0.388 43.398
		3	0.326 40.148
		2	0.257 31.324
		Bottom 1	0.076 9.602
		% AXIAL TILT	31.556 -9.770
		AVG BOT 8ft/12ft	0.8250 1.0558
Control Rod Density: %	0.00		
k-effective:	1.00002		
Void Fraction:	0.281		
Core Delta-P: psia	24.330		
Core Plate Delta-P: psia	19.763		
Coolant Temp: Deg-F	542.8		
In Channel Flow: Mlb/hr	95.98	Active Channel Flow: Mlb/hr	93.19
Total Bypass Flow (%):	10.8	(of total core flow)	
Total Water Rod Flow (%):	2.6	(of total core flow)	
Source Convergence	0.00007		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR					LHGR				
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	Value	Margin	Exp.	FT	IR
1.376	20	47	34	1.834	0.801	21	25	8.24	0.723	22.6	20	31	7.55	0.783	55.2	18	31
1.372	20	23	18	1.847	0.796	21	31	8.16	0.721	23.8	19	25	7.47	0.778	55.4	18	25
1.368	20	45	36	1.850	0.795	21	7	7.29	0.720	42.6	18	29	7.27	0.771	56.1	18	17
1.367	20	45	32	1.868	0.787	21	7	8.10	0.714	23.4	20	27	7.30	0.757	55.2	18	15
1.366	20	49	32	1.871	0.785	21	17	8.12	0.712	22.5	20	33	7.48	0.757	54.3	18	47
1.365	20	21	20	1.874	0.784	21	41	8.06	0.709	23.2	19	23	7.38	0.756	54.7	18	9
1.363	20	43	34	1.876	0.784	21	49	7.10	0.707	43.7	16	27	6.76	0.755	58.0	16	33
1.362	20	27	18	1.886	0.779	21	9	8.01	0.706	23.5	20	29	6.71	0.749	58.0	16	25
1.361	20	25	20	1.892	0.777	21	23	7.15	0.705	42.3	18	35	7.26	0.749	55.1	18	47
1.361	20	29	12	1.898	0.774	21	39	7.99	0.705	23.6	19	39	6.71	0.747	57.9	16	33

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.62 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 18,804.4 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	36772.7
Exposure: MWd/MTU (GWd)	19000.0 (2629.10)		
Delta E: MWd/MTU, (GWd)	195.6 (27.07)		
Power: MWt	3438.5 (87.01 %)		
Core Pressure: psia	1033.9		
Inlet Subcooling: Btu/lbm	-27.18		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.387 8.151 13 0.397 0.628 7 16
		24	1.018 21.704 14 0.293 0.591 27 4
		23	1.275 27.544 15 0.382 0.641 45 8
		22	1.440 31.451 16 1.046 1.152 45 34
		21	1.511 33.874 17 1.063 1.157 21 18
		20	1.547* 35.778 18 0.931 1.183 47 32
		19	1.525 36.967 19 1.313 1.356 49 36
		18	1.494 38.248 20 1.338 1.375 47 34
		17	1.450 39.366 21 1.221 1.314 7 26
		16	1.401 39.644
		15	1.410 39.688
		14	1.341 40.838
		13	1.257 41.840
		12	1.183 43.140
		11	1.085 43.664
		10	1.070 42.057
		9	0.988 43.074
		8	0.852 43.781
		7	0.712 44.586
		6	0.578 45.068*
		5	0.464 44.944
		4	0.375 43.465
		3	0.315 40.204
		2	0.248 31.368
		Bottom 1	0.073 9.617
		% AXIAL TILT	33.083 -9.502
		AVG BOT 8ft/12ft	0.8138 1.0544
Control Rod Density: %	0.00		
k-effective:	1.00003		
Void Fraction:	0.273		
Core Delta-P: psia	24.176		
Core Plate Delta-P: psia	19.613		
Coolant Temp: Deg-F	542.7		
In Channel Flow: Mlb/hr	96.08	Active Channel Flow: Mlb/hr	93.32
Total Bypass Flow (%):	10.7	(of total core flow)	
Total Water Rod Flow (%):	2.6	(of total core flow)	
Source Convergence	0.00006		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.375	20	47	34	1.898	0.774	21	25	8.04	0.703	22.0	20	31	12	20	7.24
1.369	20	23	18	1.914	0.768	21	31	7.99	0.702	23.0	19	25	12	20	7.18
1.367	20	49	32	1.916	0.767	21	7	7.06	0.700	43.0	18	29	14	20	6.98
1.366	20	45	36	1.936	0.759	21	7	7.89	0.694	22.8	20	27	14	20	7.03
1.364	20	45	32	1.941	0.757	21	17	7.94	0.693	21.7	20	33	10	20	7.11
1.362	20	29	12	1.941	0.757	21	41	7.82	0.690	23.6	19	23	14	20	7.18
1.362	20	21	20	1.946	0.755	21	49	6.96	0.689	42.6	18	35	10	20	6.46
1.359	20	43	34	1.954	0.752	21	9	6.90	0.688	44.1	16	27	12	20	6.98
1.358	20	27	18	1.956	0.751	21	23	7.83	0.687	22.7	19	39	12	20	6.96
1.356	20	25	20	1.963	0.749	21	39	7.80	0.685	22.9	19	23	10	19	6.41

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.63 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 19,000.0 MWd/MTU**

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Cycle:	21	Core Average Exposure: MWd/MTU	36972.6
Exposure: MWd/MTU (GWd)	19200.0 (2656.78)		
Delta E: MWd/MTU, (GWd)	200.0 (27.67)		
Power: MWt	3277.4 (82.93 %)		
Core Pressure: psia	1030.6		
Inlet Subcooling: Btu/lbm	-25.74		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.397 8.236	13 0.397 0.628 7 16
		24 1.048 21.931	14 0.293 0.590 27 4
		23 1.310 27.827	15 0.382 0.642 45 8
		22 1.476 31.773	16 1.043 1.150 45 34
		21 1.542 34.211	17 1.061 1.154 21 18
		20 1.571* 36.122	18 0.932 1.182 47 32
		19 1.541 37.305	19 1.313 1.358 49 36
		18 1.504 38.579	20 1.336 1.374 47 34
		17 1.455 39.687	21 1.227 1.320 7 26
		16 1.402 39.946	
		15 1.408 39.974	
		14 1.337 41.109	
		13 1.249 42.094	
		12 1.171 43.379	
		11 1.071 43.883	
		10 1.052 42.251	
		9 0.966 43.251	
		8 0.829 43.933	
		7 0.689 44.713	
		6 0.559 45.171*	
		5 0.448 45.027	
		4 0.361 43.531	
		3 0.304 40.260	
		2 0.240 31.412	
		Bottom 1 0.071 9.631	
		% AXIAL TILT	34.657 -9.223
		AVG BOT 8ft/12ft	0.8021 1.0528
Control Rod Density: %	0.00		
k-effective:	1.00002		
Void Fraction:	0.264		
Core Delta-P: psia	24.021		
Core Plate Delta-P: psia	19.461		
Coolant Temp: Deg-F	542.5		
In Channel Flow: Mlb/hr	96.18	Active Channel Flow: Mlb/hr	93.46
Total Bypass Flow (%):	10.6	(of total core flow)	
Total Water Rod Flow (%):	2.5	(of total core flow)	
Source Convergence	0.00005		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.374	20	47	34	1.970	0.746	21	25	8	7.74	0.683	23.5	19	25	12	20	6.89	0.734	56.2	18	25	10	17
1.369	20	49	32	1.990	0.739	21	7	26	7.79	0.683	22.5	20	31	12	20	6.93	0.733	56.0	18	31	48	17
1.366	20	23	18	1.990	0.739	21	31	8	6.82	0.678	43.4	18	29	14	20	6.69	0.724	56.9	18	17	18	17
1.363	20	29	12	2.013	0.730	21	7	32	7.71	0.675	22.2	20	33	10	20	6.75	0.715	56.0	18	15	16	17
1.363	20	45	36	2.017	0.729	21	41	10	7.63	0.672	23.3	20	27	14	20	6.83	0.714	55.6	18	9	26	17
1.362	20	45	32	2.019	0.728	21	17	50	6.77	0.671	43.0	18	35	10	20	6.88	0.710	55.1	18	47	32	17
1.359	20	21	20	2.025	0.726	21	49	18	7.56	0.669	24.1	19	23	14	20	6.70	0.706	55.9	18	47	18	17
1.358	19	49	36	2.027	0.725	21	37	8	7.64	0.669	22.1	19	37	10	20	6.68	0.703	55.8	18	17	48	17
1.355	20	43	34	2.030	0.724	21	9	42	7.60	0.669	23.2	19	39	12	20	6.16	0.703	58.8	16	33	50	16
1.354	20	51	34	2.035	0.722	21	39	8	6.68	0.668	44.5	16	27	12	20	6.11	0.696	58.7	16	25	14	16

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.64 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 19,200.0 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	37177.7
Exposure: MWd/MTU (GWd)	19405.1 (2685.16)		
Delta E: MWd/MTU, (GWd)	205.1 (28.38)		
Power: MWt	3085.3 (78.07 %)		
Core Pressure: psia	1026.7		
Inlet Subcooling: Btu/lbm	-24.01		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.409 8.326 13 0.397 0.629 7 16
		24	1.084 22.171 14 0.292 0.590 27 4
		23	1.351 28.127 15 0.382 0.642 45 8
		22	1.518 32.111 16 1.041 1.147 45 34
		21	1.578 34.564 17 1.060 1.152 21 18
		20	1.599* 36.480 18 0.934 1.181 47 32
		19	1.561 37.656 19 1.312 1.361 49 36
		18	1.516 38.920 20 1.334 1.373 47 34
		17	1.460 40.016 21 1.234 1.328 53 36
		16	1.402 40.256
		15	1.405 40.266
		14	1.330 41.386
		13	1.238 42.352
		12	1.156 43.621
		11	1.052 44.103
		10	1.029 42.446
		9	0.939 43.427
		8	0.801 44.084
		7	0.664 44.838
		6	0.537 45.272*
		5	0.431 45.108
		4	0.348 43.597
		3	0.293 40.316
		2	0.231 31.456
		Bottom 1	0.068 9.646
		% AXIAL TILT	36.473 -8.929
		AVG BOT 8ft/12ft	0.7883 1.0512
Control Rod Density: %	0.00		
k-effective:	0.99997		
Void Fraction:	0.254		
Core Delta-P: psia	23.842		
Core Plate Delta-P: psia	19.286		
Coolant Temp: Deg-F	542.4		
In Channel Flow: Mlb/hr	96.30	Active Channel Flow: Mlb/hr	93.62
Total Bypass Flow (%):	10.5	(of total core flow)	
Total Water Rod Flow (%):	2.5	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.373	20	47	34	2.068	0.711	21	25	7.43	0.657	24.0	19	25	12	20	6.54
1.370	20	49	32	2.088	0.704	21	7	7.47	0.657	23.0	20	29	12	20	7.36
1.365	20	29	12	2.092	0.703	21	31	7.42	0.652	22.7	20	33	10	20	6.33
1.363	20	23	18	2.115	0.695	21	7	6.53	0.651	43.9	18	29	14	20	6.49
1.361	20	45	36	2.118	0.694	21	41	6.52	0.648	43.5	18	25	10	20	6.41
1.361	19	49	36	2.122	0.693	21	37	7.37	0.646	22.5	19	23	10	20	6.51
1.359	20	51	34	2.124	0.692	21	17	7.31	0.645	23.8	20	27	14	20	6.36
1.359	20	45	32	2.130	0.690	21	49	7.31	0.645	23.6	19	21	12	20	7.10
1.355	20	21	20	2.131	0.690	21	9	6.41	0.643	44.9	16	27	12	20	7.07
1.354	20	27	10	2.133	0.689	21	39	7.25	0.643	24.5	19	23	14	20	5.81

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.65 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 19,405.1 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	37463.4
Exposure: MWd/MTU (GWd)	19690.7 (2724.68)		
Delta E: MWd/MTU, (GWd)	285.6 (39.52)		
Power: MWt	2840.1 (71.87 %)		
Core Pressure: psia	1021.7		
Inlet Subcooling: Btu/lbm	-21.84		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.425 8.455	13 0.396 0.629 7 16
		24 1.133 22.518	14 0.291 0.590 27 4
		23 1.408 28.559	15 0.381 0.643 45 8
		22 1.577 32.599	16 1.037 1.147 49 34
		21 1.627 35.069	17 1.057 1.148 21 18
		20 1.637* 36.990	18 0.937 1.180 47 32
		19 1.586 38.152	19 1.312 1.364 49 36
		18 1.530 39.400	20 1.331 1.372 49 32
		17 1.466 40.477	21 1.243 1.339 53 36
		16 1.401 40.688	
		15 1.401 40.672	
		14 1.321 41.770	
		13 1.222 42.708	
		12 1.134 43.953	
		11 1.025 44.403	
		10 0.996 42.709	
		9 0.902 43.664	
		8 0.765 44.286	
		7 0.631 45.005	
		6 0.510 45.407*	
		5 0.409 45.216	
		4 0.330 43.685	
		3 0.278 40.389	
		2 0.220 31.514	
		Bottom 1 0.065 9.665	
Control Rod Density: %	0.00		
k-effective:	1.00000		
Void Fraction:	0.240		
Core Delta-P: psia	23.614	% AXIAL TILT	38.892 -8.510
Core Plate Delta-P: psia	19.063	AVG BOT 8ft/12ft	0.7697 1.0489
Coolant Temp: Deg-F	542.2		
In Channel Flow: Mlb/hr	96.45	Active Channel Flow: Mlb/hr	93.83
Total Bypass Flow (%):	10.4	(of total core flow)	
Total Water Rod Flow (%):	2.4	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.372	20	49	32	2.212	0.665	21	25	7.02	0.623	24.7	19	25	12	20	6.97
1.372	20	47	34	2.233	0.658	21	7	7.05	0.623	23.7	20	29	12	20	6.92
1.367	20	29	12	2.242	0.656	21	31	7.03	0.620	23.4	20	33	10	20	5.86
1.366	20	51	34	2.262	0.650	21	37	7.00	0.616	23.2	19	23	10	20	6.05
1.364	19	49	36	2.266	0.649	21	7	6.17	0.616	44.1	18	25	10	20	5.96
1.361	20	27	10	2.269	0.648	21	41	6.14	0.614	44.5	18	29	14	20	6.72
1.359	20	23	18	2.278	0.645	21	39	6.91	0.612	24.3	19	21	12	20	6.69
1.358	19	51	38	2.279	0.645	21	17	6.88	0.610	24.4	20	27	14	20	6.68
1.357	20	45	36	2.279	0.645	21	7	6.05	0.609	45.5	16	27	12	20	6.68
1.355	20	45	32	2.282	0.644	21	9	6.83	0.608	25.2	19	23	14	20	6.70

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.66 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 19,690.7 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

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Cycle:	21	Core Average Exposure: MWd/MTU	37748.8
Exposure: MWd/MTU (GWd)	19976.3 (2764.20)		
Delta E: MWd/MTU, (GWd)	285.6 (39.52)		
Power: MWt	2586.6 (65.45 %)		
Core Pressure: psia	1016.5		
Inlet Subcooling: Btu/lbm	-19.60		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.442 8.589 13 0.395 0.630 7 16
		24	1.187 22.881 14 0.290 0.590 27 4
		23	1.471 29.010 15 0.380 0.643 45 8
		22	1.640 33.106 16 1.033 1.149 49 34
		21	1.679* 35.590 17 1.055 1.149 31 10
		20	1.677 37.512 18 0.939 1.179 47 32
		19	1.611 38.655 19 1.311 1.367 49 36
		18	1.543 39.884 20 1.328 1.375 49 32
		17	1.470 40.940 21 1.252 1.350 53 36
		16	1.398 41.119
		15	1.394 41.077
		14	1.309 42.151
		13	1.202 43.059
		12	1.108 44.277
		11	0.994 44.695
		10	0.960 42.964
		9	0.864 43.892
		8	0.728 44.478
		7	0.599 45.164
		6	0.484 45.535*
		5	0.388 45.319
		4	0.314 43.768
		3	0.265 40.459
		2	0.209 31.570
		Bottom 1	0.062 9.683
		% AXIAL TILT	41.361 -8.078
		AVG BOT 8ft/12ft	0.7501 1.0465
Control Rod Density: %	0.00		
k-effective:	0.99996		
Void Fraction:	0.225		
Core Delta-P: psia	23.386		
Core Plate Delta-P: psia	18.839		
Coolant Temp: Deg-F	542.0		
In Channel Flow: Mlb/hr	96.61	Active Channel Flow: Mlb/hr	94.04
Total Bypass Flow (%):	10.2	(of total core flow)	
Total Water Rod Flow (%):	2.4	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.375	20	49	32	2.391	0.615	21	25	6.56	0.585	25.4	19	25	12	20	6.55
1.373	20	51	34	2.412	0.609	21	7	6.59	0.584	24.4	20	29	12	20	6.45
1.371	20	47	34	2.427	0.606	21	31	6.60	0.584	24.1	20	27	10	20	6.39
1.369	20	29	12	2.436	0.603	21	37	6.58	0.582	23.9	19	23	10	20	6.29
1.368	20	27	10	2.452	0.599	21	7	5.79	0.580	44.7	18	25	10	20	6.30
1.367	19	49	36	2.453	0.599	21	7	6.48	0.576	25.0	19	21	12	20	5.56
1.367	19	51	38	2.456	0.599	21	41	5.71	0.574	45.1	18	29	14	20	6.27
1.363	19	23	10	2.456	0.599	21	39	6.53	0.574	22.8	21	25	8	20	6.25
1.358	19	25	12	2.468	0.596	21	9	6.52	0.573	23.1	21	31	8	20	6.23
1.354	20	23	18	2.470	0.595	21	17	5.64	0.571	46.1	16	27	12	20	6.27

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.67 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 19,976.3 MWd/MTU**

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Cycle:	21	Core Average Exposure: MWd/MTU	38034.6
Exposure: MWd/MTU (GWd)	20261.9 (2803.72)		
Delta E: MWd/MTU, (GWd)	285.6 (39.52)		
Power: MWt	2330.1 (58.96 %)		
Core Pressure: psia	1011.3		
Inlet Subcooling: Btu/lbm	-17.37		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25	0.461 8.729 13 0.394 0.630 7 16
		24	1.247 23.262 14 0.288 0.589 27 4
		23	1.541 29.481 15 0.379 0.643 45 8
		22	1.709 33.633 16 1.029 1.151 49 34
		21	1.735* 36.128 17 1.053 1.153 31 10
		20	1.719 38.047 18 0.942 1.184 51 26
		19	1.637 39.167 19 1.311 1.377 51 38
		18	1.557 40.373 20 1.325 1.381 51 34
		17	1.473 41.404 21 1.263 1.363 53 36
		16	1.395 41.549
		15	1.386 41.479
		14	1.293 42.528
		13	1.179 43.404
		12	1.078 44.594
		11	0.960 44.978
		10	0.921 43.209
		9	0.823 44.110
		8	0.690 44.661
		7	0.566 45.314
		6	0.457 45.657*
		5	0.367 45.417
		4	0.297 43.847
		3	0.251 40.526
		2	0.199 31.622
		Bottom 1	0.059 9.700
			% AXIAL TILT 44.010 -7.634
			AVG BOT 8ft/12ft 0.7287 1.0439
Control Rod Density: %	0.00		
k-effective:	1.00003		
Void Fraction:	0.209		
Core Delta-P: psia	23.157		
Core Plate Delta-P: psia	18.616		
Coolant Temp: Deg-F	541.8		
In Channel Flow: Mlb/hr	96.77	Active Channel Flow: Mlb/hr	94.26
Total Bypass Flow (%):	10.1	(of total core flow)	
Total Water Rod Flow (%):	2.3	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR							LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K
1.381	20	51	34	2.608	0.564	21	25	8	6.13	0.545	24.8	20	27	10	20	6.17	0.593	51.0	18	25	10	20
1.378	20	49	32	2.631	0.559	21	7	26	6.08	0.544	26.1	19	25	12	20	5.95	0.581	52.5	18	31	48	20
1.377	19	51	38	2.650	0.555	21	37	8	6.13	0.544	24.7	19	23	10	20	5.96	0.576	51.7	18	9	26	20
1.375	20	27	10	2.654	0.554	21	31	8	6.10	0.543	25.1	20	29	12	20	5.85	0.572	52.8	18	15	16	20
1.372	19	23	10	2.667	0.551	21	53	38	5.38	0.541	45.4	18	25	10	20	5.85	0.568	52.1	18	17	48	20
1.371	19	49	36	2.674	0.550	21	39	8	6.10	0.538	23.5	21	25	8	20	5.83	0.567	52.3	18	47	18	20
1.371	20	29	12	2.677	0.549	21	53	30	6.01	0.537	25.7	19	21	12	20	5.64	0.566	53.9	18	17	18	20
1.370	20	47	34	2.684	0.548	21	41	10	6.07	0.536	23.8	21	31	8	20	5.87	0.562	50.7	17	31	10	20
1.363	21	53	36	2.690	0.546	21	7	40	6.03	0.531	23.4	19	33	8	20	5.76	0.560	52.2	18	47	32	20
1.361	19	25	12	2.696	0.545	21	9	42	5.26	0.531	45.7	18	29	14	20	5.36	0.556	55.3	16	25	14	20

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

**Figure A.68 Browns Ferry Equilibrium Cycle Control Rod Pattern
and Axial Distributions at 20,261.9 MWd/MTU**

Appendix B Elevation Views of the Browns Ferry Equilibrium Cycle Fresh Reload Batch Fuel Assemblies

**Figure B.1 Elevation View for the Browns Ferry Equilibrium
Cycle Fresh Fuel Reload Batch BFE ATRIUM 11
[] Fuel Assembly Design**

**Figure B.2 Elevation View for the Browns Ferry Equilibrium
Cycle Fresh Fuel Reload Batch BFE ATRIUM 11
[] Fuel Assembly Design**

**Figure B.3 Elevation View for the Browns Ferry Equilibrium
Cycle Fresh Fuel Reload Batch BFE ATRIUM 11
[] Fuel Assembly Design**

Appendix C Browns Ferry Equilibrium Cycle Fresh Fuel Locations

**Table C.1 Browns Ferry Equilibrium Cycle Reload Fuel Identification
and Locations**

**Table C.3 Browns Ferry Equilibrium Cycle Reload Fuel Identification
and Locations (*Continued*)**

Appendix D Browns Ferry Equilibrium Cycle Radial Exposure and Power Distributions

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Appendix E Browns Ferry Cycle N-1 EOC Projection Control Rod Patterns and Core Average Axial Power and Exposure Distributions

**Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report**

Page E-2

Cycle:	20	Core Average Exposure: MWd/MTU	36577.8
Exposure: MWd/MTU (GWd)	18804.4 (2602.03)		
Delta E: MWd/MTU, (GWd)	304.4 (42.12)		
Power: MWt	3607.7 (91.29 %)		
Core Pressure: psia	1037.3		
Inlet Subcooling: Btu/lbm	-28.70		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.377 8.067	10 0.398 0.627 7 16
		24 0.988 21.485	11 0.294 0.591 27 4
		23 1.239 27.268	12 0.383 0.640 45 8
		22 1.403 31.136	13 1.048 1.155 45 34
		21 1.479 33.540	14 1.064 1.160 21 18
		20 1.521* 35.433	15 0.929 1.185 47 32
		19 1.507 36.624	16 1.314 1.354 49 26
		18 1.484 37.909	17 1.341 1.376 47 34
		17 1.445 39.036	18 1.214 1.306 53 26
		16 1.402 39.332	
		15 1.413 39.394	
		14 1.347 40.560	
		13 1.266 41.581	
		12 1.196 42.900	
		11 1.101 43.447	
		10 1.090 41.867	
		9 1.010 42.903	
		8 0.877 43.636	
		7 0.735 44.468	
		6 0.598 44.976*	
		5 0.480 44.876	
		4 0.387 43.419	
		3 0.325 40.177	
		2 0.255 31.355	
		Bottom 1 0.075 9.613	
		% AXIAL TILT	31.495 -9.803
		AVG BOT 8ft/12ft	0.8259 1.0559
Control Rod Density: %	0.00		
k-effective:	0.99998		
Void Fraction:	0.282		
Core Delta-P: psia	24.341		
Core Plate Delta-P: psia	19.773		
Coolant Temp: Deg-F	542.8		
In Channel Flow: Mlb/hr	95.98	Active Channel Flow: Mlb/hr	93.18
Total Bypass Flow (%):	10.8	(of total core flow)	
Total Water Rod Flow (%):	2.6	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR								LHGR							
Value	FT	IR	JR	Value	Margin	FT	IR	JR	Value	Margin	Exp.	FT	IR	JR	K	Value	Margin	Exp.	FT	IR	JR	K	
1.376	17	47	34	1.830	0.803	18	25	8	8.26	0.725	22.6	17	31	12	19	7.58	0.784	55.1	15	31	48	17	
1.373	17	23	18	1.843	0.798	18	31	8	8.19	0.723	23.8	16	25	12	19	7.49	0.780	55.4	15	25	10	17	
1.369	17	45	36	1.847	0.796	18	7	26	7.30	0.722	42.6	15	29	14	20	7.30	0.773	56.0	15	17	18	17	
1.368	17	45	32	1.864	0.789	18	7	32	8.12	0.716	23.3	17	27	14	19	7.32	0.759	55.2	15	15	16	17	
1.367	17	21	20	1.869	0.787	18	17	50	8.14	0.714	22.5	17	33	10	19	7.51	0.758	54.2	15	47	32	17	
1.366	17	49	32	1.870	0.786	18	41	10	8.07	0.710	23.1	16	37	14	20	7.40	0.757	54.7	15	9	26	17	
1.365	17	43	28	1.872	0.785	18	49	18	8.04	0.708	23.4	17	29	16	19	6.78	0.756	58.0	13	33	50	16	
1.363	17	27	18	1.883	0.781	18	9	42	7.11	0.708	43.7	13	33	12	20	6.74	0.752	58.0	13	25	14	16	
1.363	17	25	20	1.888	0.779	18	23	8	8.01	0.706	23.5	16	39	12	19	7.28	0.751	55.0	15	47	18	17	
1.361	17	29	12	1.894	0.776	18	39	8	8.06	0.706	22.5	16	37	10	19	6.74	0.750	57.9	13	33	16	16	

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure E.1 Browns Ferry Cycle N-1 Control Rod Pattern and Axial Distributions at 18,804.4 MWd/MTU (Short Window)

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

Page E-3

Cycle:	20	Core Average Exposure: MWd/MTU	37178.5
Exposure: MWd/MTU (GWd)	19405.1 (2685.16)		
Delta E: MWd/MTU, (GWd)	205.1 (28.38)		
Power: MWt	3090.8 (78.21 %)		
Core Pressure: psia	1026.8		
Inlet Subcooling: Btu/lbm	-24.07		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N(PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.408 8.323	10 0.397 0.629 7 16
		24 1.082 22.165	11 0.292 0.590 27 4
		23 1.350 28.119	12 0.381 0.642 45 8
		22 1.517 32.102	13 1.041 1.148 45 34
		21 1.577 34.552	14 1.060 1.153 21 18
		20 1.599* 36.466	15 0.934 1.182 47 32
		19 1.561 37.640	16 1.313 1.361 49 36
		18 1.517 38.904	17 1.335 1.374 47 34
		17 1.462 40.000	18 1.233 1.327 53 26
		16 1.405 40.241	
		15 1.408 40.253	
		14 1.333 41.376	
		13 1.241 42.345	
		12 1.158 43.618	
		11 1.053 44.103	
		10 1.030 42.449	
		9 0.939 43.433	
		8 0.801 44.092	
		7 0.663 44.847	
		6 0.536 45.284*	
		5 0.429 45.123	
		4 0.346 43.618	
		3 0.291 40.344	
		2 0.229 31.487	
		Bottom 1 0.068 9.656	
		% AXIAL TILT	36.514 -8.962
		AVG BOT 8ft/12ft	0.7886 1.0514
Control Rod Density: %	0.00		
k-effective:	1.00000		
Void Fraction:	0.254		
Core Delta-P: psia	23.846		
Core Plate Delta-P: psia	19.290		
Coolant Temp: Deg-F	542.4		
In Channel Flow: Mlb/hr	96.30	Active Channel Flow: Mlb/hr	93.62
Total Bypass Flow (%):	10.5	(of total core flow)	
Total Water Rod Flow (%):	2.5	(of total core flow)	
Source Convergence	0.00008		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	JR	K	Value
1.374	17	47	34	2.065	0.712	18	25	7.45	0.659	24.0	16	25	12	20	6.56
1.371	17	49	32	2.086	0.705	18	7	7.49	0.658	23.0	17	31	12	20	7.36
1.366	17	29	12	2.088	0.704	18	31	7.44	0.653	22.7	17	33	10	20	6.35
1.365	17	23	18	2.113	0.696	18	7	6.54	0.652	43.8	15	29	14	20	6.43
1.362	17	45	36	2.115	0.695	18	41	6.53	0.649	43.4	15	35	10	20	6.51
1.361	16	49	36	2.119	0.694	18	37	7.38	0.648	22.5	16	37	10	20	6.53
1.360	17	45	32	2.123	0.693	18	17	7.32	0.647	23.7	17	27	14	20	6.38
1.359	17	51	34	2.126	0.691	18	49	7.32	0.646	23.6	16	39	12	20	6.35
1.357	17	21	20	2.130	0.690	18	9	6.42	0.644	44.9	13	27	12	20	7.08
1.354	17	27	10	2.130	0.690	18	39	7.26	0.644	24.5	16	23	14	20	5.84

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure E.2 Browns Ferry Cycle N-1 Control Rod Pattern and Axial Distributions at 19,405.1 MWd/MTU (Nominal Window)

Browns Ferry ATRIUM 11 Equilibrium Cycle
Fuel Cycle Design Report

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Cycle:	20	Core Average Exposure: MWd/MTU	37577.2
Exposure: MWd/MTU (GWd)	19803.9 (2740.34)		
Delta E: MWd/MTU, (GWd)	113.2 (15.66)		
Power: MWt	2747.6 (69.52 %)		
Core Pressure: psia	1019.8		
Inlet Subcooling: Btu/lbm	-21.03		
Flow: Mlb/hr	107.62 (105.00 %)		
		Axial Profile	Edit Radial Power
		N (PRA) Power Exposure	Zone Avg. Max. IR JR
		Top 25 0.431 8.505	10 0.396 0.629 7 16
		24 1.151 22.653	11 0.290 0.590 27 4
		23 1.430 28.726	12 0.380 0.643 45 8
		22 1.598 32.787	13 1.036 1.148 49 34
		21 1.645 35.261	14 1.057 1.148 21 18
		20 1.652* 37.181	15 0.937 1.180 47 32
		19 1.596 38.334	16 1.312 1.365 49 36
		18 1.537 39.575	17 1.331 1.374 49 32
		17 1.470 40.645	18 1.245 1.342 53 36
		16 1.403 40.844	
		15 1.402 40.821	
		14 1.320 41.912	
		13 1.218 42.842	
		12 1.127 44.080	
		11 1.015 44.521	
		10 0.983 42.815	
		9 0.888 43.762	
		8 0.750 44.371	
		7 0.617 45.078	
		6 0.498 45.470*	
		5 0.399 45.272	
		4 0.322 43.738	
		3 0.271 40.446	
		2 0.214 31.567	
		Bottom 1 0.063 9.682	
		% AXIAL TILT	39.896 -8.372
		AVG BOT 8ft/12ft	0.7625 1.0481
Control Rod Density: %	0.00		
k-effective:	1.00002		
Void Fraction:	0.234		
Core Delta-P: psia	23.529		
Core Plate Delta-P: psia	18.980		
Coolant Temp: Deg-F	542.1		
In Channel Flow: Mlb/hr	96.51	Active Channel Flow: Mlb/hr	93.91
Total Bypass Flow (%):	10.3	(of total core flow)	
Total Water Rod Flow (%):	2.4	(of total core flow)	
Source Convergence	0.00009		

Top Ten Thermal Limits Summary - Sorted by Margin

Power				MCPR				APLHGR				LHGR			
Value	FT	IR	JR	Value	Margin	FT	IR	Value	Margin	Exp.	FT	IR	Value	Margin	Exp.
1.374	17	49	32	2.273	0.647	18	25	6.86	0.610	24.9	16	25	6.82	0.656	51.1
1.372	17	47	34	2.295	0.640	18	7	6.89	0.609	23.9	17	29	6.75	0.651	51.3
1.368	17	29	12	2.305	0.638	18	31	6.89	0.608	23.6	17	33	6.65	0.636	50.6
1.368	17	51	34	2.322	0.633	18	37	6.86	0.604	23.5	16	23	5.69	0.636	58.1
1.365	16	49	36	2.331	0.631	18	7	6.04	0.604	44.3	15	25	6.56	0.634	51.6
1.363	17	27	10	2.333	0.630	18	41	5.99	0.600	44.7	15	29	6.57	0.630	50.9
1.360	16	51	38	2.338	0.629	18	39	6.76	0.600	24.5	16	21	6.54	0.630	51.2
1.358	17	23	18	2.339	0.628	18	53	6.79	0.596	22.6	18	31	6.51	0.626	51.0
1.357	17	45	36	2.346	0.627	18	17	6.71	0.596	24.7	17	27	6.53	0.626	50.8
1.357	16	23	10	2.347	0.626	18	9	5.91	0.596	45.7	13	27	6.55	0.620	49.7

* LHGR calculated with pin-power reconstruction

* CPR calculated with pin-power reconstruction & CPR limit TYPE 3

Figure E.3 Browns Ferry Cycle N-1 Control Rod Pattern and Axial Distributions at 19,803.9 MWd/MTU (Long Window)

ATTACHMENT 7a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3850P Revision 0

(Proprietary)

Browns Ferry ATRIUM 11 Equilibrium Cycle Nuclear Fuel Design Report

ATTACHMENT 7b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3850NP Revision 0

(Non Proprietary)

Browns Ferry ATRIUM 11 Equilibrium Cycle Nuclear Fuel Design Report

Browns Ferry ATRIUM 11 Equilibrium Cycle

ANP-3850NP
Revision 0

Nuclear Fuel Design Report

May 2020

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

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Nomenclature

Acronym	Definition
[]	the information contained within brackets is proprietary to Framatome Inc.
BOL	beginning of life
BWR	boiling water reactor
EVC	plenum region in a fuel pin modeled as an evacuated section
kg/MTU	kilograms per metric ton of initial uranium
LHGR	linear heat generation rate
LPF	local peaking factor
MCPR	minimum critical power ratio
MWd/MTU	megawatt days per metric ton of initial uranium
NRC	(United States) Nuclear Regulatory Commission
PLFR	part-length fuel rod
SLC	standby liquid boron control

1.0 INTRODUCTION

This report provides results of the neutronic design analyses performed by Framatome Inc. for the Browns Ferry ATRIUM 11 equilibrium cycle design. The mechanical design parameters for the fuel are from Reference 1 and are shown in Table 2.1.

Applicable neutronic design criteria are provided in the approved topical report ANF-89-98(P)(A) Revision 1 and Supplement 1 (Reference 2). Neutronic design analysis methodology used to determine conformance to design criteria has been reviewed and approved by the NRC in the topical report EMF-2158(P)(A) (Reference 3).

The fuel design includes advanced fuel channels that use beta quenched Zircaloy-4 (Z4B) material.

The neutronic design for the equilibrium cycle includes axially-varying enrichment and gadolinia designs with natural UO_2 blankets at the top and bottom of the assembly. Pertinent fuel and reactor core design information associated with this equilibrium cycle batch is given in Section 2.0 and in Appendices A through D.

2.0 NEUTRONIC DESIGN

The results of the Browns Ferry equilibrium cycle neutronic design analyses are presented in this section. The fuel was designed to meet applicable design criteria, as well as reactivity and control requirements. Reactor core loading patterns and the number of assemblies to be loaded will depend upon final cycle energy requirements as specified by the utility. Applicable neutronic design criteria outlined in Reference 2 are summarized below:

- **Power Distribution.** The local power distribution in the fuel assembly combined with the core power distribution shall result in Linear Heat Generation Rate (LHGR) and Minimum Critical Power Ratio (MCPR) values that are within the limits established for each fuel design.
- **Kinetics Parameters.** The moderator void reactivity coefficient due to boiling in the active channels and the Doppler fuel temperature reactivity coefficient shall be negative. The negative void and Doppler reactivity coefficients ensure a negative power coefficient during reactor operation. Additional calculations were performed to show that the assembly average Doppler and void reactivity coefficients remain negative for the life of the assembly. These results demonstrate that the Reference 2 kinetics criteria are met on a bundle average basis.
- **Control Blade Reactivity.** The design of the fuel assembly and the reactor core loading shall be such that the technical specification shutdown margin requirement is met for all reactor conditions.

2.1 *Neutronic Design Description*

The neutronic design parameters for equilibrium cycle ATRIUM 11 assemblies are presented in Table 2.1. The key nuclear design characteristics are summarized below:

- The fuel assembly contains []
- Each fuel assembly has top and bottom natural uranium blankets.
- The plenum region above the PLFRs will be explicitly modeled.
- The enrichments are designed to yield a local power distribution which results in a balanced design relative to MCPR, LHGR, and other reactor operating requirements, e.g., power peaking.
- Gadolinia (Gd_2O_3 blended with UO_2) rods are designed to control assembly reactivity in order to meet reactivity control requirements in the reactor, e.g. cold shutdown margin.
- The equilibrium cycle reload batch consists of 3 assembly designs which vary axially in enrichment and/or gadolinia. The axial distributions of the lattices in the assemblies are shown in Figures 2.1, 2.2, and 2.3. The fuel rod distribution and axial descriptions are presented in Figures 2.4 through 2.7. The enrichment and gadolinia distribution maps for each of the reload assembly lattices are displayed in Appendix D.

- The fuel assembly incorporates an advanced fuel channel which improves uranium utilization. For D-lattice plants, the fuel assembly is offset [] toward the control blade.

2.2 *Lattice Control Blade Worths and Kinetics Parameters*

Beginning of life (BOL) lattice reactivities (k_{∞}) have been calculated for moderator and fuel conditions ranging from cold to hot operating conditions. From these reactivities, BOL control blade worths and kinetics parameters have been determined based on ABB/Westinghouse Main Body, and ABB/Westinghouse Hafnium Tip control blades. Kinetics parameters are calculated for fuel temperature (Doppler), moderator void, and moderator temperature. The Doppler reactivity was calculated over a fuel temperature range from hot standby to hot operating. The moderator void reactivity was evaluated between the 0% and 40% voided hot operating cases, and the moderator temperature reactivity was calculated from the cold to hot standby condition. The calculations neglect the spacer material and assume zero void in the coolant outside the fuel assembly channel as well as inside the internal water channel. The results of these calculations are presented in Tables 2.2 through 2.70.

2.3 *Enriched Lattice Uncontrolled Reactivities and Isotopic Data*

The enriched lattice exposure-dependent uncontrolled reactivities calculated at three void fractions are presented graphically in Appendix A, and in tabular format in Appendix B. The enriched lattice exposure-dependent isotopic data calculated at three void fractions are presented in Appendix C.

Table 2.1 Neutronic Design Parameters

Patient Information	
Full Name	
Date of Birth	
Gender	
Address	
City	
State	
Zip	
Phone	
Medical History	
Past Medical History	
Current Medical History	
Allergies	
Medications	
Vital Signs	
Physical Examination	
Laboratory Tests	
Imaging Studies	
Diagnosis	
Treatment Plan	
Follow-up	

Case No.	Case Name	Case Type	Case Status	Case Date	Case Location	Case Description	Case Details	Case Notes	Case Comments	Case Actions
1	John Doe	Case 1	Open	2023-01-01	New York	Case 1 Description	Case 1 Details	Case 1 Notes	Case 1 Comments	Case 1 Actions
2	Jane Smith	Case 2	Closed	2023-01-02	California	Case 2 Description	Case 2 Details	Case 2 Notes	Case 2 Comments	Case 2 Actions
3	Bob Johnson	Case 3	Pending	2023-01-03	Texas	Case 3 Description	Case 3 Details	Case 3 Notes	Case 3 Comments	Case 3 Actions
4	Alice Brown	Case 4	Open	2023-01-04	Florida	Case 4 Description	Case 4 Details	Case 4 Notes	Case 4 Comments	Case 4 Actions
5	Charlie Davis	Case 5	Closed	2023-01-05	Illinois	Case 5 Description	Case 5 Details	Case 5 Notes	Case 5 Comments	Case 5 Actions
6	Diana Prince	Case 6	Pending	2023-01-06	Washington	Case 6 Description	Case 6 Details	Case 6 Notes	Case 6 Comments	Case 6 Actions
7	Edward Norton	Case 7	Open	2023-01-07	Massachusetts	Case 7 Description	Case 7 Details	Case 7 Notes	Case 7 Comments	Case 7 Actions
8	Fiona Glenanne	Case 8	Closed	2023-01-08	Ontario	Case 8 Description	Case 8 Details	Case 8 Notes	Case 8 Comments	Case 8 Actions
9	George Clooney	Case 9	Pending	2023-01-09	Georgia	Case 9 Description	Case 9 Details	Case 9 Notes	Case 9 Comments	Case 9 Actions
10	Helen Mirren	Case 10	Open	2023-01-10	London	Case 10 Description	Case 10 Details	Case 10 Notes	Case 10 Comments	Case 10 Actions
11	Ian McKellen	Case 11	Closed	2023-01-11	Edinburgh	Case 11 Description	Case 11 Details	Case 11 Notes	Case 11 Comments	Case 11 Actions
12	Jennifer Lawrence	Case 12	Pending	2023-01-12	Atlanta	Case 12 Description	Case 12 Details	Case 12 Notes	Case 12 Comments	Case 12 Actions
13	Keanu Reeves	Case 13	Open	2023-01-13	Los Angeles	Case 13 Description	Case 13 Details	Case 13 Notes	Case 13 Comments	Case 13 Actions
14	Liam Neeson	Case 14	Closed	2023-01-14	Jerusalem	Case 14 Description	Case 14 Details	Case 14 Notes	Case 14 Comments	Case 14 Actions
15	Mel Gibson	Case 15	Pending	2023-01-15	Hollywood	Case 15 Description	Case 15 Details	Case 15 Notes	Case 15 Comments	Case 15 Actions
16	Natalie Portman	Case 16	Open	2023-01-16	Paris	Case 16 Description	Case 16 Details	Case 16 Notes	Case 16 Comments	Case 16 Actions
17	Orlando Bloom	Case 17	Closed	2023-01-17	London	Case 17 Description	Case 17 Details	Case 17 Notes	Case 17 Comments	Case 17 Actions
18	Penelope Cruz	Case 18	Pending	2023-01-18	Madrid	Case 18 Description	Case 18 Details	Case 18 Notes	Case 18 Comments	Case 18 Actions
19	Quentin Tarantino	Case 19	Open	2023-01-19	Los Angeles	Case 19 Description	Case 19 Details	Case 19 Notes	Case 19 Comments	Case 19 Actions
20	Rachel Watson	Case 20	Closed	2023-01-20	London	Case 20 Description	Case 20 Details	Case 20 Notes	Case 20 Comments	Case 20 Actions
21	Samuel L. Jackson	Case 21	Pending	2023-01-21	Atlanta	Case 21 Description	Case 21 Details	Case 21 Notes	Case 21 Comments	Case 21 Actions
22	Tina Turner	Case 22	Open	2023-01-22	Amsterdam	Case 22 Description	Case 22 Details	Case 22 Notes	Case 22 Comments	Case 22 Actions
23	Uma Thurman	Case 23	Closed	2023-01-23	London	Case 23 Description	Case 23 Details	Case 23 Notes	Case 23 Comments	Case 23 Actions
24	Viola Davis	Case 24	Pending	2023-01-24	Atlanta	Case 24 Description	Case 24 Details	Case 24 Notes	Case 24 Comments	Case 24 Actions
25	Wesley Snipes	Case 25	Open	2023-01-25	Los Angeles	Case 25 Description	Case 25 Details	Case 25 Notes	Case 25 Comments	Case 25 Actions
26	Xosha Roquemore	Case 26	Closed	2023-01-26	London	Case 26 Description	Case 26 Details	Case 26 Notes	Case 26 Comments	Case 26 Actions
27	Yasmine Bleeth	Case 27	Pending	2023-01-27	London	Case 27 Description	Case 27 Details	Case 27 Notes	Case 27 Comments	Case 27 Actions
28	Zoe Lister-Jones	Case 28	Open	2023-01-28	Los Angeles	Case 28 Description	Case 28 Details	Case 28 Notes	Case 28 Comments	Case 28 Actions
29	Adam Sandler	Case 29	Closed	2023-01-29	Los Angeles	Case 29 Description	Case 29 Details	Case 29 Notes	Case 29 Comments	Case 29 Actions
30	Ben Stiller	Case 30	Pending	2023-01-30	Los Angeles	Case 30 Description	Case 30 Details	Case 30 Notes	Case 30 Comments	Case 30 Actions
31	Cameron Diaz	Case 31	Open	2023-01-31	Los Angeles	Case 31 Description	Case 31 Details	Case 31 Notes	Case 31 Comments	Case 31 Actions
32	Drew Barrymore	Case 32	Closed	2023-02-01	Los Angeles	Case 32 Description	Case 32 Details	Case 32 Notes	Case 32 Comments	Case 32 Actions
33	Ewan McGregor	Case 33	Pending	2023-02-02	London	Case 33 Description	Case 33 Details	Case 33 Notes	Case 33 Comments	Case 33 Actions
34	Faye Dunaway	Case 34	Open	2023-02-03	London	Case 34 Description	Case 34 Details	Case 34 Notes	Case 34 Comments	Case 34 Actions
35	Gary Oldman	Case 35	Closed	2023-02-04	London	Case 35 Description	Case 35 Details	Case 35 Notes	Case 35 Comments	Case 35 Actions
36	Hugh Grant	Case 36	Pending	2023-02-05	London	Case 36 Description	Case 36 Details	Case 36 Notes	Case 36 Comments	Case 36 Actions
37	Isla Fisher	Case 37	Open	2023-02-06	Los Angeles	Case 37 Description	Case 37 Details	Case 37 Notes	Case 37 Comments	Case 37 Actions
38	Jake Gyllenhaal	Case 38	Closed	2023-02-07	Los Angeles	Case 38 Description	Case 38 Details	Case 38 Notes	Case 38 Comments	Case 38 Actions
39	Kate Winslet	Case 39	Pending	202						

Table 2.1 Neutronic Design Parameters (Continued)

Parameter	Design Value
Core Data*	
Number of fuel assemblies in the core	764
Rated thermal power level, MWt	3952.0
Rated core flow, Mlbm/hr	102.5
Inlet subcooling, Btu/lbm	27.00
Dome pressure, psia	1050
Boron concentration, PPM	720.0
Intermediate temperature, °F	200.00
Warm temperature, °F	360.00

* Some values are representative of rated conditions and may vary depending on the core statepoint.

**Table 2.2 Lattice [] Control Blade Worths at BOL
for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.65148	0.81379	-0.1994
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.64214	0.82016	-0.2171
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.60679	0.85460	-0.2900
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.60314	0.85002	-0.2904
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.60319	0.85002	-0.2904
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.57283	0.87265	-0.3436
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.51464	0.88861	-0.4209

**Table 2.3 Lattice [] Control Blade Worths at BOL
for Control Blade Type ABB/Westinghouse Hafnium Tip**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.66756	0.81379	-0.1797
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.65955	0.82016	-0.1958
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.63193	0.85460	-0.2606
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.62813	0.85002	-0.2610
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.62813	0.85002	-0.2610
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.60448	0.87265	-0.3073
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.55512	0.88861	-0.3753

Table 2.4 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	0.85002	0.85460	-0.0054
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	0.87265	0.85002	0.0266
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	0.85460	0.81379	0.0502

**Table 2.5 Lattice [] Control Blade Worths at BOL
for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.68961	0.84780	-0.1866
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.67994	0.85239	-0.2023
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.64098	0.87595	-0.2682
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.63747	0.87164	-0.2686
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.63752	0.87164	-0.2686
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.60343	0.88510	-0.3182
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.54273	0.89039	-0.3905

**Table 2.6 Lattice [] Control Blade Worths at BOL
for Control Blade Type ABB/Westinghouse Hafnium Tip**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.70586	0.84780	-0.1674
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.69739	0.85239	-0.1818
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.66561	0.87595	-0.2401
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.66197	0.87164	-0.2406
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.66197	0.87164	-0.2406
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.63418	0.88510	-0.2835
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.58171	0.89039	-0.3467

Table 2.7 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	0.87164	0.87595	-0.0049
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	0.88510	0.87164	0.0154
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	0.87595	0.84780	0.0332

**Table 2.8 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93681	1.10097	-0.1491
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92285	1.09165	-0.1546
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.86547	1.05847	-0.1823
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.86146	1.05361	-0.1824
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.86153	1.05361	-0.1823
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.81409	1.03109	-0.2105
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.75780	1.00588	-0.2466

Table 2.9 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.95733	1.10097	-0.1305
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.94400	1.09165	-0.1353
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.89169	1.05847	-0.1576
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.88752	1.05361	-0.1576
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.88752	1.05361	-0.1576
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.84533	1.03109	-0.1802
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.79596	1.00588	-0.2087

Table 2.10 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.05361	1.05847	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.03109	1.05361	-0.0214
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.05847	1.10097	-0.0386

**Table 2.11 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.97473	1.14688	-0.1501
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.96108	1.13874	-0.1560
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.90203	1.10639	-0.1847
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.89784	1.10131	-0.1847
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.89793	1.10131	-0.1847
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.84657	1.07685	-0.2139
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.78385	1.04868	-0.2525

Table 2.12 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.99702	1.14688	-0.1307
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.98406	1.13874	-0.1358
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.93030	1.10639	-0.1592
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.92593	1.10131	-0.1593
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.92593	1.10131	-0.1593
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.88000	1.07685	-0.1828
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.82428	1.04868	-0.2140

Table 2.13 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.10131	1.10639	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.07685	1.10131	-0.0222
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.10639	1.14688	-0.0353

**Table 2.14 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93739	1.10674	-0.1530
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92526	1.10044	-0.1592
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87321	1.07634	-0.1887
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.86906	1.07128	-0.1888
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.86914	1.07128	-0.1887
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.82099	1.05132	-0.2191
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.75953	1.02705	-0.2605

Table 2.15 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.95872	1.10674	-0.1337
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.94736	1.10044	-0.1391
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.90076	1.07634	-0.1631
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.89644	1.07128	-0.1632
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.89644	1.07128	-0.1632
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.85394	1.05132	-0.1877
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.80003	1.02705	-0.2210

Table 2.16 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.07128	1.07634	-0.0047
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.05132	1.07128	-0.0186
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.07634	1.10674	-0.0275

**Table 2.17 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93950	1.10614	-0.1507
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92701	1.09953	-0.1569
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87429	1.07496	-0.1867
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.87019	1.06997	-0.1867
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.87027	1.06997	-0.1866
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.82158	1.04983	-0.2174
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.75870	1.02478	-0.2596

Table 2.18 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.96028	1.10614	-0.1319
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.94855	1.09953	-0.1373
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.90129	1.07496	-0.1616
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.89702	1.06997	-0.1616
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.89702	1.06997	-0.1616
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.85406	1.04983	-0.1865
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.79887	1.02478	-0.2205

Table 2.19 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.06997	1.07496	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.04983	1.06997	-0.0188
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.07496	1.10614	-0.0282

**Table 2.20 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.91296	1.08139	-0.1557
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.90022	1.07450	-0.1622
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.84810	1.05038	-0.1926
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.84398	1.04533	-0.1926
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.84406	1.04533	-0.1925
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.79704	1.02698	-0.2239
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.73449	1.00264	-0.2674

Table 2.21 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93359	1.08139	-0.1367
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92162	1.07450	-0.1423
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87496	1.05038	-0.1670
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.87068	1.04533	-0.1671
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.87068	1.04533	-0.1671
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.82940	1.02698	-0.1924
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.77463	1.00264	-0.2274

Table 2.22 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.04533	1.05038	-0.0048
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.02698	1.04533	-0.0175
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.05038	1.08139	-0.0287

**Table 2.23 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.91380	1.07462	-0.1497
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.90091	1.06772	-0.1562
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.84941	1.04524	-0.1873
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.84539	1.04034	-0.1874
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.84546	1.04034	-0.1873
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.79804	1.02300	-0.2199
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.73301	0.99873	-0.2661

Table 2.24 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93328	1.07462	-0.1315
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92114	1.06772	-0.1373
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87515	1.04524	-0.1627
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.87097	1.04034	-0.1628
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.87097	1.04034	-0.1628
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.82955	1.02300	-0.1891
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.77282	0.99873	-0.2262

Table 2.25 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.04034	1.04524	-0.0047
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.02300	1.04034	-0.0167
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.04524	1.07462	-0.0273

**Table 2.26 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.95980	1.13294	-0.1528
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.94835	1.12905	-0.1600
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.90006	1.11494	-0.1927
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.89587	1.10981	-0.1928
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.89595	1.10981	-0.1927
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.84890	1.09611	-0.2255
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.78207	1.07487	-0.2724

Table 2.27 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.98113	1.13294	-0.1340
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.97060	1.12905	-0.1403
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.92851	1.11494	-0.1672
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.92414	1.10981	-0.1673
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.92414	1.10981	-0.1673
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.88364	1.09611	-0.1938
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.82593	1.07487	-0.2316

Table 2.28 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.10981	1.11494	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.09611	1.10981	-0.0123
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.11494	1.13294	-0.0159

**Table 2.29 Lattice [] Control Blade Worths at BOL
for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.65223	0.79845	-0.1831
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.64455	0.80597	-0.2003
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.61712	0.84779	-0.2721
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.61365	0.84353	-0.2725
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.61370	0.84353	-0.2725
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.58746	0.87408	-0.3279
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.52737	0.89620	-0.4116

**Table 2.30 Lattice [] Control Blade Worths at BOL
for Control Blade Type ABB/Westinghouse Hafnium Tip**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.66635	0.79845	-0.1655
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.65992	0.80597	-0.1812
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.64008	0.84779	-0.2450
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.63649	0.84353	-0.2454
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.63649	0.84353	-0.2454
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.61746	0.87408	-0.2936
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.56741	0.89620	-0.3669

Table 2.31 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	0.84353	0.84779	-0.0050
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	0.87408	0.84353	0.0362
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	0.84779	0.79845	0.0618

**Table 2.32 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93194	1.09494	-0.1489
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.91786	1.08549	-0.1544
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.86032	1.05222	-0.1824
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.85633	1.04737	-0.1824
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.85640	1.04737	-0.1823
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.80894	1.02488	-0.2107
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.75262	0.99969	-0.2472

Table 2.33 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.95224	1.09494	-0.1303
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.93880	1.08549	-0.1351
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.88633	1.05222	-0.1577
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.88217	1.04737	-0.1577
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.88217	1.04737	-0.1577
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.83997	1.02488	-0.1804
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.79055	0.99969	-0.2092

Table 2.34 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.04737	1.05222	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.02488	1.04737	-0.0215
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.05222	1.09494	-0.0390

**Table 2.35 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.97102	1.14202	-0.1497
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.95730	1.13382	-0.1557
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.89820	1.10151	-0.1846
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.89402	1.09645	-0.1846
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.89410	1.09645	-0.1845
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.84274	1.07204	-0.2139
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.78000	1.04396	-0.2528

Table 2.36 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.99312	1.14202	-0.1304
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.98010	1.13382	-0.1356
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.92629	1.10151	-0.1591
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.92193	1.09645	-0.1592
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.92193	1.09645	-0.1592
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.87599	1.07204	-0.1829
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.82026	1.04396	-0.2143

Table 2.37 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.09645	1.10151	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.07204	1.09645	-0.0223
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.10151	1.14202	-0.0355

Table 2.38 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Main Body

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93295	1.10093	-0.1526
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92079	1.09459	-0.1588
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.86871	1.07059	-0.1886
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.86458	1.06555	-0.1886
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.86466	1.06555	-0.1885
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.81653	1.04568	-0.2191
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.75513	1.02157	-0.2608

Table 2.39 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.95406	1.10093	-0.1334
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.94265	1.09459	-0.1388
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.89605	1.07059	-0.1630
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.89175	1.06555	-0.1631
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.89175	1.06555	-0.1631
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.84927	1.04568	-0.1878
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.79541	1.02157	-0.2214

Table 2.40 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.06555	1.07059	-0.0047
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.04568	1.06555	-0.0186
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.07059	1.10093	-0.0276

**Table 2.41 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93571	1.10089	-0.1500
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92323	1.09430	-0.1563
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87073	1.07008	-0.1863
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.86665	1.06511	-0.1863
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.86673	1.06511	-0.1862
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.81821	1.04520	-0.2172
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.75561	1.02052	-0.2596

Table 2.42 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.95627	1.10089	-0.1314
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.94455	1.09430	-0.1368
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.89752	1.07008	-0.1613
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.89326	1.06511	-0.1613
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.89326	1.06511	-0.1613
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.85048	1.04520	-0.1863
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.79559	1.02052	-0.2204

Table 2.43 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.06511	1.07008	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.04520	1.06511	-0.0187
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.07008	1.10089	-0.0280

**Table 2.44 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.90904	1.07596	-0.1551
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.89630	1.06906	-0.1616
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.84437	1.04526	-0.1922
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.84027	1.04024	-0.1922
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.84035	1.04024	-0.1922
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.79348	1.02209	-0.2237
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.73120	0.99807	-0.2674

Table 2.45 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.92944	1.07596	-0.1362
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.91745	1.06906	-0.1418
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87101	1.04526	-0.1667
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.86674	1.04024	-0.1668
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.86674	1.04024	-0.1668
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.82562	1.02209	-0.1922
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.77114	0.99807	-0.2274

Table 2.46 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.04024	1.04526	-0.0048
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.02209	1.04024	-0.0175
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.04526	1.07596	-0.0285

**Table 2.47 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.90275	1.05904	-0.1476
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.88963	1.05185	-0.1542
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.83773	1.02936	-0.1862
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.83375	1.02450	-0.1862
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.83382	1.02450	-0.1861
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.78654	1.00750	-0.2193
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.72189	0.98364	-0.2661

Table 2.48 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.92155	1.05904	-0.1298
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.90917	1.05185	-0.1356
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.86277	1.02936	-0.1618
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.85863	1.02450	-0.1619
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.85863	1.02450	-0.1619
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.81734	1.00750	-0.1887
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.76100	0.98364	-0.2263

Table 2.49 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.02450	1.02936	-0.0047
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.00750	1.02450	-0.0166
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.02936	1.05904	-0.0280

**Table 2.50 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.94835	1.11773	-0.1515
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.93655	1.11347	-0.1589
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.88756	1.09908	-0.1925
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.88340	1.09399	-0.1925
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.88347	1.09399	-0.1924
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.83647	1.08054	-0.2259
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.76979	1.05953	-0.2735

Table 2.51 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.96906	1.11773	-0.1330
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.95817	1.11347	-0.1395
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.91536	1.09908	-0.1672
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.91103	1.09399	-0.1672
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.91103	1.09399	-0.1672
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.87057	1.08054	-0.1943
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.81300	1.05953	-0.2327

Table 2.52 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.09399	1.09908	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.08054	1.09399	-0.0123
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.09908	1.11773	-0.0167

**Table 2.53 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.97625	1.16879	-0.1647
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.96239	1.16166	-0.1715
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.90349	1.13045	-0.2008
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.89931	1.12530	-0.2008
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.89940	1.12530	-0.2008
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.85110	1.10304	-0.2284
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.79195	1.07734	-0.2649

Table 2.54 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	1.00123	1.16879	-0.1434
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.98819	1.16166	-0.1493
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.93465	1.13045	-0.1732
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void, No xenon	0.93028	1.12530	-0.1733
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 0% Void	0.93028	1.12530	-0.1733
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 40% Void	0.88716	1.10304	-0.1957
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=929^{\circ}\text{ F}$ 80% Void	0.83468	1.07734	-0.2252

Table 2.55 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.12530	1.13045	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.10304	1.12530	-0.0198
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.13045	1.16879	-0.0328

**Table 2.56 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93573	1.12679	-0.1696
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92333	1.12158	-0.1768
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87146	1.09890	-0.2070
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.86734	1.09380	-0.2070
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.86743	1.09380	-0.2070
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.82246	1.07608	-0.2357
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.76481	1.05438	-0.2746

Table 2.57 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.95986	1.12679	-0.1482
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.94834	1.12158	-0.1545
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.90205	1.09890	-0.1791
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.89774	1.09380	-0.1792
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.89774	1.09380	-0.1792
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.85817	1.07608	-0.2025
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.80770	1.05438	-0.2340

Table 2.58 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.09380	1.09890	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.07608	1.09380	-0.0162
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.09890	1.12679	-0.0248

**Table 2.59 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93918	1.12804	-0.1674
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92656	1.12276	-0.1747
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87466	1.10056	-0.2053
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.87059	1.09552	-0.2053
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.87068	1.09552	-0.2052
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.82539	1.07796	-0.2343
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.76642	1.05572	-0.2740

Table 2.60 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.96284	1.12804	-0.1464
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.95110	1.12276	-0.1529
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.90483	1.10056	-0.1779
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void, No xenon	0.90057	1.09552	-0.1779
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 0% Void	0.90057	1.09552	-0.1779
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 40% Void	0.86079	1.07796	-0.2015
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=975^{\circ}\text{ F}$ 80% Void	0.80919	1.05572	-0.2335

Table 2.61 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.09552	1.10056	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.07796	1.09552	-0.0160
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.10056	1.12804	-0.0244

**Table 2.62 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.91120	1.10227	-0.1733
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.89829	1.09667	-0.1809
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.84702	1.07491	-0.2120
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.84294	1.06981	-0.2121
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.84303	1.06981	-0.2120
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.79971	1.05429	-0.2415
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.74154	1.03330	-0.2824

Table 2.63 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.93473	1.10227	-0.1520
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92271	1.09667	-0.1586
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.87707	1.07491	-0.1840
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.87280	1.06981	-0.1842
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.87280	1.06981	-0.1842
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.83499	1.05429	-0.2080
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.78428	1.03330	-0.2410

Table 2.64 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.06981	1.07491	-0.0047
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.05429	1.06981	-0.0145
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.07491	1.10227	-0.0248

**Table 2.65 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.88374	1.05858	-0.1652
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.87002	1.05100	-0.1722
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.82066	1.02791	-0.2016
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.81684	1.02318	-0.2017
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.81692	1.02318	-0.2016
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.77505	1.00840	-0.2314
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.71792	0.98904	-0.2741

Table 2.66 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.90488	1.05858	-0.1452
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.89193	1.05100	-0.1514
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.84776	1.02791	-0.1753
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.84378	1.02318	-0.1753
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.84378	1.02318	-0.1753
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.80740	1.00840	-0.1993
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.75801	0.98904	-0.2336

Table 2.67 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.02318	1.02791	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.00840	1.02318	-0.0144
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.02791	1.05858	-0.0290

**Table 2.68 Lattice [] Control Blade Worths at
BOL for Control Blade Type ABB/Westinghouse Main Body**

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.91821	1.10607	-0.1698
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.90568	1.10121	-0.1776
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.85917	1.08560	-0.2086
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.85521	1.08066	-0.2086
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.85529	1.08066	-0.2086
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.81366	1.06894	-0.2388
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.75500	1.05221	-0.2825

Table 2.69 Lattice [] Control Blade Worths at BOL for Control Blade Type ABB/Westinghouse Hafnium Tip

Blade Worth = $\frac{k_{\text{Controlled}} - k_{\text{Uncontrolled}}}{k_{\text{Uncontrolled}}}$		$k_{\text{Controlled}}$	$k_{\text{Uncontrolled}}$	Blade Worth ($\Delta k/k$)
Cold	$T_{\text{Moderator}}=68^{\circ}\text{ F}$ $T_{\text{Fuel}}=68^{\circ}\text{ F}$ 0% Void, No xenon	0.94122	1.10607	-0.1490
Intermediate	$T_{\text{Moderator}}=200^{\circ}\text{ F}$ $T_{\text{Fuel}}=200^{\circ}\text{ F}$ 0% Void, No xenon	0.92963	1.10121	-0.1558
Hot Standby	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=550^{\circ}\text{ F}$ 0% Void, No xenon	0.88892	1.08560	-0.1812
Hot Operating _{NoXe}	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void, No xenon	0.88477	1.08066	-0.1813
Hot Operating ₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 0% Void	0.88477	1.08066	-0.1813
Hot Operating ₄₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 40% Void	0.84906	1.06894	-0.2057
Hot Operating ₈₀	$T_{\text{Moderator}}=550^{\circ}\text{ F}$ $T_{\text{Fuel}}=1013^{\circ}\text{ F}$ 80% Void	0.79877	1.05221	-0.2409

Table 2.70 Lattice [] Kinetics Parameters at BOL

Kinetics Parameter = $\frac{k_{\alpha} - k_{\beta}}{k_{\beta}}$	k_{α}	k_{β}	Kinetics Parameter ($\Delta k/k$)
Doppler = $\frac{k_{\text{HotOperatingNoXe}} - k_{\text{HotStandby}}}{k_{\text{HotStandby}}}$	1.08066	1.08560	-0.0046
Moderator _{Void} = $\frac{k_{\text{HotOperating40}} - k_{\text{HotOperating0}}}{k_{\text{HotOperating0}}}$	1.06894	1.08066	-0.0109
Moderator _{Temperature} = $\frac{k_{\text{HotStandby}} - k_{\text{Cold}}}{k_{\text{Cold}}}$	1.08560	1.10607	-0.0185

Figure 2.1 Assembly Type []

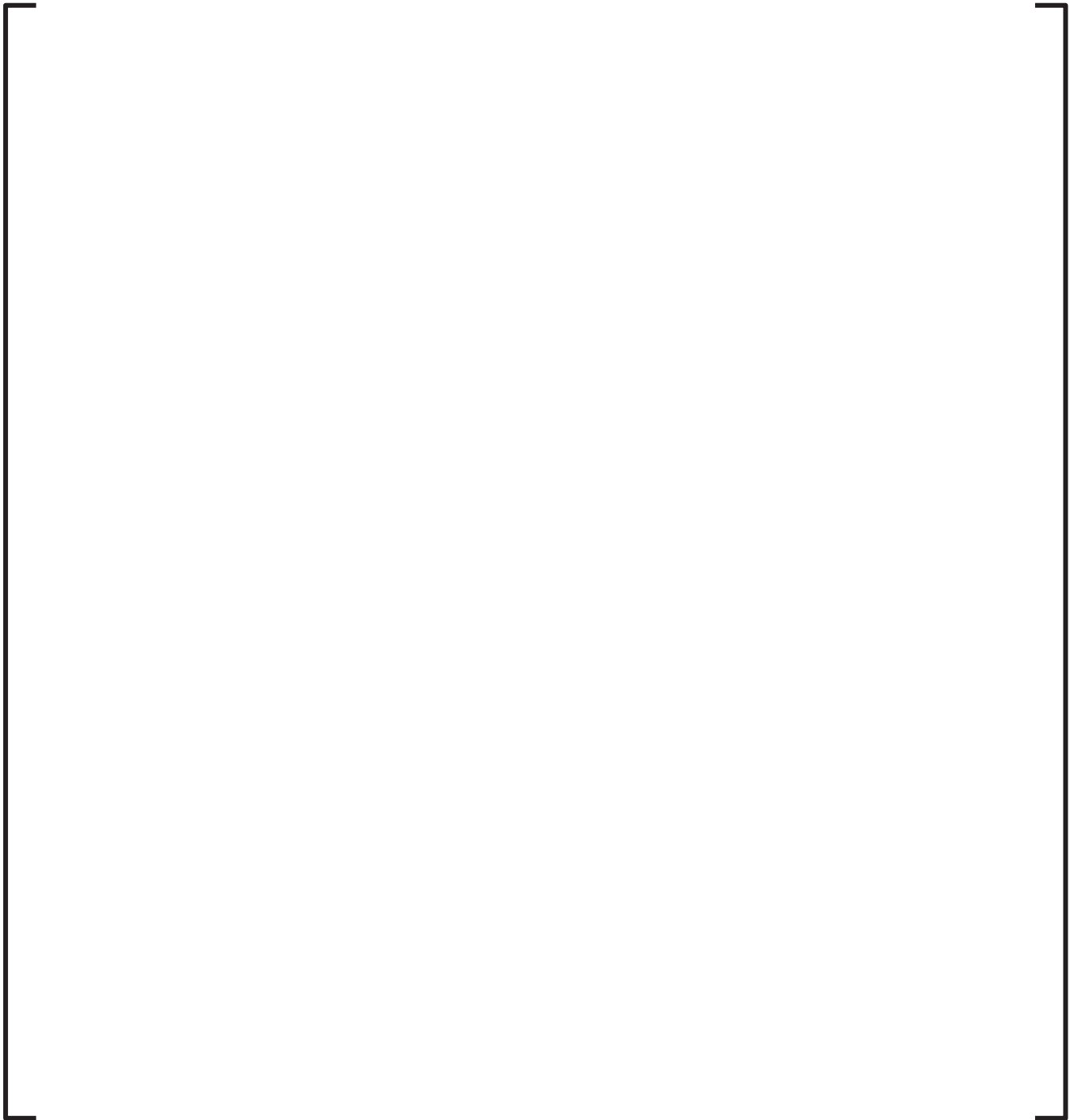


Figure 2.2 Assembly Type []

Figure 2.3 Assembly Type []

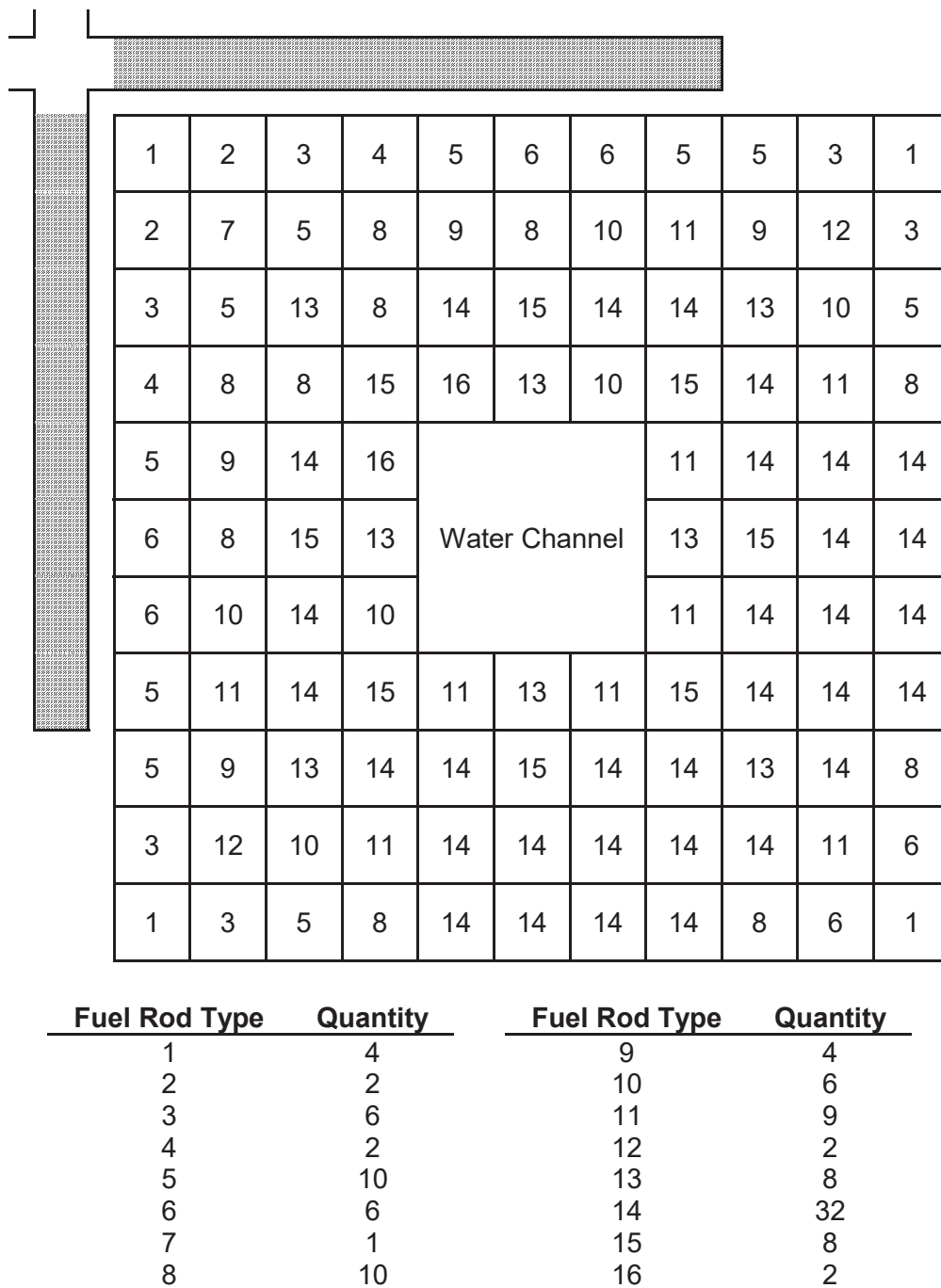


Figure 2.4 [

] Fuel Rod Distribution

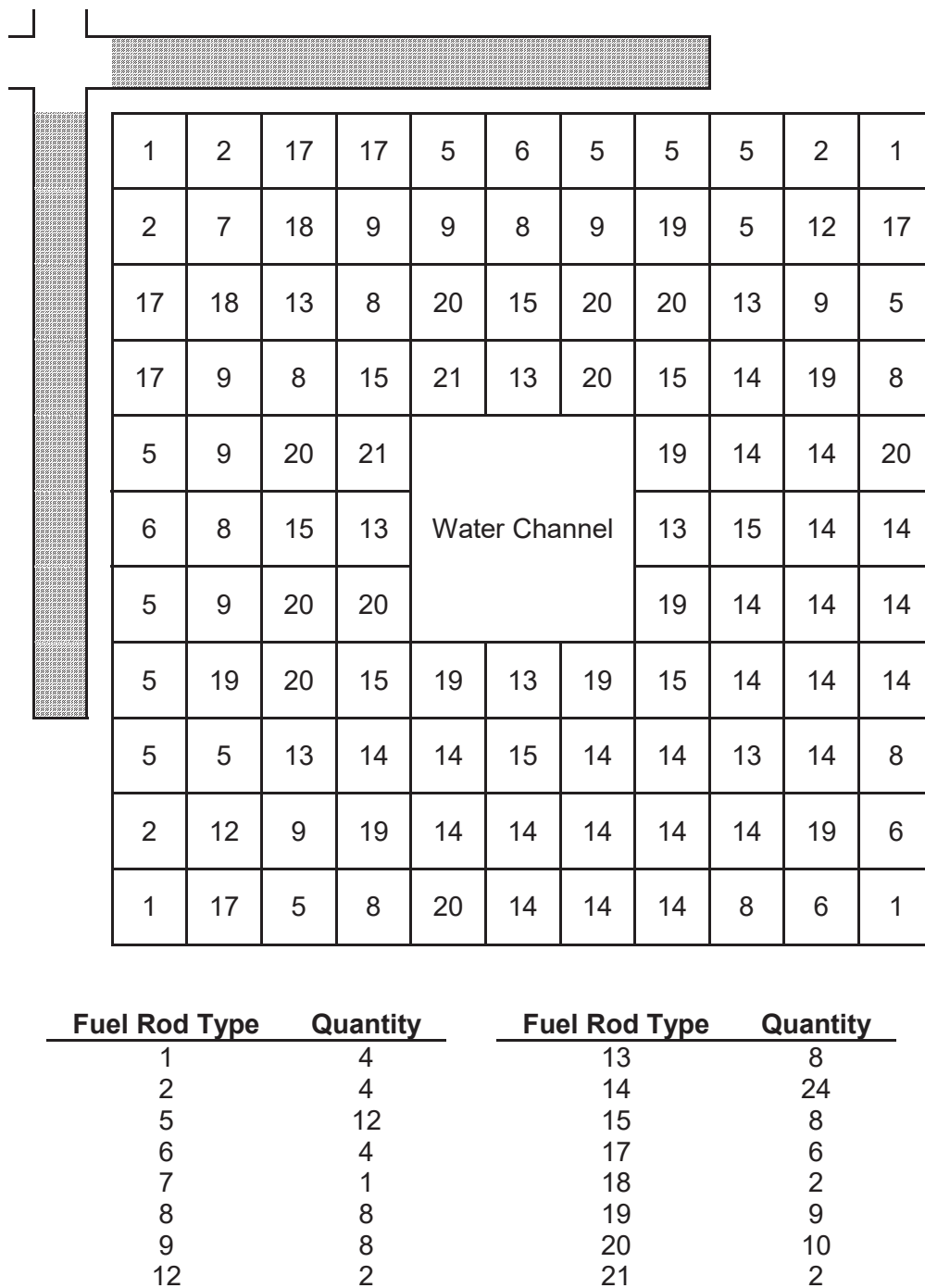


Figure 2.5 [] Fuel Rod Distribution

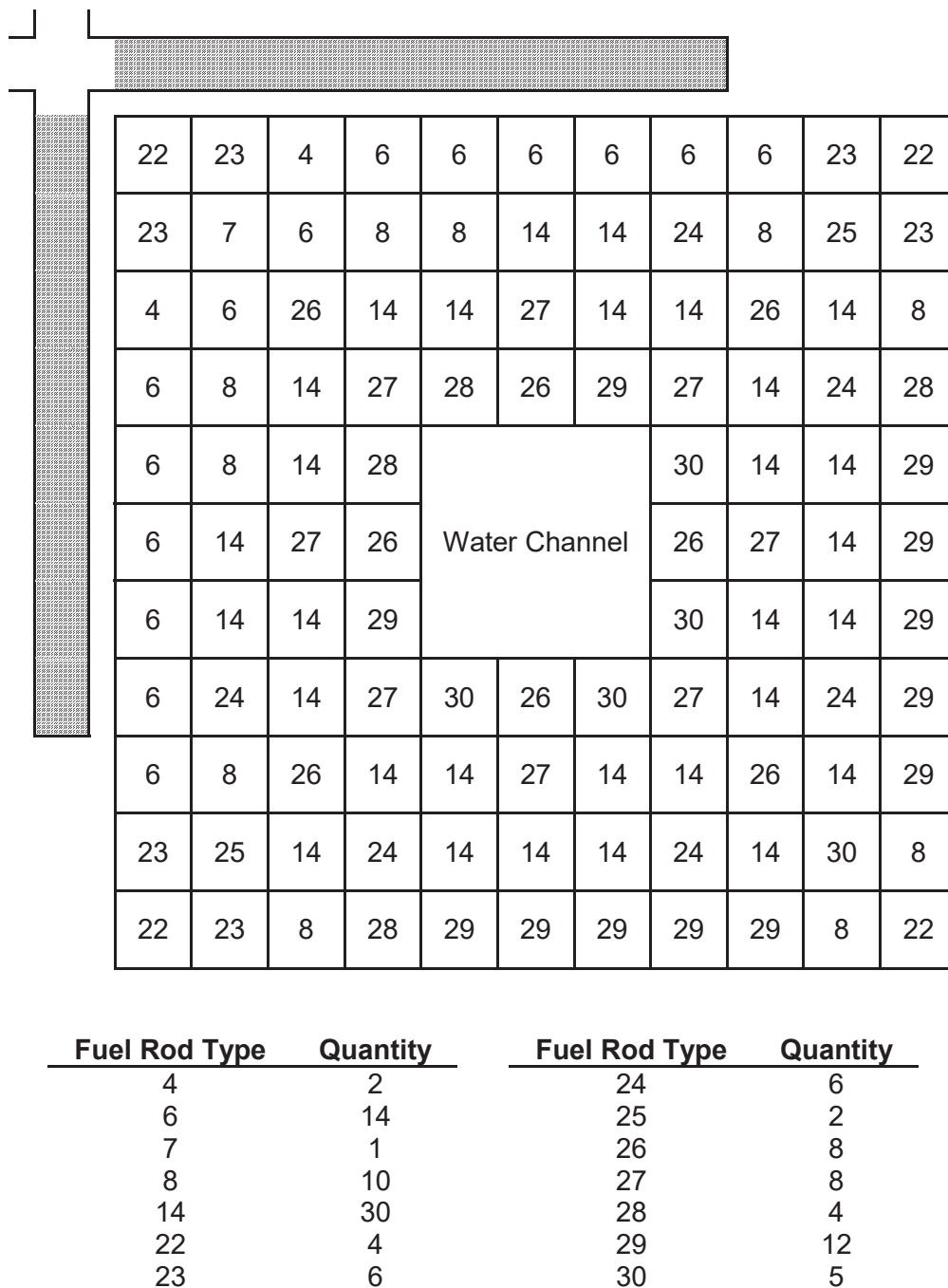


Figure 2.6 [] Fuel Rod Distribution

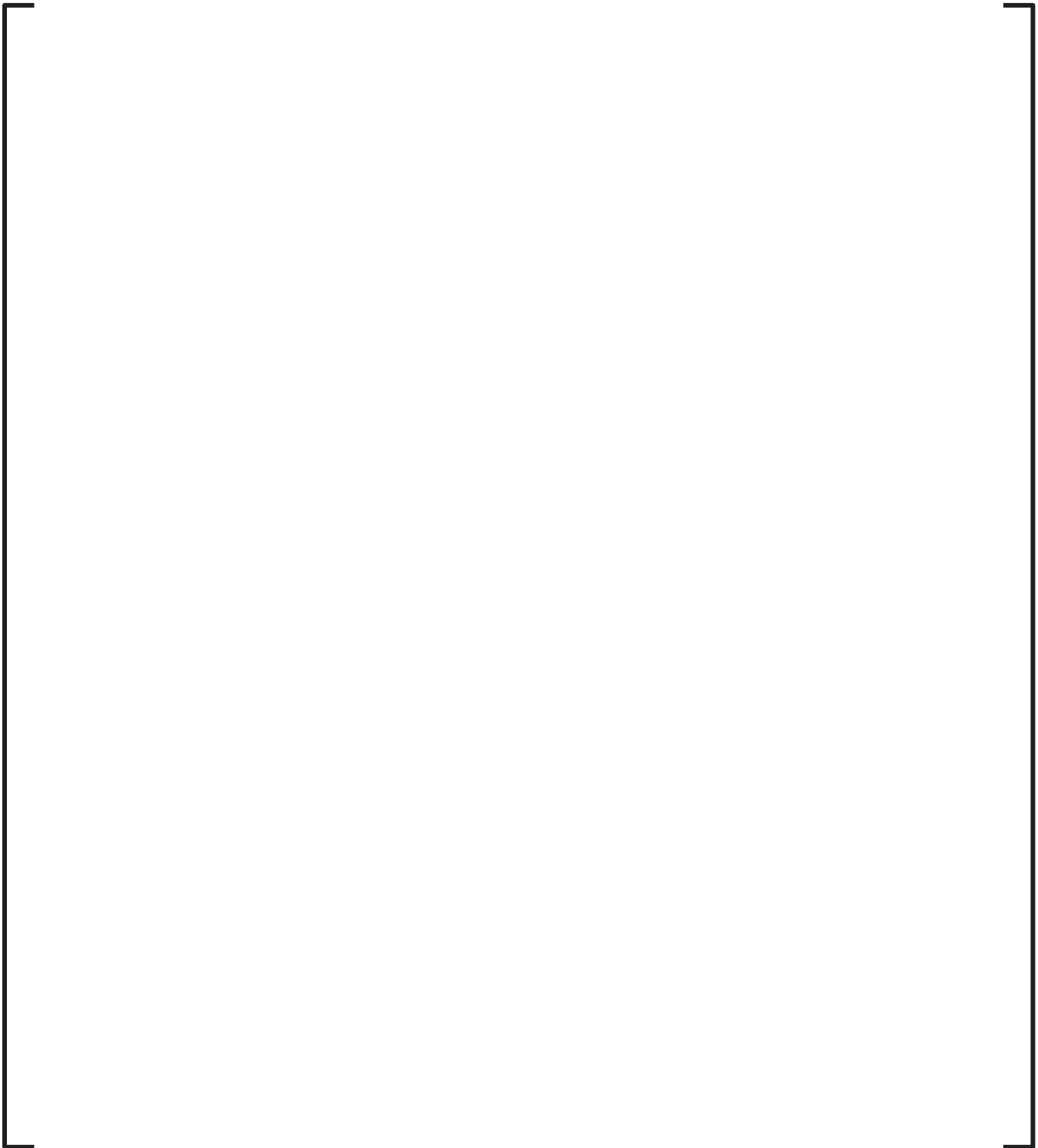


Figure 2.7 Fuel Rod Axial Description

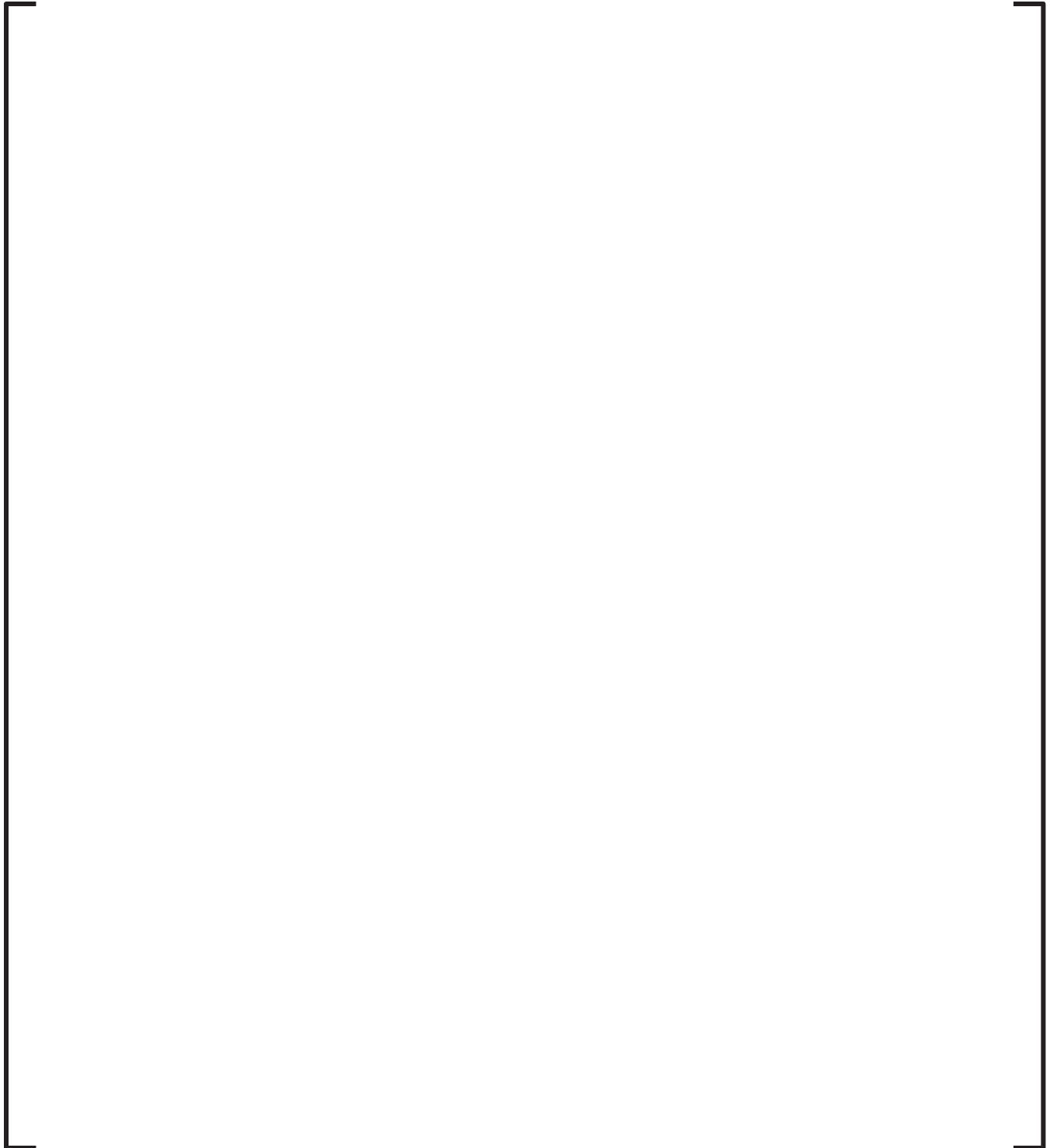


Figure 2.7 Fuel Rod Axial Description *(continued)*

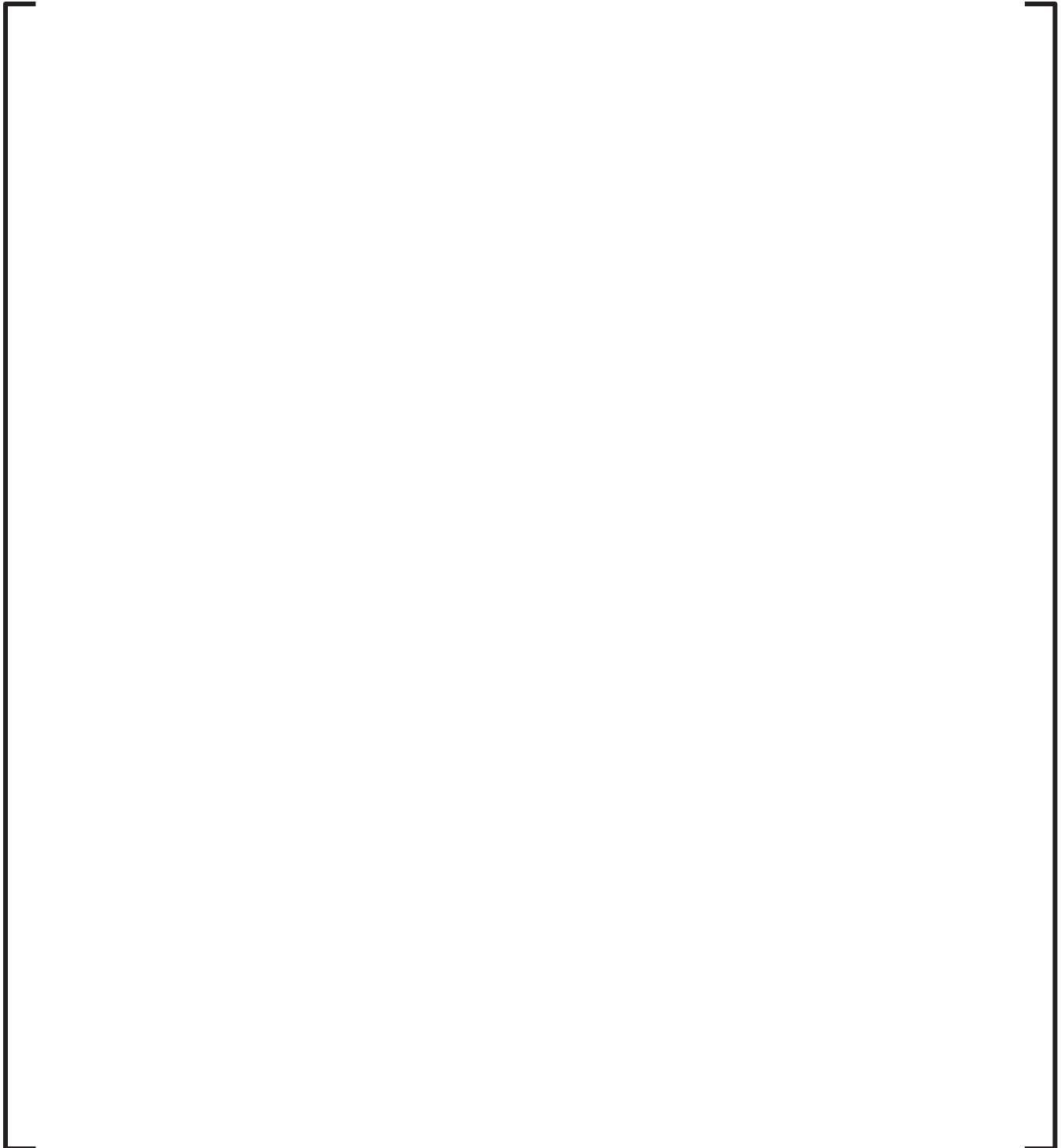


Figure 2.7 Fuel Rod Axial Description *(continued)*

3.0 REFERENCES

1. FS1-0048891 Revision 1.0, Browns Ferry LAR Equilibrium Cycle Specific ATRIUM 11 Fuel Assembly Mechanical Data for Core Engineering, April 2020.
2. ANF-89-98(P)(A) Revision 1 and Supplement 1, *Generic Mechanical Design Criteria for BWR Fuel Designs*, Advanced Nuclear Fuels Corporation, May 1995.
3. EMF-2158(P)(A), Revision 0, *Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2*, Siemens Power Corporation, October 1999.

Appendix A Enriched Lattice Hot Uncontrolled Reactivity and LPF Plots

The results in this appendix are based on hot operating and equilibrium xenon conditions.

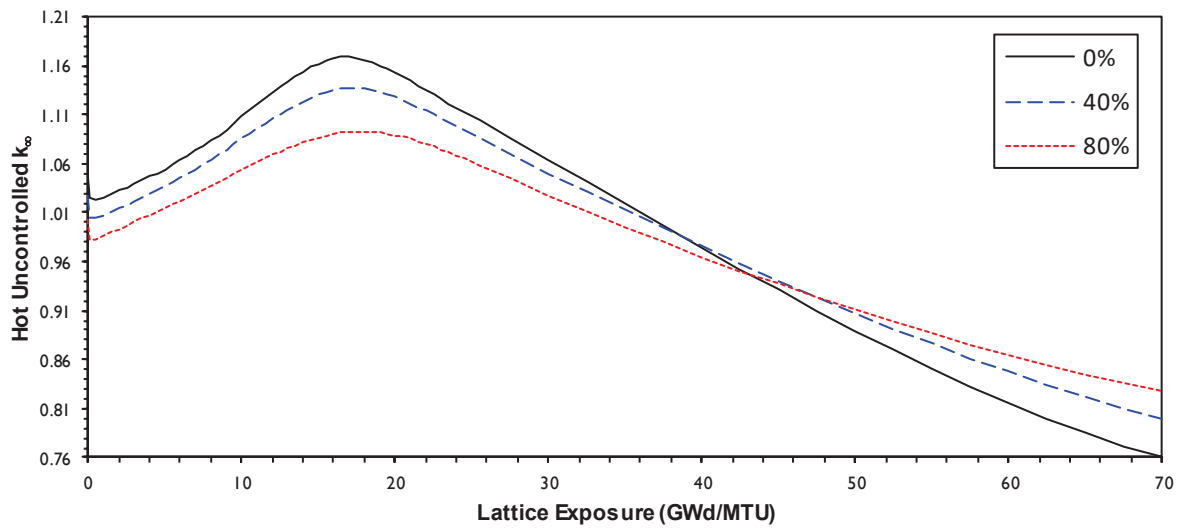


Figure A.1 [] Hot Uncontrolled k_{∞}

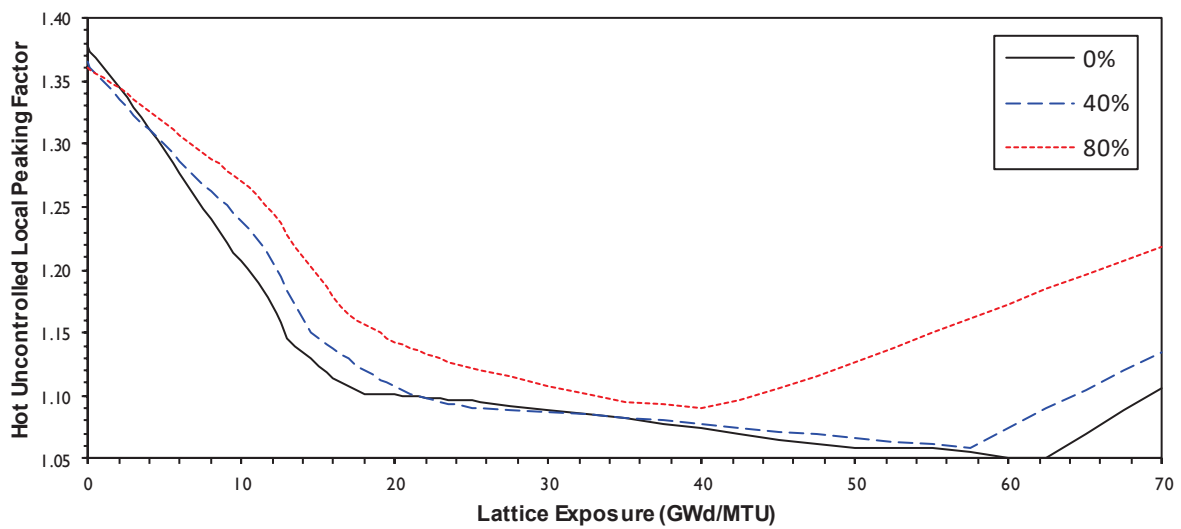


Figure A.2 [] Hot Uncontrolled LPF

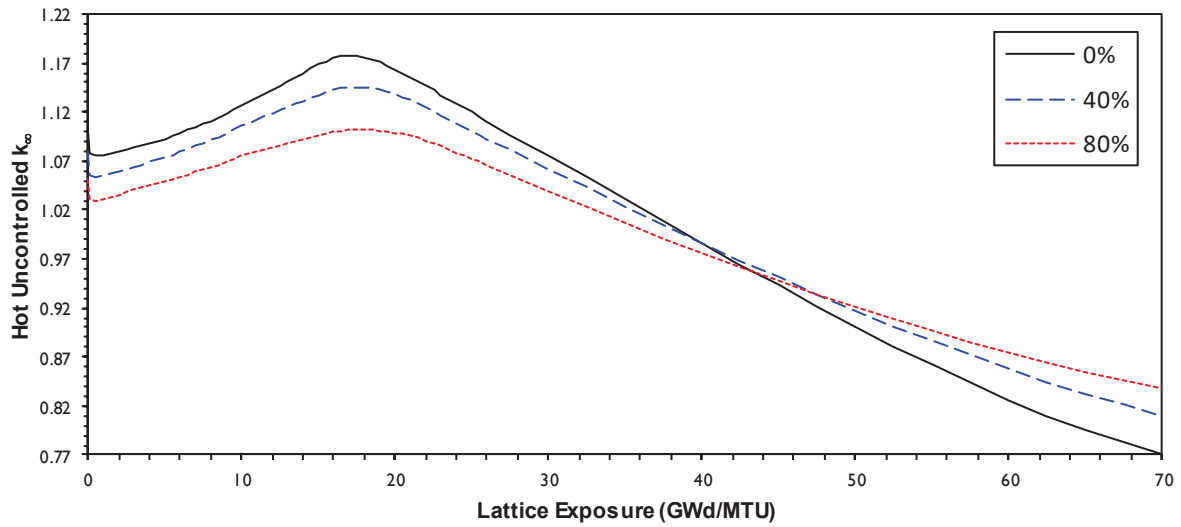


Figure A.3 [] Hot Uncontrolled k_{∞}

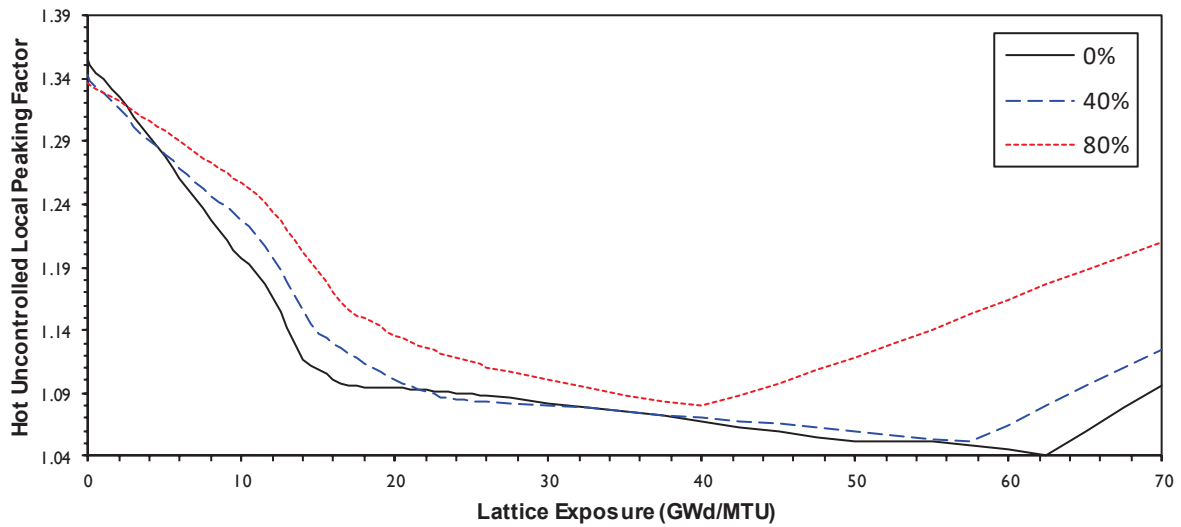


Figure A.4 [] Hot Uncontrolled LPF

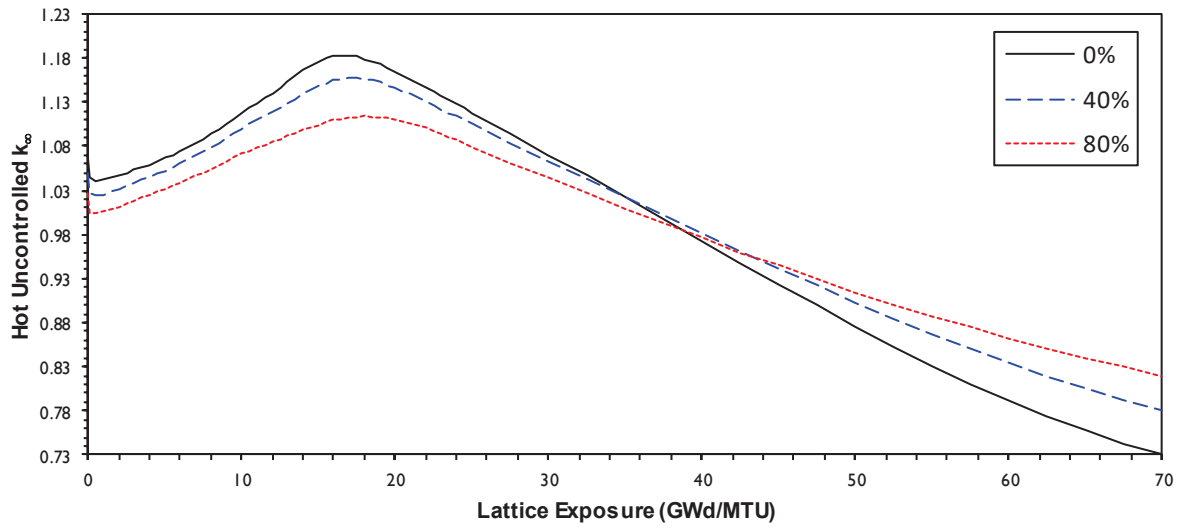


Figure A.5 [

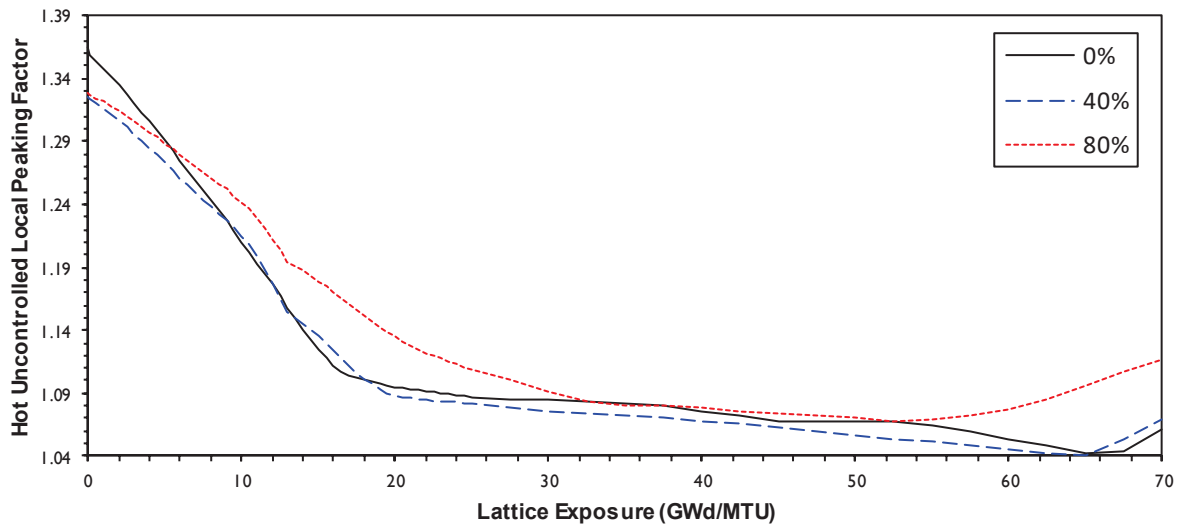
] Hot Uncontrolled k_{∞} 

Figure A.6 [

] Hot Uncontrolled LPF

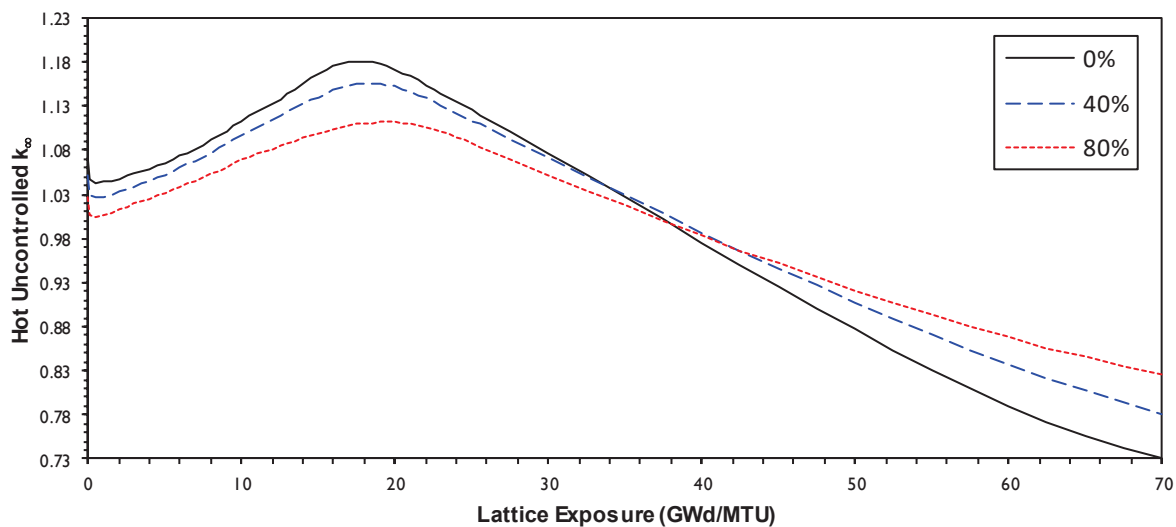


Figure A.7 [] Hot Uncontrolled k_{∞}

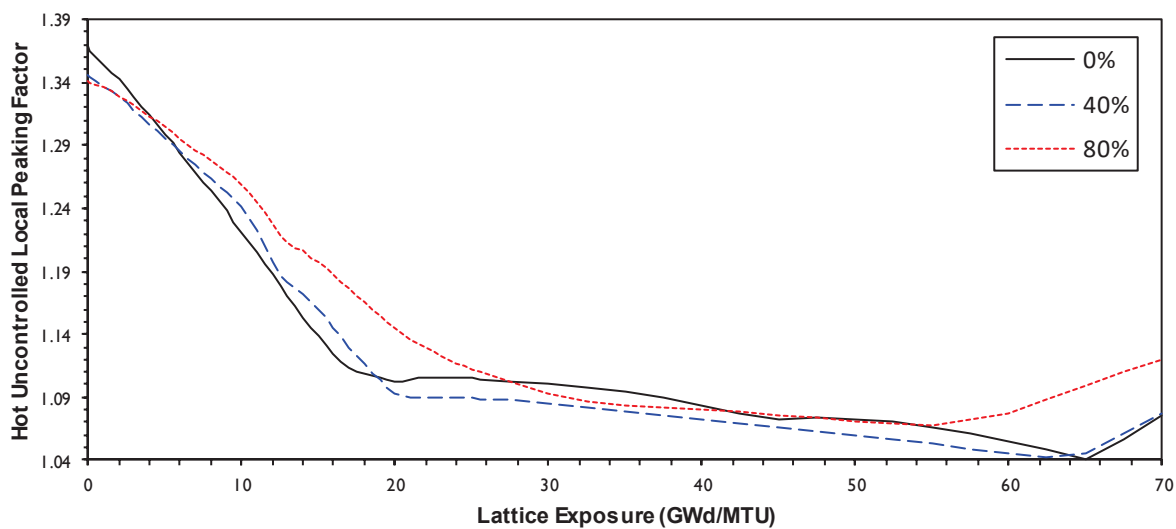


Figure A.8 [] Hot Uncontrolled LPF

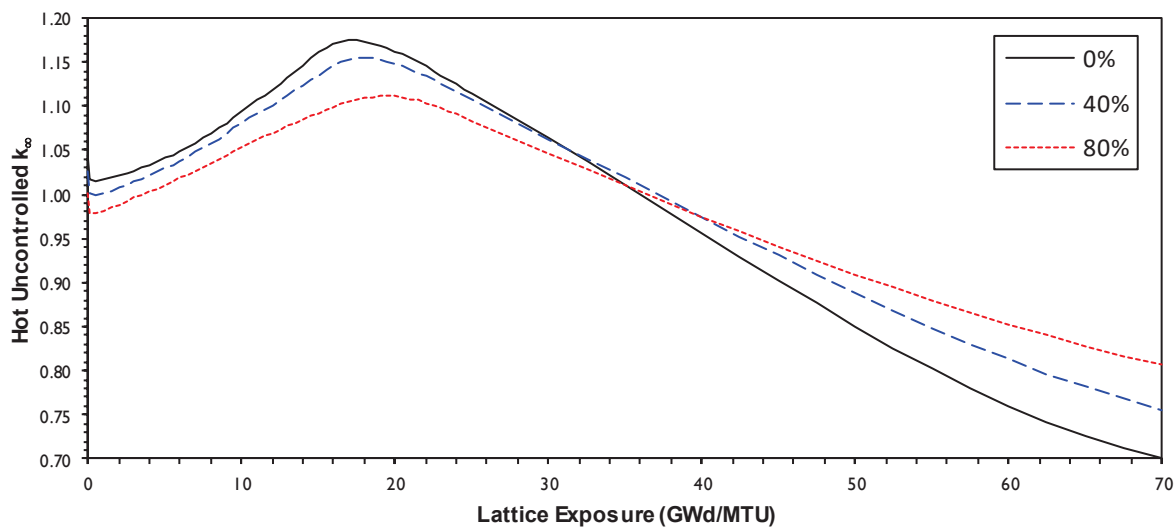
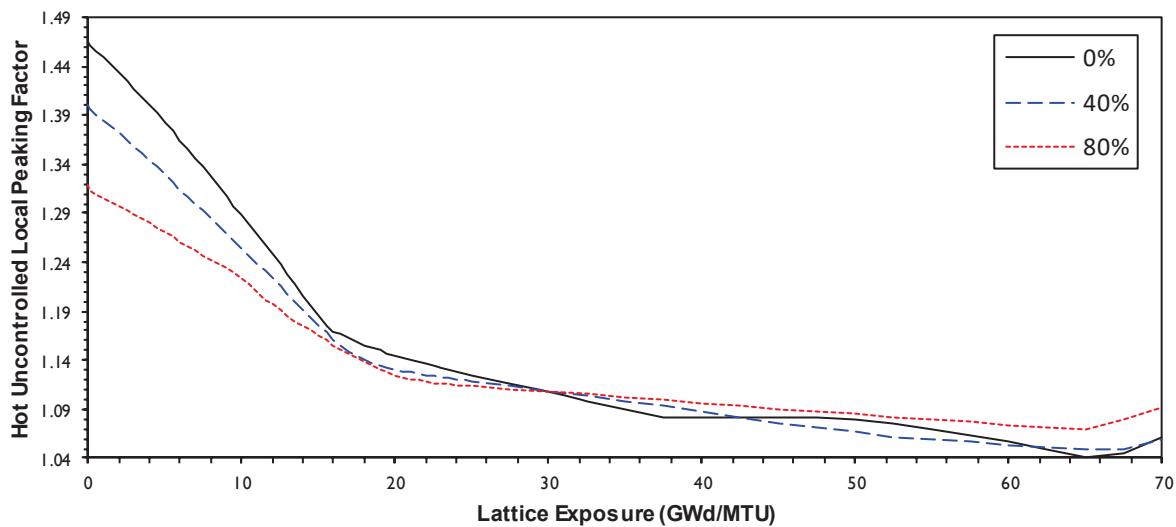
Figure A.9 [] Hot Uncontrolled k_{∞} 

Figure A.10 [] Hot Uncontrolled LPF

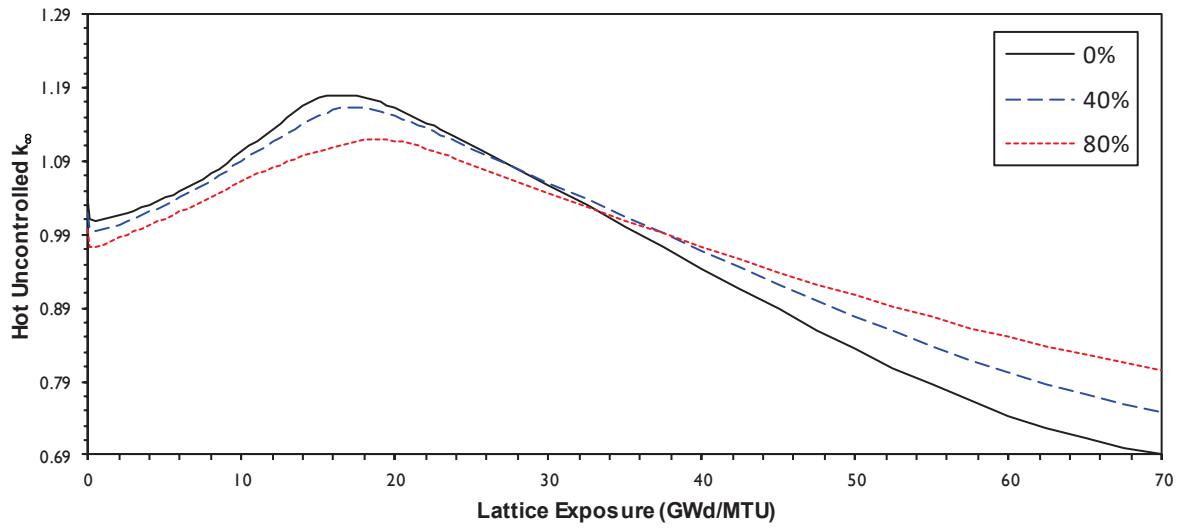


Figure A.11 [] Hot Uncontrolled k_{∞}

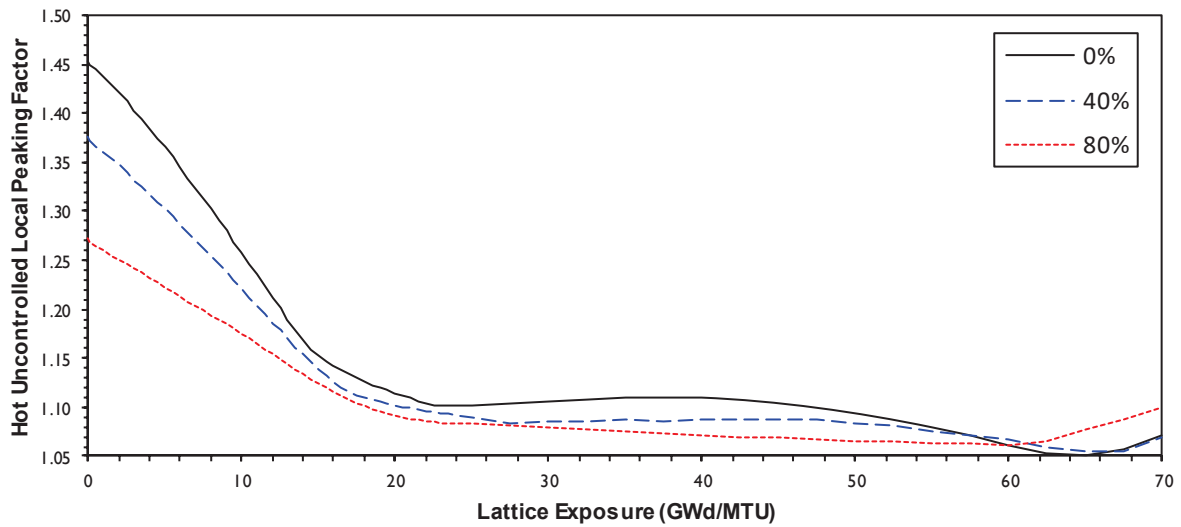


Figure A.12 [] Hot Uncontrolled LPF

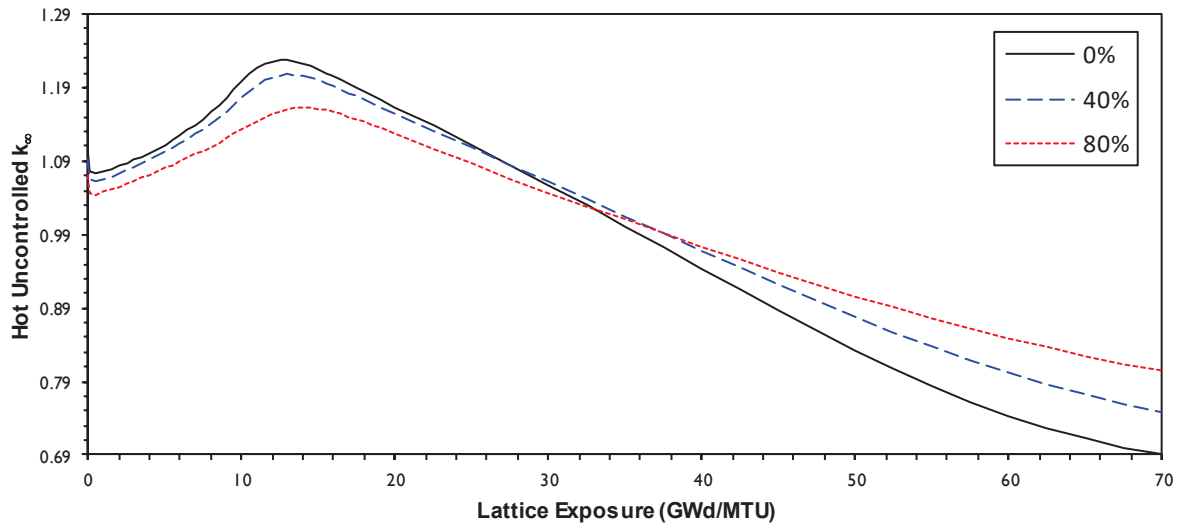


Figure A.13 [] Hot Uncontrolled k_{∞}

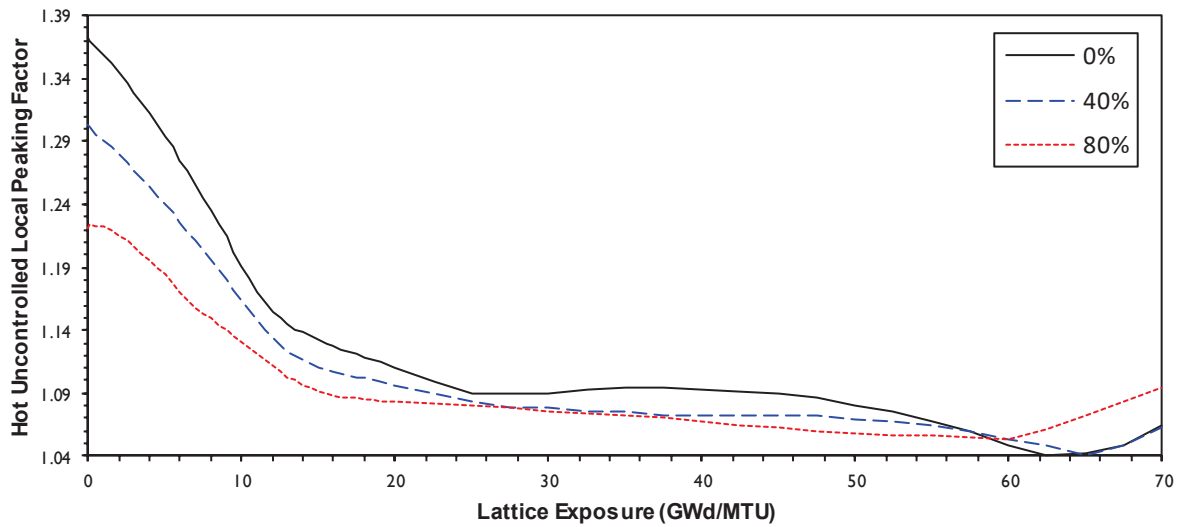


Figure A.14 [] Hot Uncontrolled LPF

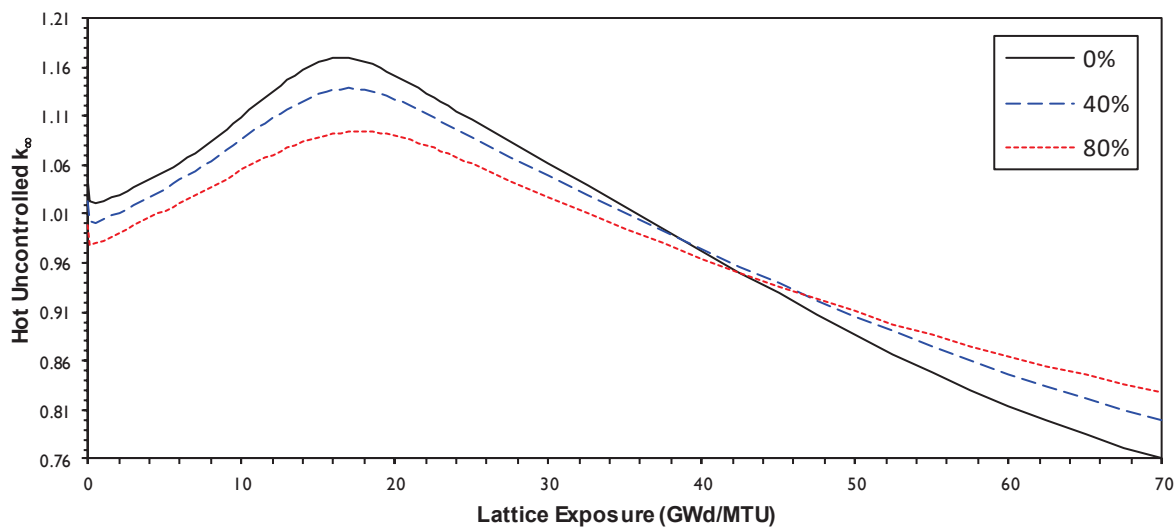
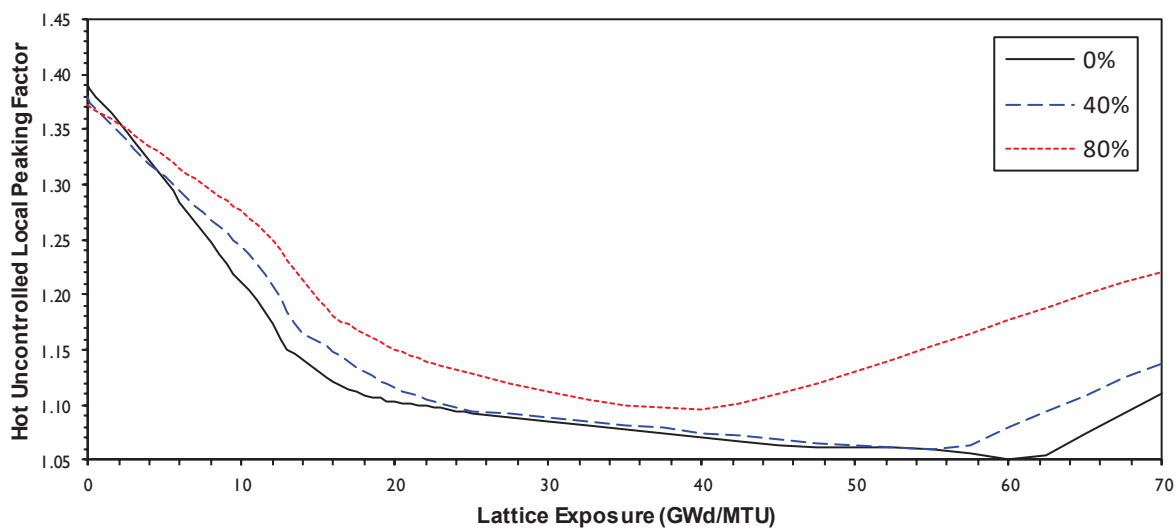
Figure A.15 [] Hot Uncontrolled k_{∞} 

Figure A.16 [] Hot Uncontrolled LPF

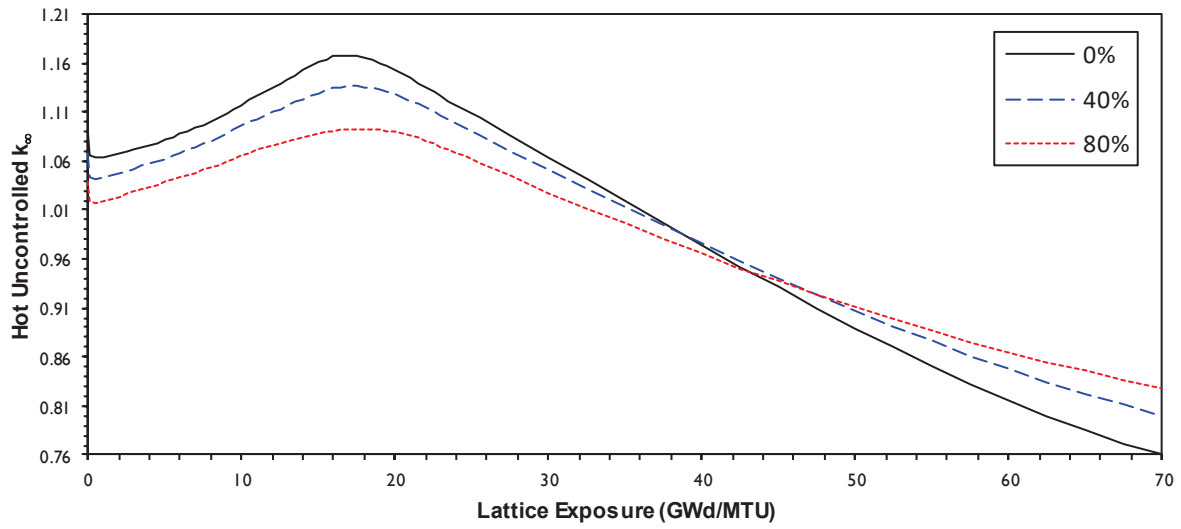


Figure A.17 [] Hot Uncontrolled k_{∞}

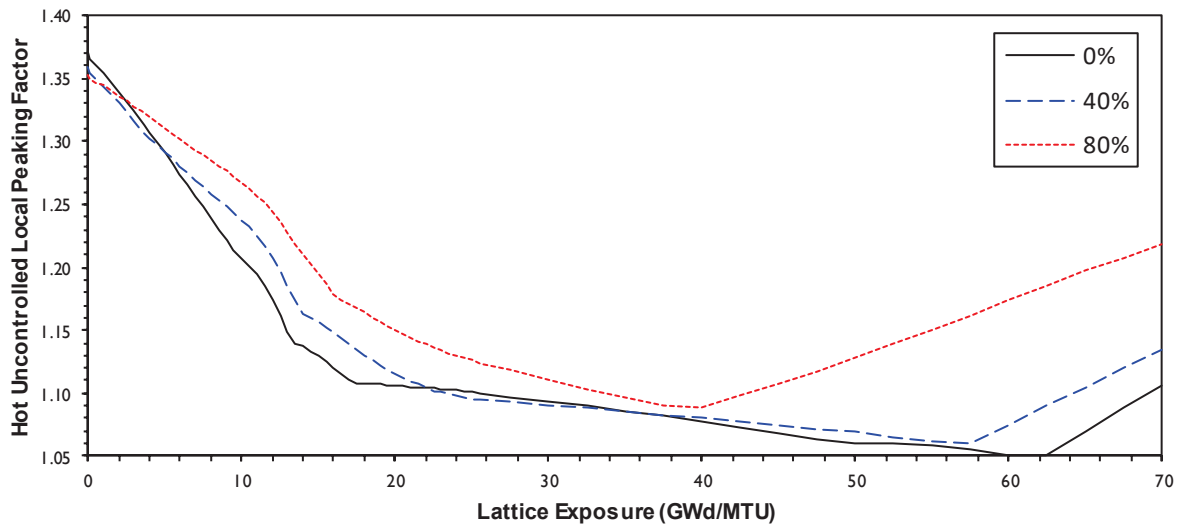


Figure A.18 [] Hot Uncontrolled LPF

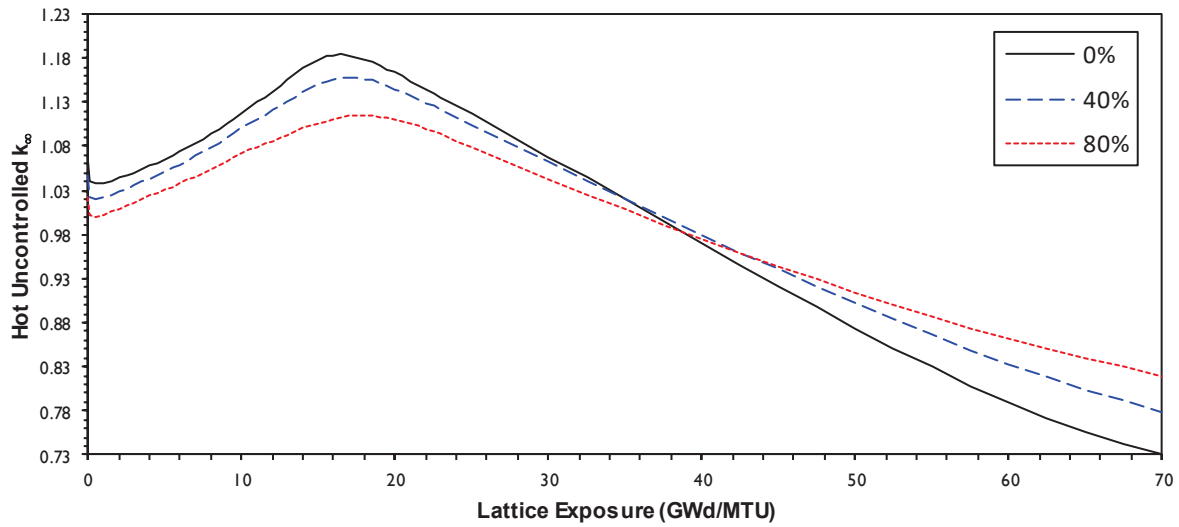


Figure A.19 [] Hot Uncontrolled k_{∞}

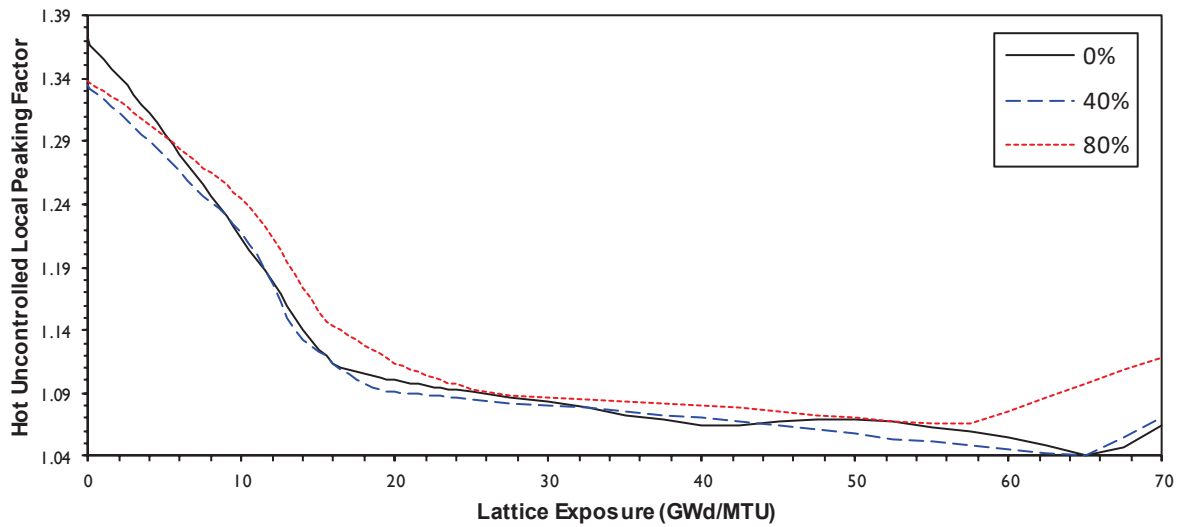


Figure A.20 [] Hot Uncontrolled LPF

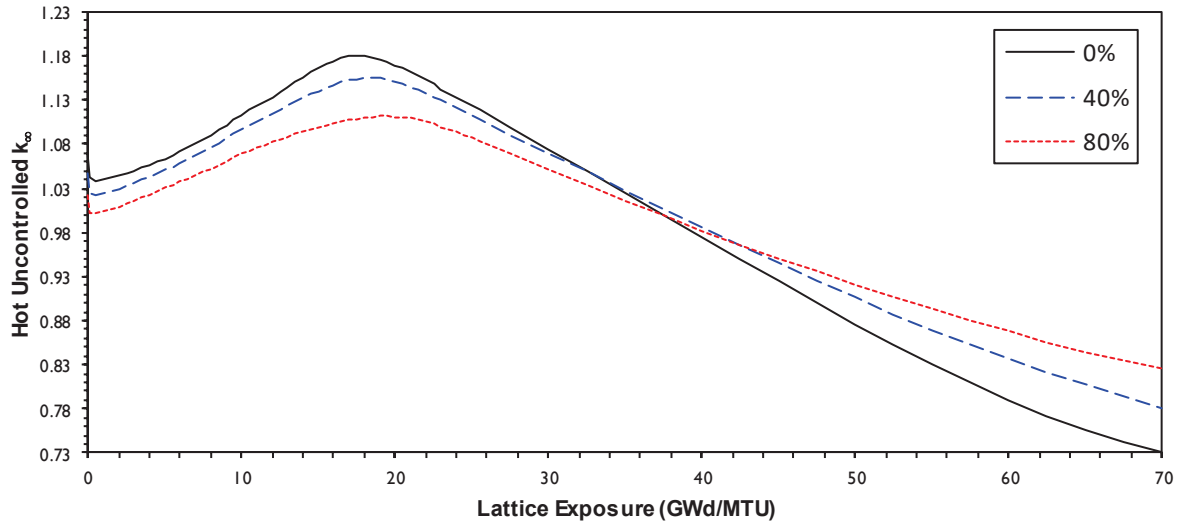


Figure A.21 [] Hot Uncontrolled k_{∞}

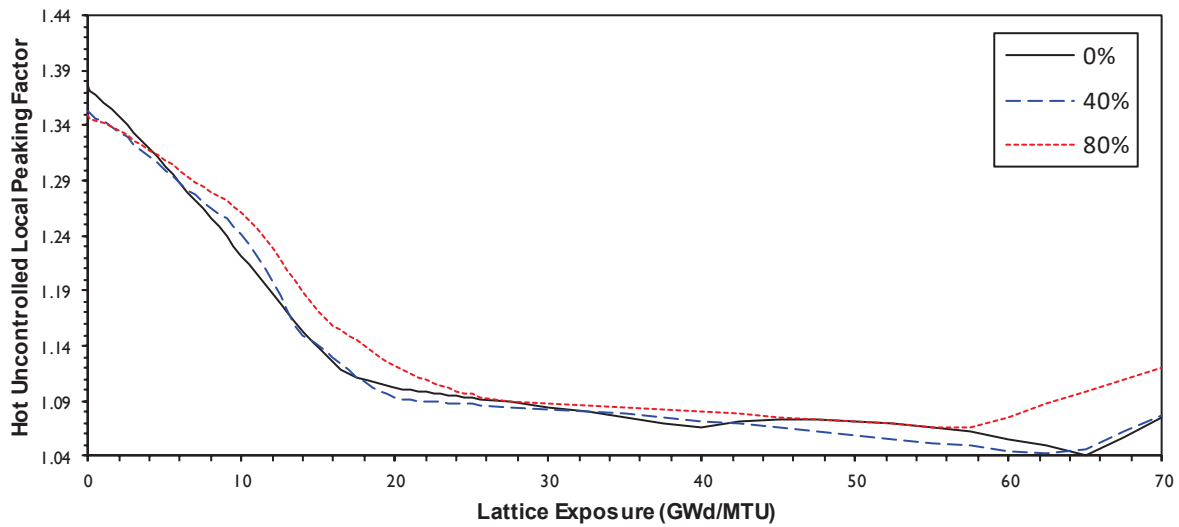


Figure A.22 [] Hot Uncontrolled LPF

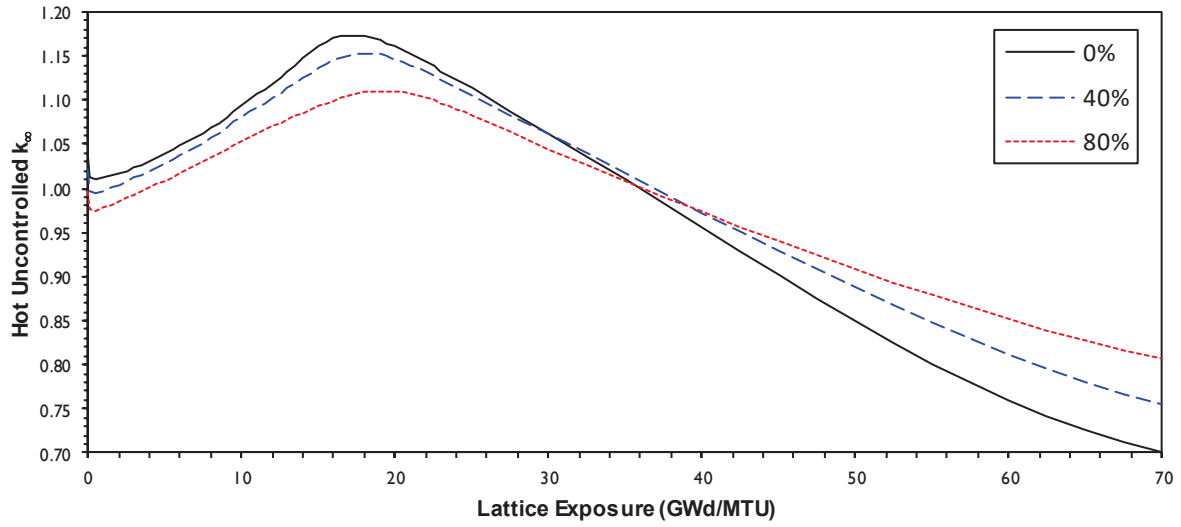


Figure A.23 [] Hot Uncontrolled k_{∞}

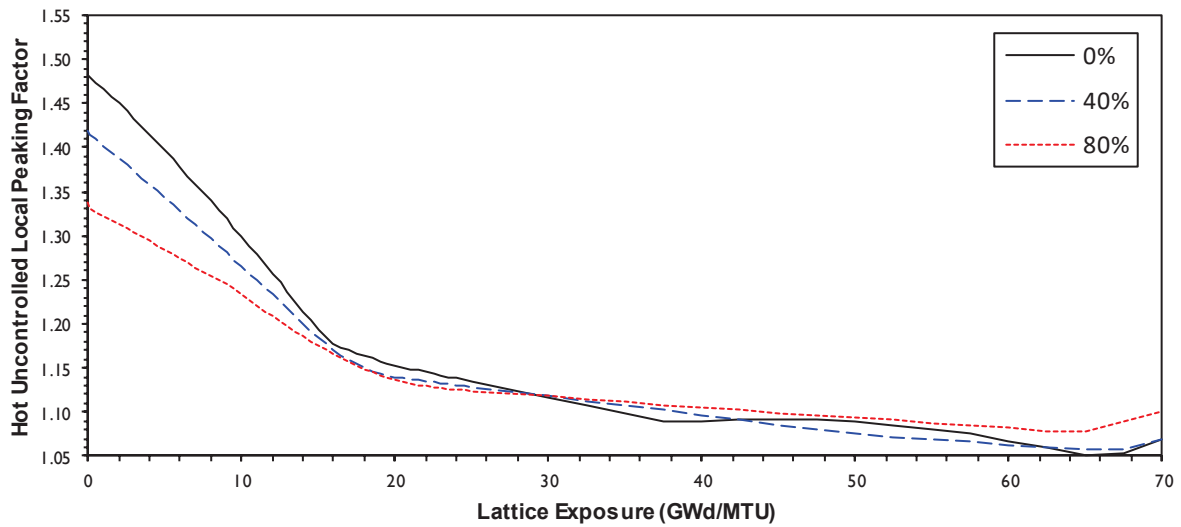


Figure A.24 [] Hot Uncontrolled LPF

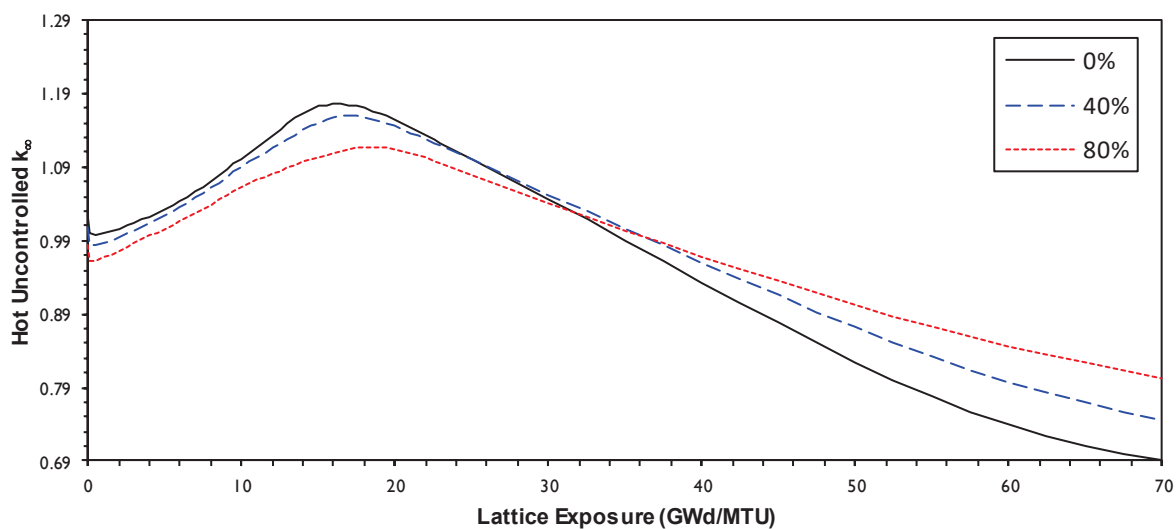


Figure A.25 [] Hot Uncontrolled k_{∞}

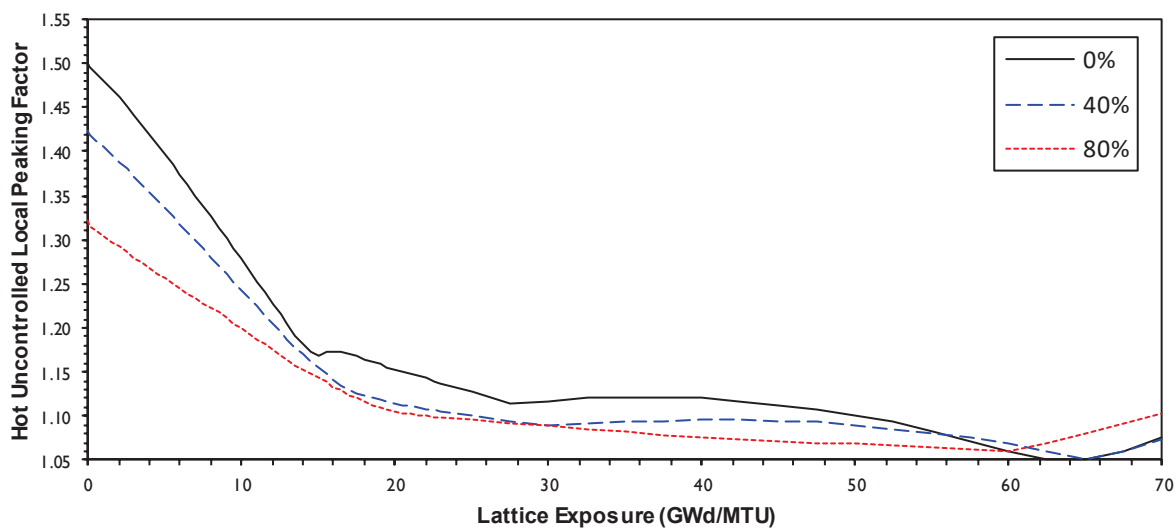


Figure A.26 [] Hot Uncontrolled LPF

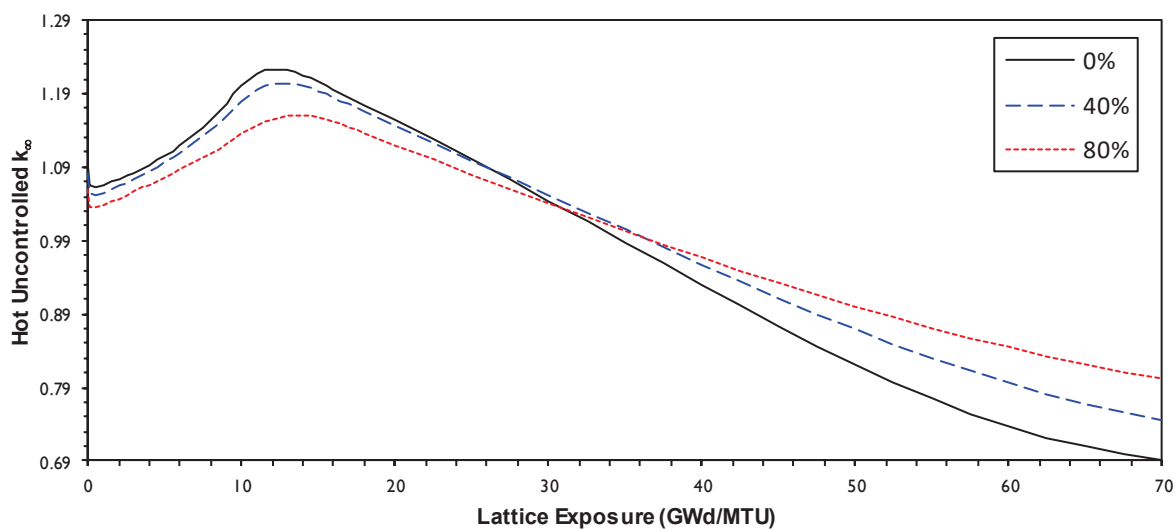
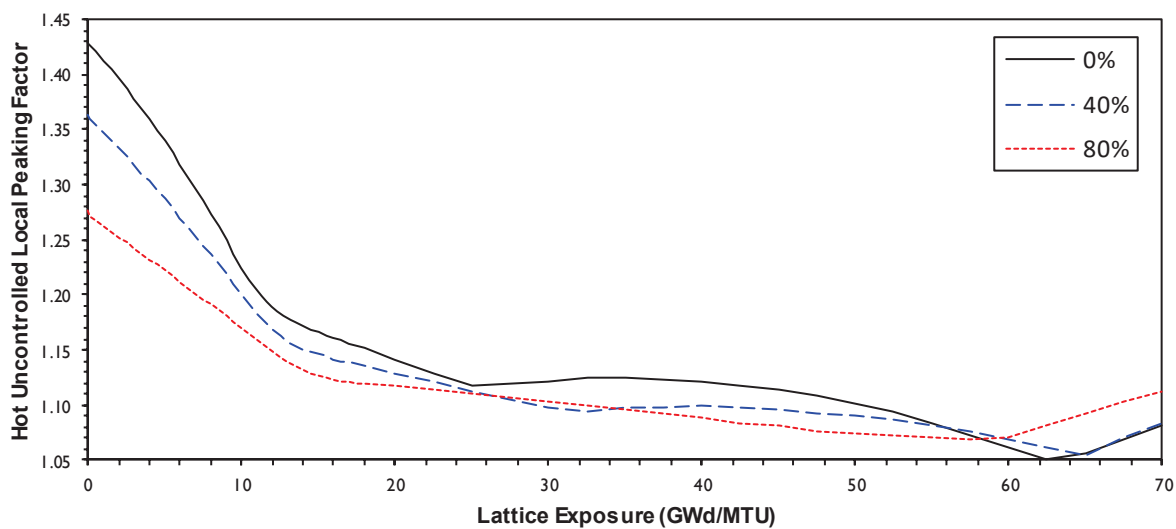
Figure A.27 [] Hot Uncontrolled k_{∞} 

Figure A.28 [] Hot Uncontrolled LPF

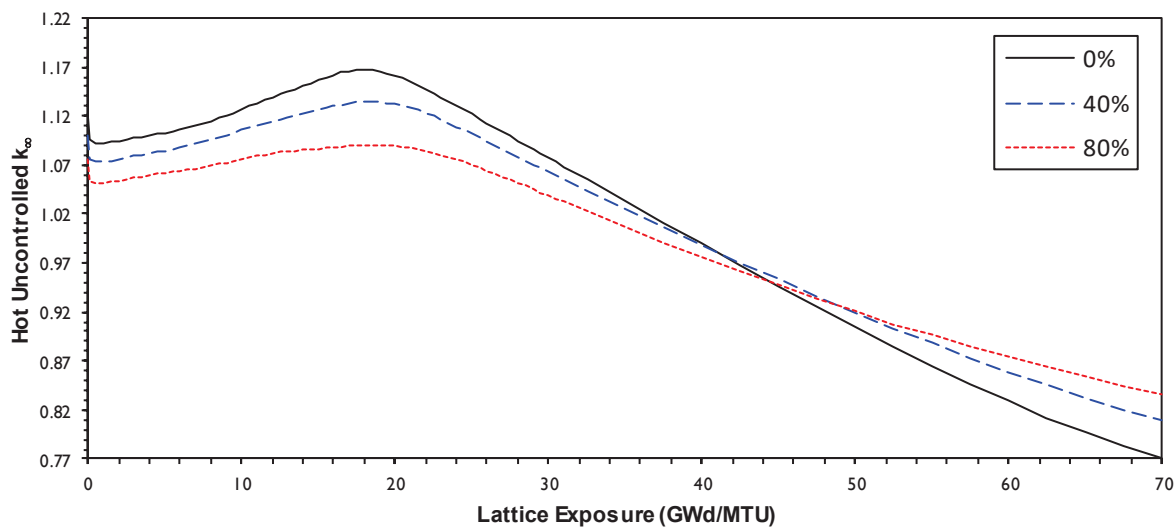
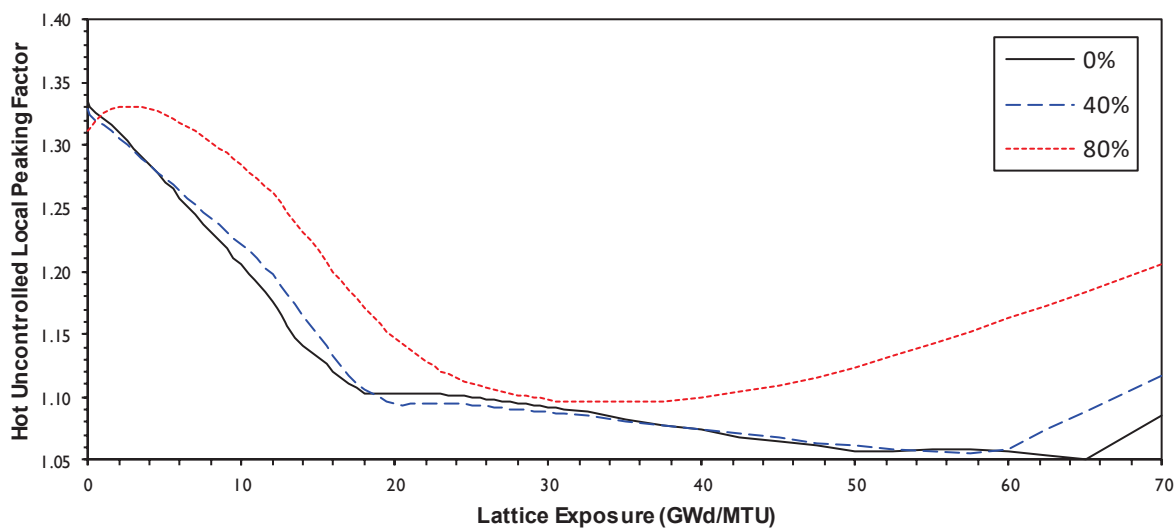
Figure A.29 [] Hot Uncontrolled k_{∞} 

Figure A.30 [] Hot Uncontrolled LPF

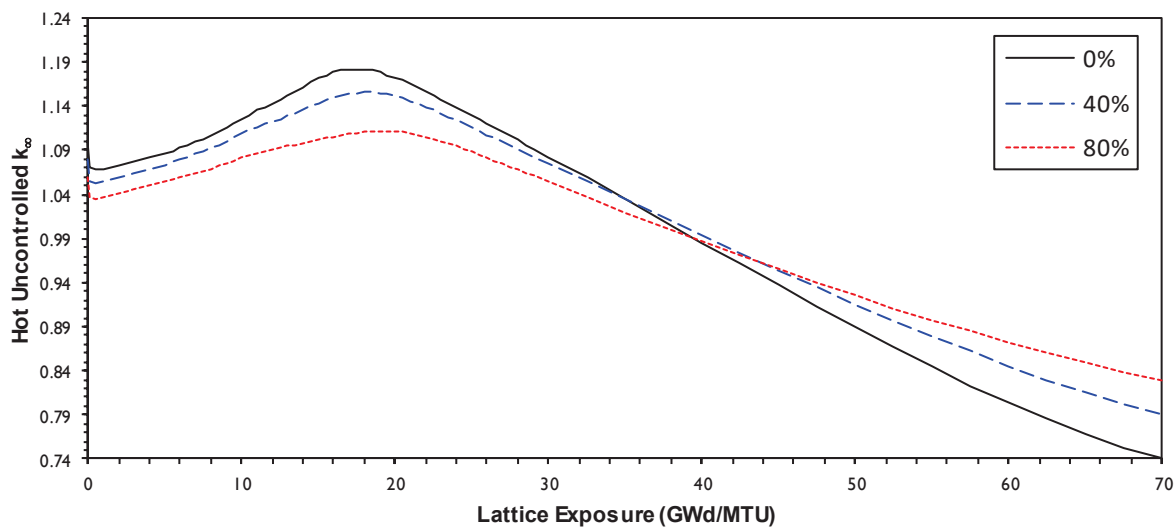
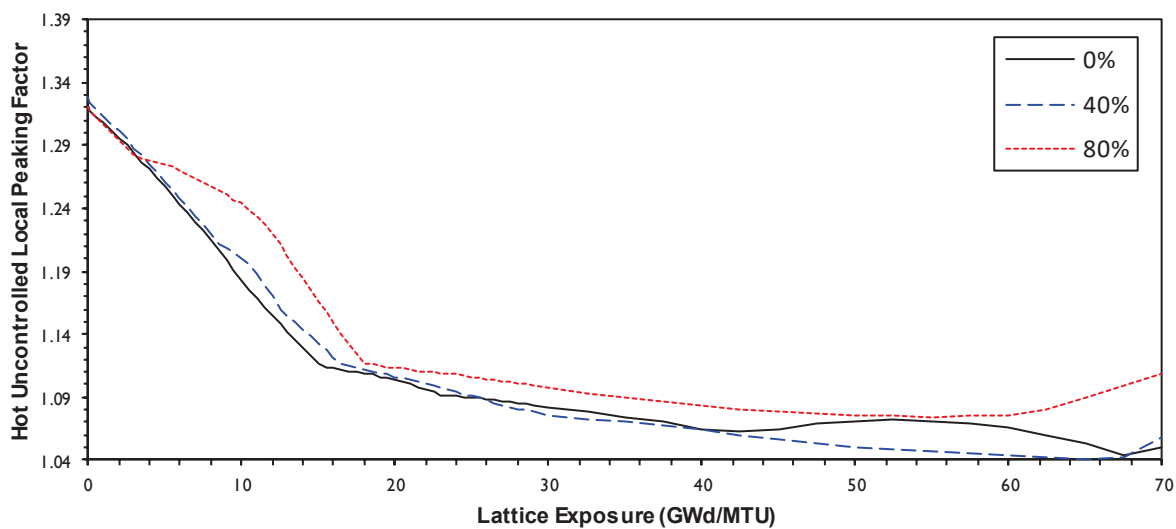
Figure A.31 [Hot Uncontrolled k_{∞}]

Figure A.32 [Hot Uncontrolled LPF]

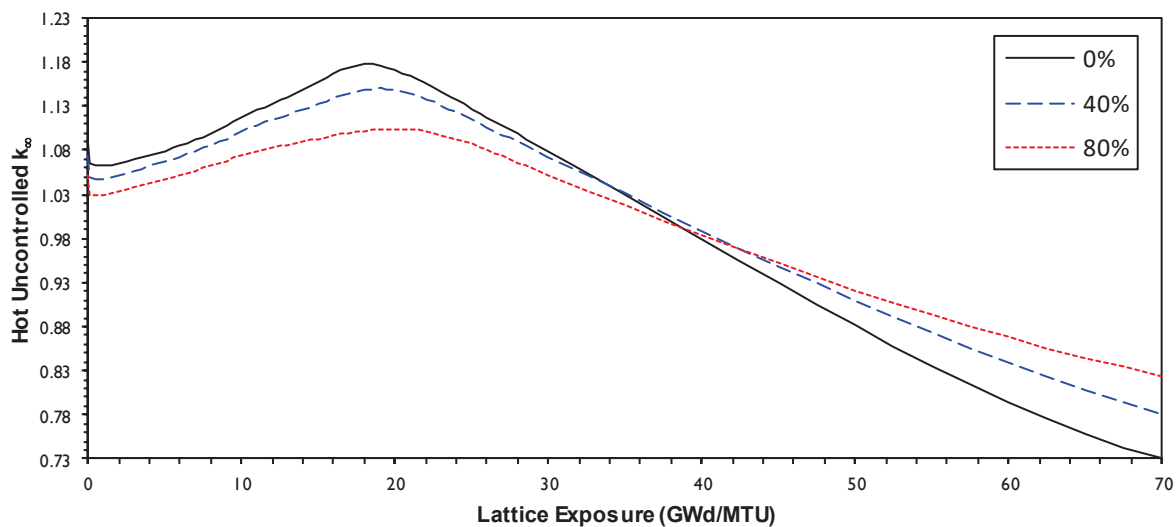
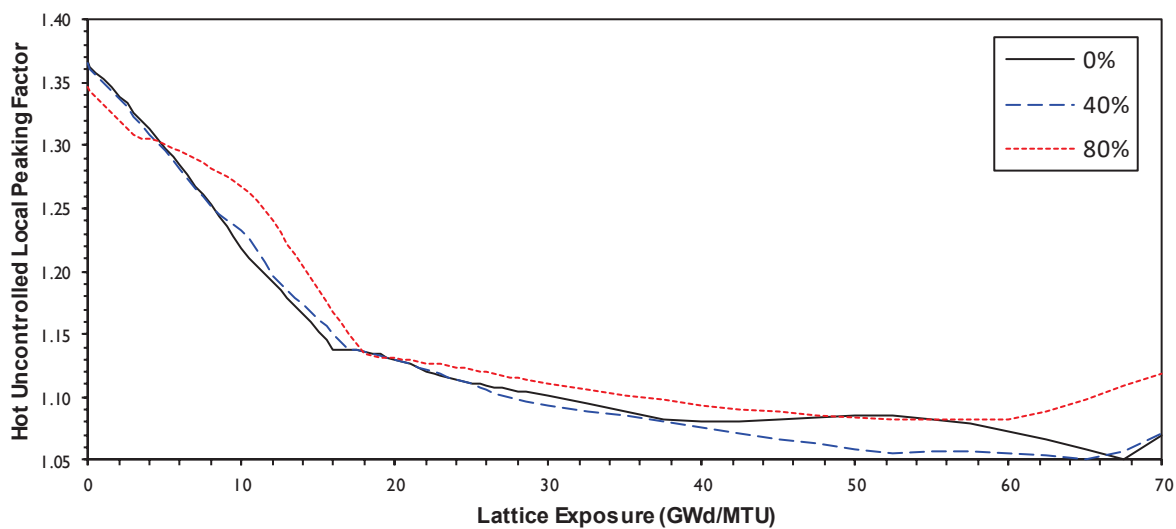
Figure A.33 [] Hot Uncontrolled k_{∞} 

Figure A.34 [] Hot Uncontrolled LPF

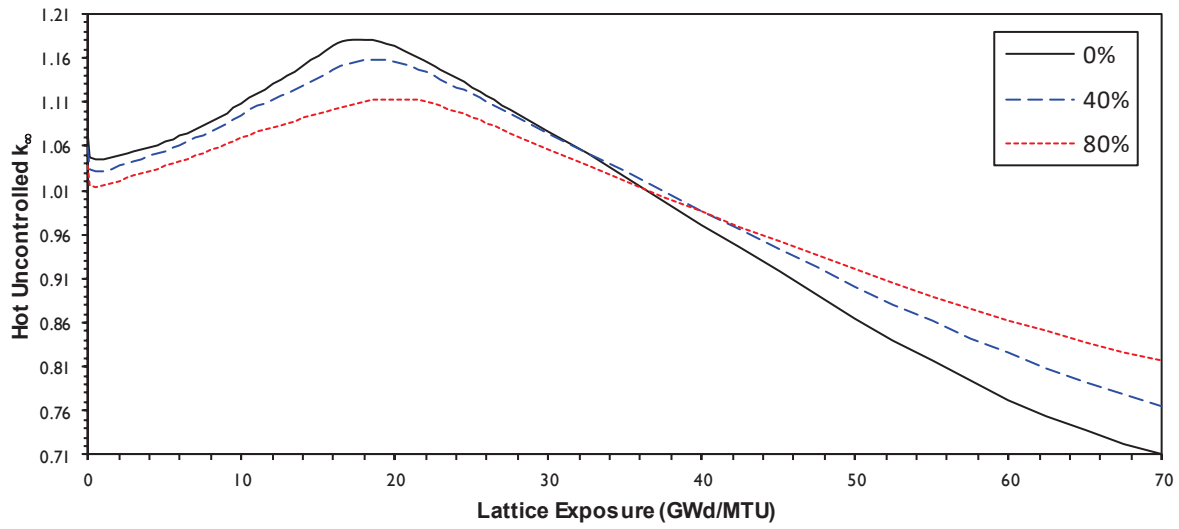


Figure A.35 [] Hot Uncontrolled k_{∞}

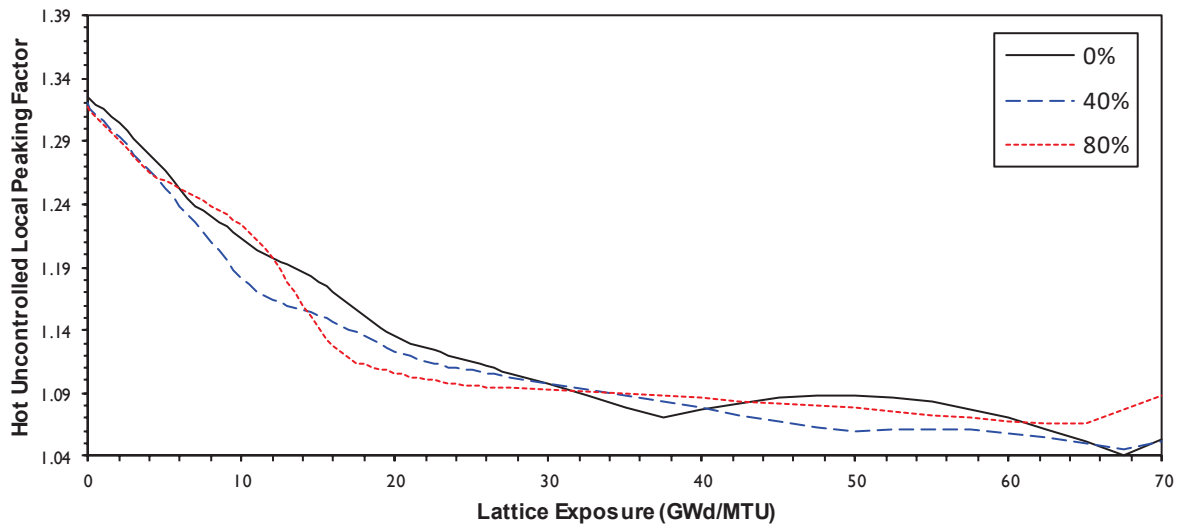


Figure A.36 [] Hot Uncontrolled LPF

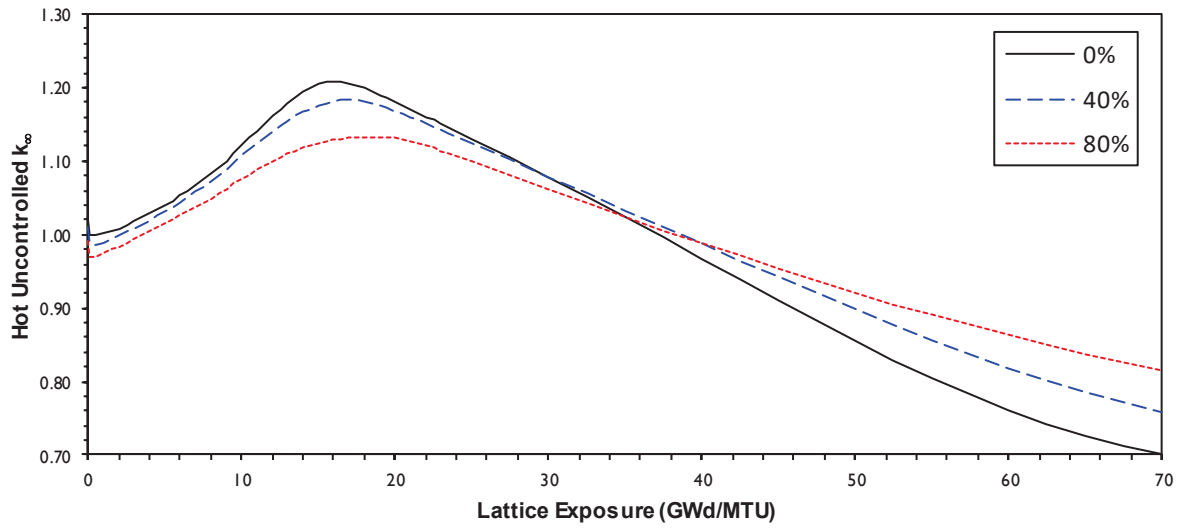


Figure A.37 [] Hot Uncontrolled k_{∞}

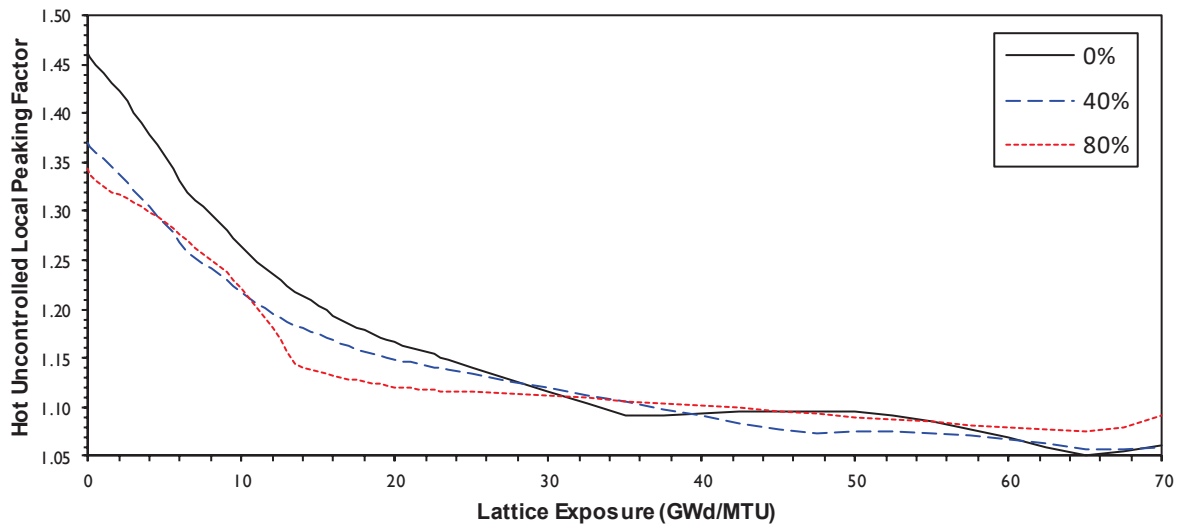


Figure A.38 [] Hot Uncontrolled LPF

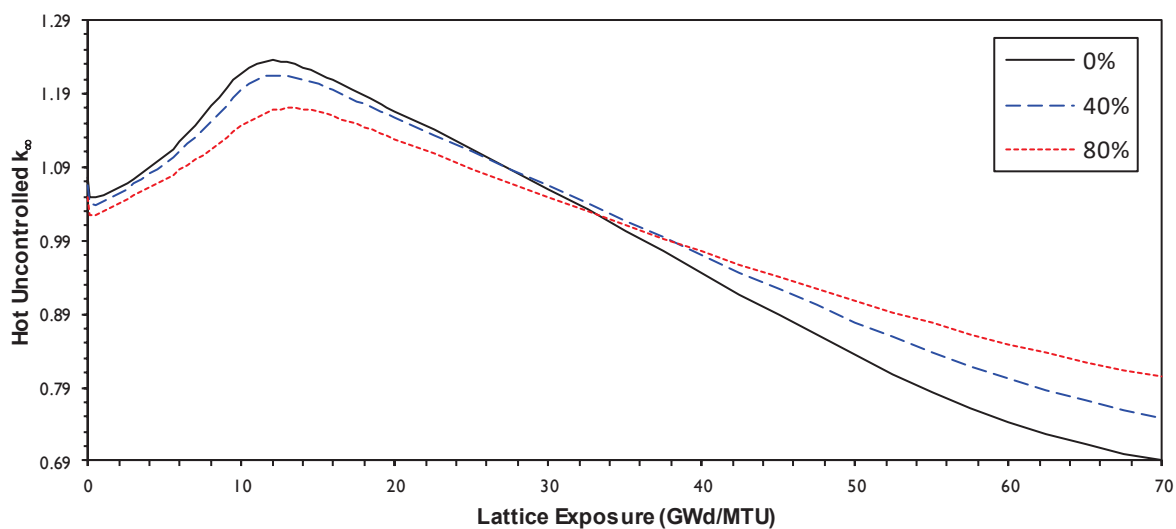


Figure A.39 [] Hot Uncontrolled k_{∞}

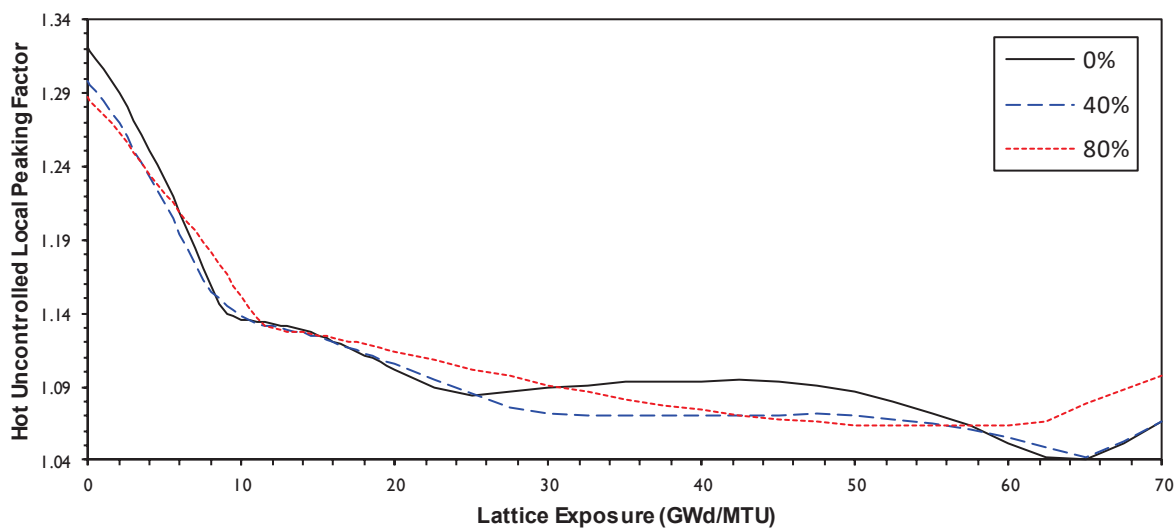


Figure A.40 [] Hot Uncontrolled LPF

Appendix B Enriched Lattice Hot Uncontrolled Reactivity and LPF Tables

The results in this appendix are based on hot operating and equilibrium xenon conditions.

Table B.1 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.05361	1.03109	1.00588
100.	1.02989	1.00933	0.98671
500.	1.02809	1.00849	0.98690
1000.	1.02994	1.01105	0.99002
1500.	1.03300	1.01461	0.99379
2000.	1.03638	1.01837	0.99763
2500.	1.03981	1.02213	1.00135
3000.	1.04330	1.02584	1.00494
3500.	1.04688	1.02956	1.00843
4000.	1.05060	1.03332	1.01187
4500.	1.05451	1.03719	1.01532
5000.	1.05863	1.04120	1.01879
5500.	1.06295	1.04533	1.02232
6000.	1.06747	1.04960	1.02592
6500.	1.07216	1.05400	1.02959
7000.	1.07706	1.05854	1.03333
7500.	1.08217	1.06322	1.03715
8000.	1.08754	1.06806	1.04108
8500.	1.09319	1.07310	1.04512
9000.	1.09915	1.07835	1.04928
9500.	1.10543	1.08378	1.05352
10000.	1.11195	1.08929	1.05775
10500.	1.11853	1.09475	1.06186
11000.	1.12499	1.10008	1.06581
11500.	1.13115	1.10516	1.06956
12000.	1.13693	1.10994	1.07310
12500.	1.14243	1.11448	1.07644
13000.	1.14776	1.11887	1.07962
13500.	1.15291	1.12311	1.08265
14000.	1.15782	1.12711	1.08553
14500.	1.16237	1.13078	1.08818
15000.	1.16637	1.13402	1.09055
15500.	1.16959	1.13674	1.09259
16000.	1.17181	1.13884	1.09425
16500.	1.17295	1.14026	1.09549
17000.	1.17303	1.14097	1.09631
17500.	1.17208	1.14099	1.09674
18000.	1.17022	1.14034	1.09678
18500.	1.16760	1.13905	1.09645
19000.	1.16440	1.13718	1.09573
19500.	1.16076	1.13480	1.09464
20000.	1.15680	1.13198	1.09319
20500.	1.15262	1.12880	1.09141
21000.	1.14830	1.12534	1.08933
21500.	1.14376	1.12168	1.08698
22000.	1.13923	1.11788	1.08439
22500.	1.13469	1.11398	1.08160
23000.	1.13019	1.10996	1.07864
23500.	1.12568	1.10594	1.07553
24000.	1.12118	1.10192	1.07231
24500.	1.11667	1.09790	1.06902
25000.	1.11217	1.09388	1.06567
25500.	1.10769	1.08992	1.06229
27500.	1.08977	1.07410	1.04858
30000.	1.06741	1.05460	1.03182
32500.	1.04510	1.03542	1.01547
35000.	1.02284	1.01654	0.99959
37500.	1.00066	0.99798	0.98417
40000.	0.97863	0.97976	0.96924
42500.	0.95681	0.96193	0.95479
45000.	0.93530	0.94451	0.94086
47500.	0.91422	0.92755	0.92746
50000.	0.89369	0.91111	0.91459
52500.	0.87384	0.89525	0.90228
55000.	0.85481	0.88001	0.89054
57500.	0.83672	0.86546	0.87936
60000.	0.81971	0.85163	0.86876
62500.	0.80387	0.83856	0.85874
65000.	0.78929	0.82629	0.84929
67500.	0.77601	0.81484	0.84041
70000.	0.76405	0.80422	0.83207

Table B.2 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.375	1.363	1.358
100.	1.370	1.358	1.356
500.	1.365	1.353	1.353
1000.	1.358	1.347	1.349
1500.	1.350	1.340	1.345
2000.	1.342	1.333	1.341
2500.	1.334	1.326	1.337
3000.	1.326	1.320	1.332
3500.	1.318	1.314	1.327
4000.	1.309	1.308	1.323
4500.	1.300	1.302	1.318
5000.	1.291	1.296	1.313
5500.	1.282	1.290	1.309
6000.	1.273	1.284	1.304
6500.	1.264	1.277	1.299
7000.	1.255	1.271	1.295
7500.	1.246	1.265	1.290
8000.	1.237	1.259	1.285
8500.	1.228	1.253	1.281
9000.	1.219	1.248	1.276
9500.	1.211	1.242	1.272
10000.	1.204	1.236	1.267
10500.	1.197	1.229	1.262
11000.	1.189	1.222	1.256
11500.	1.179	1.213	1.249
12000.	1.168	1.202	1.242
12500.	1.155	1.192	1.234
13000.	1.142	1.180	1.225
13500.	1.136	1.169	1.216
14000.	1.131	1.158	1.208
14500.	1.126	1.147	1.199
15000.	1.120	1.142	1.191
15500.	1.116	1.138	1.183
16000.	1.111	1.134	1.175
16500.	1.107	1.130	1.168
17000.	1.104	1.126	1.161
17500.	1.101	1.121	1.157
18000.	1.099	1.118	1.153
18500.	1.099	1.114	1.150
19000.	1.098	1.110	1.147
19500.	1.098	1.107	1.143
20000.	1.098	1.104	1.140
20500.	1.097	1.102	1.138
21000.	1.097	1.099	1.135
21500.	1.096	1.097	1.133
22000.	1.096	1.095	1.130
22500.	1.095	1.093	1.128
23000.	1.095	1.092	1.126
23500.	1.094	1.091	1.124
24000.	1.094	1.090	1.122
24500.	1.093	1.089	1.121
25000.	1.093	1.088	1.119
25500.	1.092	1.088	1.117
27500.	1.089	1.086	1.112
30000.	1.086	1.084	1.105
32500.	1.083	1.082	1.098
35000.	1.079	1.080	1.092
37500.	1.075	1.077	1.090
40000.	1.071	1.075	1.088
42500.	1.067	1.072	1.094
45000.	1.062	1.069	1.103
47500.	1.058	1.067	1.113
50000.	1.056	1.064	1.124
52500.	1.056	1.061	1.135
55000.	1.055	1.058	1.147
57500.	1.052	1.055	1.158
60000.	1.047	1.071	1.170
62500.	1.047	1.087	1.182
65000.	1.067	1.102	1.193
67500.	1.085	1.117	1.204
70000.	1.103	1.131	1.215

Table B.3 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.10131	1.07685	1.04868
100.	1.07540	1.05292	1.02741
500.	1.07233	1.05077	1.02625
1000.	1.07275	1.05187	1.02790
1500.	1.07439	1.05399	1.03027
2000.	1.07632	1.05632	1.03274
2500.	1.07833	1.05866	1.03512
3000.	1.08038	1.06097	1.03741
3500.	1.08251	1.06329	1.03962
4000.	1.08474	1.06564	1.04180
4500.	1.08709	1.06807	1.04397
5000.	1.08959	1.07059	1.04618
5500.	1.09224	1.07321	1.04842
6000.	1.09504	1.07592	1.05072
6500.	1.09798	1.07875	1.05307
7000.	1.10106	1.08169	1.05549
7500.	1.10430	1.08474	1.05799
8000.	1.10772	1.08792	1.06058
8500.	1.11134	1.09124	1.06327
9000.	1.11518	1.09472	1.06605
9500.	1.11926	1.09834	1.06889
10000.	1.12353	1.10203	1.07171
10500.	1.12783	1.10563	1.07440
11000.	1.13205	1.10909	1.07690
11500.	1.13614	1.11235	1.07921
12000.	1.14008	1.11544	1.08132
12500.	1.14401	1.11846	1.08331
13000.	1.14808	1.12153	1.08524
13500.	1.15236	1.12470	1.08719
14000.	1.15681	1.12797	1.08914
14500.	1.16123	1.13119	1.09108
15000.	1.16537	1.13424	1.09291
15500.	1.16895	1.13698	1.09457
16000.	1.17171	1.13926	1.09601
16500.	1.17347	1.14096	1.09717
17000.	1.17416	1.14199	1.09799
17500.	1.17378	1.14236	1.09846
18000.	1.17242	1.14204	1.09859
18500.	1.17023	1.14108	1.09836
19000.	1.16738	1.13952	1.09778
19500.	1.16402	1.13741	1.09684
20000.	1.16028	1.13483	1.09555
20500.	1.15627	1.13186	1.09391
21000.	1.15206	1.12857	1.09197
21500.	1.14773	1.12504	1.08976
22000.	1.14321	1.12133	1.08729
22500.	1.13869	1.11750	1.08461
23000.	1.13419	1.11360	1.08173
23500.	1.12968	1.10958	1.07870
24000.	1.12518	1.10556	1.07555
24500.	1.12067	1.10153	1.07230
25000.	1.11617	1.09751	1.06899
25500.	1.11170	1.09355	1.06563
26000.	1.10723	1.08960	1.06224
27500.	1.09382	1.07773	1.05195
30000.	1.07151	1.05825	1.03516
32500.	1.04924	1.03906	1.01877
35000.	1.02702	1.02018	1.00284
37500.	1.00488	1.00161	0.98738
40000.	0.98286	0.98337	0.97239
42500.	0.96105	0.96550	0.95788
45000.	0.93953	0.94804	0.94388
47500.	0.91841	0.93104	0.93040
50000.	0.89781	0.91453	0.91745
52500.	0.87786	0.89859	0.90506
55000.	0.85869	0.88326	0.89323
57500.	0.84045	0.86860	0.88197
60000.	0.82325	0.85465	0.87127
62500.	0.80720	0.84145	0.86115
65000.	0.79238	0.82905	0.85161
67500.	0.77887	0.81746	0.84263
70000.	0.76666	0.80669	0.83420

Table B.4 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.357	1.345	1.339
100.	1.352	1.340	1.337
500.	1.347	1.335	1.334
1000.	1.341	1.330	1.331
1500.	1.334	1.324	1.328
2000.	1.327	1.317	1.324
2500.	1.319	1.311	1.320
3000.	1.311	1.304	1.316
3500.	1.304	1.297	1.312
4000.	1.296	1.292	1.308
4500.	1.288	1.287	1.304
5000.	1.280	1.281	1.300
5500.	1.271	1.276	1.296
6000.	1.263	1.271	1.292
6500.	1.255	1.265	1.288
7000.	1.246	1.260	1.283
7500.	1.238	1.255	1.279
8000.	1.229	1.249	1.275
8500.	1.221	1.244	1.271
9000.	1.213	1.240	1.267
9500.	1.205	1.235	1.263
10000.	1.200	1.230	1.259
10500.	1.194	1.224	1.255
11000.	1.187	1.217	1.250
11500.	1.178	1.209	1.243
12000.	1.168	1.200	1.236
12500.	1.156	1.190	1.229
13000.	1.144	1.180	1.221
13500.	1.131	1.169	1.213
14000.	1.118	1.158	1.204
14500.	1.114	1.147	1.196
15000.	1.111	1.139	1.188
15500.	1.107	1.136	1.180
16000.	1.103	1.132	1.172
16500.	1.100	1.128	1.165
17000.	1.098	1.124	1.158
17500.	1.098	1.120	1.154
18000.	1.097	1.116	1.151
18500.	1.097	1.113	1.148
19000.	1.096	1.109	1.145
19500.	1.096	1.106	1.141
20000.	1.096	1.103	1.138
20500.	1.096	1.100	1.136
21000.	1.095	1.098	1.133
21500.	1.095	1.095	1.130
22000.	1.095	1.093	1.128
22500.	1.094	1.091	1.126
23000.	1.093	1.089	1.124
23500.	1.093	1.088	1.122
24000.	1.092	1.087	1.120
24500.	1.092	1.087	1.118
25000.	1.091	1.086	1.117
25500.	1.090	1.086	1.115
26000.	1.090	1.085	1.113
27500.	1.088	1.084	1.109
30000.	1.084	1.082	1.102
32500.	1.081	1.080	1.096
35000.	1.077	1.077	1.090
37500.	1.074	1.075	1.085
40000.	1.069	1.073	1.082
42500.	1.065	1.070	1.090
45000.	1.061	1.068	1.100
47500.	1.057	1.065	1.110
50000.	1.053	1.062	1.120
52500.	1.054	1.059	1.131
55000.	1.053	1.056	1.143
57500.	1.051	1.054	1.155
60000.	1.047	1.067	1.166
62500.	1.042	1.082	1.178
65000.	1.062	1.098	1.190
67500.	1.081	1.113	1.201
70000.	1.098	1.127	1.212

Table B.5 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.07128	1.05132	1.02705
100.	1.04540	1.02725	1.00552
500.	1.04260	1.02537	1.00464
1000.	1.04347	1.02697	1.00684
1500.	1.04573	1.02979	1.00996
2000.	1.04841	1.03294	1.01329
2500.	1.05125	1.03619	1.01661
3000.	1.05425	1.03950	1.01989
3500.	1.05740	1.04290	1.02315
4000.	1.06075	1.04641	1.02642
4500.	1.06431	1.05007	1.02975
5000.	1.06810	1.05388	1.03315
5500.	1.07210	1.05785	1.03662
6000.	1.07629	1.06198	1.04017
6500.	1.08068	1.06625	1.04380
7000.	1.08528	1.07069	1.04755
7500.	1.09012	1.07530	1.05141
8000.	1.09523	1.08011	1.05541
8500.	1.10065	1.08514	1.05954
9000.	1.10640	1.09039	1.06379
9500.	1.11243	1.09577	1.06805
10000.	1.11853	1.10106	1.07217
10500.	1.12457	1.10617	1.07607
11000.	1.13043	1.11103	1.07972
11500.	1.13614	1.11567	1.08312
12000.	1.14189	1.12028	1.08638
12500.	1.14789	1.12502	1.08962
13000.	1.15423	1.12999	1.09290
13500.	1.16078	1.13509	1.09624
14000.	1.16719	1.14014	1.09955
14500.	1.17310	1.14498	1.10274
15000.	1.17808	1.14936	1.10573
15500.	1.18177	1.15304	1.10842
16000.	1.18402	1.15581	1.11071
16500.	1.18484	1.15764	1.11254
17000.	1.18439	1.15855	1.11391
17500.	1.18288	1.15853	1.11481
18000.	1.18055	1.15764	1.11522
18500.	1.17761	1.15595	1.11512
19000.	1.17419	1.15362	1.11450
19500.	1.17039	1.15076	1.11339
20000.	1.16628	1.14750	1.11182
20500.	1.16195	1.14393	1.10983
21000.	1.15746	1.14014	1.10748
21500.	1.15272	1.13618	1.10480
22000.	1.14797	1.13211	1.10186
22500.	1.14323	1.12790	1.09870
23000.	1.13849	1.12365	1.09538
23500.	1.13375	1.11940	1.09194
24000.	1.12900	1.11516	1.08841
24500.	1.12426	1.11091	1.08484
25000.	1.11952	1.10666	1.08118
27500.	1.09576	1.08570	1.06296
30000.	1.07179	1.06486	1.04513
32500.	1.04763	1.04414	1.02765
35000.	1.02327	1.02355	1.01053
37500.	0.99877	1.00310	0.99378
40000.	0.97418	0.98284	0.97741
42500.	0.94960	0.96281	0.96145
45000.	0.92518	0.94307	0.94593
47500.	0.90107	0.92369	0.93088
50000.	0.87747	0.90476	0.91633
52500.	0.85459	0.88639	0.90233
55000.	0.83265	0.86866	0.88888
57500.	0.81188	0.85169	0.87602
60000.	0.79247	0.83555	0.86377
62500.	0.77462	0.82034	0.85215
65000.	0.75843	0.80613	0.84117
67500.	0.74399	0.79296	0.83085
70000.	0.73127	0.78087	0.82117

Table B.6 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.364	1.326	1.329
100.	1.359	1.324	1.327
500.	1.354	1.320	1.324
1000.	1.348	1.316	1.322
1500.	1.341	1.311	1.318
2000.	1.334	1.306	1.314
2500.	1.327	1.301	1.310
3000.	1.320	1.295	1.306
3500.	1.313	1.290	1.302
4000.	1.306	1.284	1.297
4500.	1.298	1.279	1.293
5000.	1.291	1.273	1.288
5500.	1.283	1.267	1.284
6000.	1.275	1.261	1.279
6500.	1.267	1.255	1.274
7000.	1.259	1.249	1.270
7500.	1.251	1.243	1.265
8000.	1.243	1.238	1.261
8500.	1.235	1.232	1.256
9000.	1.227	1.227	1.252
9500.	1.219	1.222	1.247
10000.	1.210	1.215	1.242
10500.	1.202	1.208	1.236
11000.	1.193	1.199	1.229
11500.	1.185	1.188	1.221
12000.	1.176	1.176	1.212
12500.	1.167	1.164	1.203
13000.	1.158	1.154	1.194
13500.	1.149	1.150	1.191
14000.	1.140	1.145	1.187
14500.	1.132	1.141	1.183
15000.	1.124	1.135	1.179
15500.	1.118	1.130	1.175
16000.	1.112	1.124	1.170
16500.	1.107	1.118	1.165
17000.	1.104	1.112	1.161
17500.	1.102	1.106	1.156
18000.	1.101	1.101	1.151
18500.	1.099	1.097	1.146
19000.	1.098	1.093	1.142
19500.	1.096	1.089	1.138
20000.	1.095	1.088	1.135
20500.	1.094	1.087	1.131
21000.	1.093	1.086	1.128
21500.	1.092	1.085	1.125
22000.	1.092	1.085	1.122
22500.	1.091	1.084	1.120
23000.	1.090	1.084	1.118
23500.	1.089	1.083	1.115
24000.	1.089	1.083	1.113
24500.	1.088	1.082	1.111
25000.	1.087	1.082	1.109
27500.	1.085	1.079	1.100
30000.	1.085	1.076	1.092
32500.	1.084	1.074	1.084
35000.	1.082	1.072	1.081
37500.	1.080	1.070	1.080
40000.	1.076	1.068	1.078
42500.	1.072	1.066	1.076
45000.	1.067	1.063	1.074
47500.	1.068	1.060	1.072
50000.	1.068	1.057	1.070
52500.	1.067	1.054	1.068
55000.	1.064	1.051	1.069
57500.	1.059	1.048	1.073
60000.	1.054	1.045	1.077
62500.	1.049	1.042	1.085
65000.	1.042	1.040	1.096
67500.	1.044	1.054	1.107
70000.	1.062	1.069	1.117

Table B.7 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.06997	1.04983	1.02478
100.	1.04391	1.02557	1.00310
500.	1.04089	1.02351	1.00209
1000.	1.04148	1.02491	1.00414
1500.	1.04345	1.02752	1.00711
2000.	1.04583	1.03046	1.01028
2500.	1.04837	1.03351	1.01346
3000.	1.05108	1.03663	1.01662
3500.	1.05397	1.03985	1.01978
4000.	1.05707	1.04321	1.02298
4500.	1.06033	1.04669	1.02622
5000.	1.06377	1.05027	1.02951
5500.	1.06738	1.05397	1.03283
6000.	1.07120	1.05780	1.03620
6500.	1.07523	1.06180	1.03965
7000.	1.07949	1.06597	1.04320
7500.	1.08403	1.07036	1.04688
8000.	1.08888	1.07499	1.05072
8500.	1.09407	1.07989	1.05471
9000.	1.09961	1.08500	1.05883
9500.	1.10528	1.09008	1.06290
10000.	1.11086	1.09497	1.06675
10500.	1.11619	1.09957	1.07034
11000.	1.12118	1.10384	1.07363
11500.	1.12599	1.10794	1.07669
12000.	1.13091	1.11207	1.07963
12500.	1.13614	1.11636	1.08256
13000.	1.14172	1.12083	1.08555
13500.	1.14750	1.12534	1.08857
14000.	1.15332	1.12980	1.09154
14500.	1.15903	1.13414	1.09437
15000.	1.16436	1.13822	1.09704
15500.	1.16908	1.14196	1.09952
16000.	1.17299	1.14535	1.10176
16500.	1.17599	1.14829	1.10374
17000.	1.17803	1.15070	1.10547
17500.	1.17900	1.15249	1.10694
18000.	1.17879	1.15361	1.10816
18500.	1.17748	1.15394	1.10910
19000.	1.17529	1.15341	1.10970
19500.	1.17243	1.15204	1.10989
20000.	1.16904	1.14993	1.10962
20500.	1.16523	1.14723	1.10887
21000.	1.16107	1.14407	1.10764
21500.	1.15666	1.14054	1.10597
22000.	1.15189	1.13675	1.10390
22500.	1.14711	1.13276	1.10146
23000.	1.14225	1.12865	1.09871
23500.	1.13739	1.12432	1.09569
24000.	1.13253	1.11999	1.09246
24500.	1.12767	1.11566	1.08907
25000.	1.12281	1.11133	1.08558
25500.	1.11794	1.10705	1.08202
27500.	1.09845	1.08993	1.06733
30000.	1.07387	1.06866	1.04929
32500.	1.04907	1.04750	1.03160
35000.	1.02405	1.02646	1.01426
37500.	0.99887	1.00554	0.99730
40000.	0.97360	0.98481	0.98072
42500.	0.94836	0.96430	0.96456
45000.	0.92328	0.94408	0.94884
47500.	0.89857	0.92425	0.93360
50000.	0.87442	0.90489	0.91888
52500.	0.85107	0.88611	0.90470
55000.	0.82876	0.86802	0.89109
57500.	0.80774	0.85072	0.87807
60000.	0.78820	0.83432	0.86568
62500.	0.77034	0.81891	0.85393
65000.	0.75426	0.80455	0.84285
67500.	0.74003	0.79129	0.83243
70000.	0.72760	0.77918	0.82268

Table B.8 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.370	1.347	1.342
100.	1.366	1.345	1.341
500.	1.361	1.342	1.339
1000.	1.355	1.338	1.337
1500.	1.349	1.334	1.334
2000.	1.343	1.329	1.330
2500.	1.336	1.324	1.327
3000.	1.329	1.319	1.323
3500.	1.322	1.314	1.319
4000.	1.315	1.308	1.314
4500.	1.308	1.303	1.310
5000.	1.300	1.297	1.305
5500.	1.293	1.292	1.301
6000.	1.285	1.286	1.296
6500.	1.278	1.280	1.292
7000.	1.270	1.275	1.287
7500.	1.262	1.269	1.283
8000.	1.255	1.264	1.279
8500.	1.247	1.259	1.274
9000.	1.239	1.254	1.270
9500.	1.230	1.249	1.266
10000.	1.222	1.242	1.260
10500.	1.214	1.233	1.254
11000.	1.206	1.223	1.246
11500.	1.197	1.211	1.238
12000.	1.189	1.199	1.229
12500.	1.180	1.187	1.219
13000.	1.172	1.183	1.214
13500.	1.163	1.178	1.210
14000.	1.154	1.173	1.207
14500.	1.146	1.167	1.202
15000.	1.139	1.161	1.198
15500.	1.132	1.154	1.193
16000.	1.125	1.146	1.188
16500.	1.119	1.139	1.183
17000.	1.114	1.131	1.177
17500.	1.112	1.124	1.172
18000.	1.110	1.117	1.166
18500.	1.108	1.110	1.161
19000.	1.106	1.105	1.155
19500.	1.105	1.099	1.150
20000.	1.103	1.094	1.146
20500.	1.104	1.092	1.141
21000.	1.105	1.091	1.137
21500.	1.106	1.091	1.133
22000.	1.106	1.091	1.130
22500.	1.106	1.091	1.127
23000.	1.106	1.091	1.124
23500.	1.106	1.091	1.121
24000.	1.106	1.090	1.118
24500.	1.106	1.090	1.116
25000.	1.106	1.090	1.113
25500.	1.106	1.090	1.111
27500.	1.104	1.089	1.103
30000.	1.102	1.086	1.094
32500.	1.099	1.083	1.087
35000.	1.095	1.080	1.085
37500.	1.090	1.076	1.083
40000.	1.084	1.073	1.081
42500.	1.078	1.070	1.079
45000.	1.074	1.067	1.077
47500.	1.075	1.064	1.075
50000.	1.074	1.060	1.072
52500.	1.071	1.057	1.070
55000.	1.067	1.054	1.069
57500.	1.063	1.050	1.073
60000.	1.056	1.047	1.078
62500.	1.049	1.044	1.089
65000.	1.041	1.047	1.100
67500.	1.058	1.063	1.111
70000.	1.076	1.078	1.121

Table B.9 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.04533	1.02698	1.00264
100.	1.01948	1.00284	0.98102
500.	1.01663	1.00097	0.98027
1000.	1.01744	1.00266	0.98273
1500.	1.01968	1.00561	0.98615
2000.	1.02235	1.00892	0.98980
2500.	1.02519	1.01234	0.99347
3000.	1.02822	1.01584	0.99711
3500.	1.03145	1.01947	1.00077
4000.	1.03491	1.02326	1.00448
4500.	1.03856	1.02718	1.00824
5000.	1.04242	1.03123	1.01205
5500.	1.04649	1.03543	1.01590
6000.	1.05079	1.03978	1.01982
6500.	1.05532	1.04431	1.02383
7000.	1.06010	1.04904	1.02795
7500.	1.06517	1.05399	1.03221
8000.	1.07055	1.05919	1.03663
8500.	1.07628	1.06467	1.04122
9000.	1.08239	1.07041	1.04597
9500.	1.08881	1.07627	1.05073
10000.	1.09529	1.08203	1.05532
10500.	1.10169	1.08758	1.05967
11000.	1.10787	1.09286	1.06375
11500.	1.11384	1.09790	1.06757
12000.	1.11986	1.10292	1.07125
12500.	1.12621	1.10810	1.07492
13000.	1.13308	1.11355	1.07866
13500.	1.14048	1.11928	1.08248
14000.	1.14816	1.12516	1.08631
14500.	1.15565	1.13108	1.09007
15000.	1.16249	1.13687	1.09373
15500.	1.16821	1.14226	1.09724
16000.	1.17238	1.14693	1.10055
16500.	1.17486	1.15069	1.10359
17000.	1.17586	1.15344	1.10629
17500.	1.17570	1.15516	1.10859
18000.	1.17464	1.15579	1.11047
18500.	1.17282	1.15535	1.11185
19000.	1.17035	1.15398	1.11268
19500.	1.16734	1.15186	1.11290
20000.	1.16386	1.14920	1.11248
20500.	1.15995	1.14609	1.11143
21000.	1.15568	1.14263	1.10979
21500.	1.15113	1.13887	1.10766
22000.	1.14620	1.13489	1.10511
22500.	1.14127	1.13073	1.10222
23000.	1.13623	1.12628	1.09906
23500.	1.13119	1.12183	1.09570
24000.	1.12616	1.11738	1.09219
24500.	1.12112	1.11293	1.08857
25000.	1.11608	1.10848	1.08488
27500.	1.09072	1.08636	1.06591
30000.	1.06497	1.06421	1.04731
32500.	1.03884	1.04205	1.02899
35000.	1.01233	1.01989	1.01098
37500.	0.98551	0.99775	0.99328
40000.	0.95848	0.97568	0.97591
42500.	0.93138	0.95376	0.95891
45000.	0.90441	0.93206	0.94232
47500.	0.87783	0.91072	0.92617
50000.	0.85190	0.88986	0.91053
52500.	0.82696	0.86962	0.89542
55000.	0.80330	0.85015	0.88090
57500.	0.78125	0.83160	0.86700
60000.	0.76106	0.81412	0.85376
62500.	0.74293	0.79781	0.84122
65000.	0.72695	0.78277	0.82941
67500.	0.71311	0.76906	0.81833
70000.	0.70132	0.75671	0.80801

Table B.10 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.469	1.405	1.323
100.	1.465	1.401	1.317
500.	1.460	1.395	1.313
1000.	1.453	1.389	1.309
1500.	1.445	1.383	1.305
2000.	1.438	1.376	1.302
2500.	1.430	1.369	1.297
3000.	1.421	1.362	1.293
3500.	1.413	1.355	1.289
4000.	1.404	1.348	1.284
4500.	1.396	1.341	1.279
5000.	1.387	1.333	1.275
5500.	1.378	1.326	1.270
6000.	1.369	1.318	1.265
6500.	1.360	1.311	1.260
7000.	1.350	1.304	1.256
7500.	1.341	1.296	1.251
8000.	1.332	1.289	1.246
8500.	1.322	1.281	1.242
9000.	1.312	1.273	1.237
9500.	1.302	1.266	1.233
10000.	1.293	1.258	1.227
10500.	1.283	1.250	1.221
11000.	1.273	1.243	1.214
11500.	1.262	1.235	1.206
12000.	1.252	1.227	1.201
12500.	1.242	1.219	1.195
13000.	1.231	1.211	1.190
13500.	1.221	1.203	1.184
14000.	1.210	1.195	1.179
14500.	1.199	1.187	1.174
15000.	1.189	1.179	1.169
15500.	1.180	1.172	1.164
16000.	1.173	1.165	1.159
16500.	1.170	1.159	1.154
17000.	1.166	1.153	1.150
17500.	1.163	1.148	1.146
18000.	1.159	1.144	1.142
18500.	1.156	1.140	1.138
19000.	1.154	1.138	1.135
19500.	1.151	1.136	1.132
20000.	1.148	1.135	1.129
20500.	1.146	1.133	1.127
21000.	1.144	1.132	1.125
21500.	1.142	1.130	1.124
22000.	1.140	1.129	1.122
22500.	1.138	1.128	1.121
23000.	1.136	1.127	1.120
23500.	1.134	1.126	1.120
24000.	1.133	1.125	1.119
24500.	1.131	1.124	1.118
25000.	1.129	1.123	1.118
27500.	1.120	1.118	1.115
30000.	1.111	1.112	1.112
32500.	1.102	1.107	1.109
35000.	1.093	1.102	1.106
37500.	1.086	1.097	1.103
40000.	1.085	1.091	1.099
42500.	1.086	1.086	1.097
45000.	1.086	1.080	1.094
47500.	1.086	1.075	1.092
50000.	1.083	1.071	1.089
52500.	1.079	1.066	1.086
55000.	1.074	1.064	1.083
57500.	1.068	1.061	1.081
60000.	1.061	1.057	1.078
62500.	1.053	1.055	1.075
65000.	1.044	1.053	1.073
67500.	1.048	1.053	1.084
70000.	1.065	1.063	1.096

Table B.11 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.04034	1.02300	0.99873
100.	1.01434	0.99869	0.97700
500.	1.01163	0.99705	0.97659
1000.	1.01281	0.99921	0.97965
1500.	1.01547	1.00268	0.98368
2000.	1.01855	1.00651	0.98793
2500.	1.02185	1.01048	0.99221
3000.	1.02540	1.01459	0.99648
3500.	1.02921	1.01888	1.00079
4000.	1.03327	1.02335	1.00517
4500.	1.03755	1.02796	1.00960
5000.	1.04208	1.03272	1.01407
5500.	1.04686	1.03767	1.01861
6000.	1.05193	1.04283	1.02323
6500.	1.05730	1.04824	1.02799
7000.	1.06301	1.05391	1.03291
7500.	1.06909	1.05987	1.03802
8000.	1.07558	1.06614	1.04332
8500.	1.08247	1.07272	1.04878
9000.	1.08978	1.07952	1.05431
9500.	1.09736	1.08635	1.05975
10000.	1.10501	1.09305	1.06498
10500.	1.11259	1.09954	1.06995
11000.	1.12004	1.10578	1.07464
11500.	1.12753	1.11192	1.07912
12000.	1.13530	1.11809	1.08347
12500.	1.14337	1.12429	1.08767
13000.	1.15159	1.13049	1.09171
13500.	1.15959	1.13664	1.09556
14000.	1.16683	1.14264	1.09922
14500.	1.17294	1.14833	1.10270
15000.	1.17760	1.15358	1.10602
15500.	1.18063	1.15811	1.10923
16000.	1.18217	1.16170	1.11228
16500.	1.18258	1.16421	1.11509
17000.	1.18209	1.16555	1.11755
17500.	1.18077	1.16569	1.11958
18000.	1.17868	1.16473	1.12107
18500.	1.17595	1.16288	1.12191
19000.	1.17269	1.16038	1.12202
19500.	1.16894	1.15737	1.12139
20000.	1.16475	1.15396	1.12008
20500.	1.16018	1.15020	1.11816
21000.	1.15536	1.14616	1.11573
21500.	1.15013	1.14190	1.11289
22000.	1.14491	1.13733	1.10972
22500.	1.13968	1.13276	1.10631
23000.	1.13441	1.12814	1.10272
23500.	1.12914	1.12351	1.09900
24000.	1.12386	1.11889	1.09521
25000.	1.11832	1.11416	1.09136
27500.	1.08665	1.08659	1.06795
30000.	1.05952	1.06351	1.04892
32500.	1.03193	1.04037	1.03020
35000.	1.00392	1.01720	1.01178
37500.	0.97558	0.99404	0.99369
40000.	0.94706	0.97097	0.97596
42500.	0.91857	0.94807	0.95863
45000.	0.89038	0.92547	0.94173
47500.	0.86280	0.90331	0.92533
50000.	0.83619	0.88176	0.90947
52500.	0.81093	0.86100	0.89420
55000.	0.78737	0.84119	0.87956
57500.	0.76584	0.82251	0.86560
60000.	0.74656	0.80510	0.85236
62500.	0.72965	0.78907	0.83988
65000.	0.71512	0.77451	0.82818
67500.	0.70284	0.76144	0.81727
70000.	0.69263	0.74985	0.80716

Table B.12 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.453	1.375	1.272
100.	1.449	1.371	1.267
500.	1.444	1.365	1.263
1000.	1.436	1.359	1.259
1500.	1.428	1.353	1.254
2000.	1.420	1.346	1.250
2500.	1.411	1.339	1.245
3000.	1.402	1.331	1.240
3500.	1.393	1.324	1.236
4000.	1.383	1.316	1.231
4500.	1.374	1.309	1.226
5000.	1.364	1.301	1.221
5500.	1.354	1.293	1.217
6000.	1.344	1.285	1.212
6500.	1.333	1.277	1.207
7000.	1.323	1.269	1.203
7500.	1.312	1.261	1.198
8000.	1.301	1.253	1.193
8500.	1.290	1.245	1.189
9000.	1.279	1.237	1.184
9500.	1.268	1.228	1.179
10000.	1.257	1.220	1.174
10500.	1.246	1.211	1.169
11000.	1.234	1.203	1.164
11500.	1.223	1.194	1.158
12000.	1.211	1.185	1.153
12500.	1.200	1.177	1.148
13000.	1.188	1.169	1.143
13500.	1.177	1.160	1.138
14000.	1.167	1.153	1.133
14500.	1.157	1.145	1.128
15000.	1.151	1.138	1.124
15500.	1.146	1.131	1.120
16000.	1.142	1.125	1.115
16500.	1.137	1.119	1.111
17000.	1.133	1.114	1.107
17500.	1.129	1.111	1.103
18000.	1.125	1.109	1.100
18500.	1.122	1.106	1.097
19000.	1.119	1.104	1.094
19500.	1.116	1.102	1.092
20000.	1.113	1.101	1.090
20500.	1.111	1.099	1.088
21000.	1.108	1.098	1.087
21500.	1.106	1.096	1.086
22000.	1.103	1.095	1.085
22500.	1.101	1.094	1.084
23000.	1.101	1.093	1.083
23500.	1.101	1.092	1.083
24000.	1.101	1.090	1.083
25000.	1.101	1.088	1.082
27500.	1.103	1.083	1.080
30000.	1.104	1.085	1.078
32500.	1.107	1.085	1.076
35000.	1.108	1.086	1.074
37500.	1.109	1.085	1.072
40000.	1.108	1.086	1.070
42500.	1.106	1.087	1.069
45000.	1.103	1.087	1.068
47500.	1.098	1.086	1.066
50000.	1.093	1.083	1.065
52500.	1.086	1.080	1.064
55000.	1.079	1.075	1.063
57500.	1.070	1.071	1.062
60000.	1.061	1.066	1.061
62500.	1.051	1.059	1.064
65000.	1.049	1.053	1.076
67500.	1.056	1.053	1.087
70000.	1.070	1.068	1.099

Table B.13 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.10981	1.09611	1.07487
100.	1.08126	1.06908	1.05031
500.	1.07857	1.06722	1.04936
1000.	1.08030	1.06961	1.05216
1500.	1.08368	1.07349	1.05608
2000.	1.08752	1.07772	1.06021
2500.	1.09158	1.08209	1.06430
3000.	1.09588	1.08658	1.06835
3500.	1.10048	1.09124	1.07240
4000.	1.10544	1.09612	1.07649
4500.	1.11080	1.10128	1.08068
5000.	1.11658	1.10673	1.08500
5500.	1.12278	1.11247	1.08947
6000.	1.12939	1.11848	1.09410
6500.	1.13646	1.12480	1.09887
7000.	1.14405	1.13146	1.10381
7500.	1.15224	1.13851	1.10895
8000.	1.16111	1.14598	1.11431
8500.	1.17074	1.15395	1.11994
9000.	1.18115	1.16244	1.12583
9500.	1.19213	1.17143	1.13191
10000.	1.20313	1.18062	1.13799
10500.	1.21318	1.18952	1.14388
11000.	1.22149	1.19750	1.14941
11500.	1.22745	1.20396	1.15438
12000.	1.23086	1.20864	1.15862
12500.	1.23203	1.21147	1.16205
13000.	1.23145	1.21249	1.16463
13500.	1.22956	1.21196	1.16628
14000.	1.22671	1.21019	1.16696
14500.	1.22313	1.20752	1.16670
15000.	1.21900	1.20418	1.16557
15500.	1.21449	1.20036	1.16367
16000.	1.20973	1.19622	1.16113
16500.	1.20460	1.19186	1.15808
17000.	1.19947	1.18736	1.15467
17500.	1.19434	1.18269	1.15099
18000.	1.18917	1.17798	1.14713
18500.	1.18401	1.17328	1.14317
19000.	1.17884	1.16857	1.13914
20000.	1.16851	1.15916	1.13088
22500.	1.14252	1.13591	1.11053
25000.	1.11612	1.11268	1.09062
27500.	1.08925	1.08941	1.07106
30000.	1.06190	1.06610	1.05183
32500.	1.03407	1.04273	1.03290
35000.	1.00582	1.01933	1.01428
37500.	0.97726	0.99595	0.99600
40000.	0.94853	0.97266	0.97808
42500.	0.91985	0.94957	0.96056
45000.	0.89150	0.92680	0.94351
47500.	0.86381	0.90450	0.92696
50000.	0.83715	0.88284	0.91098
52500.	0.81188	0.86201	0.89561
55000.	0.78838	0.84218	0.88090
57500.	0.76695	0.82352	0.86689
60000.	0.74781	0.80616	0.85363
62500.	0.73107	0.79023	0.84115
65000.	0.71672	0.77578	0.82948
67500.	0.70462	0.76285	0.81861
70000.	0.69457	0.75141	0.80856

Table B.14 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.376	1.307	1.225
100.	1.374	1.305	1.228
500.	1.369	1.300	1.227
1000.	1.363	1.295	1.226
1500.	1.356	1.289	1.223
2000.	1.348	1.283	1.219
2500.	1.340	1.277	1.215
3000.	1.332	1.271	1.210
3500.	1.324	1.264	1.205
4000.	1.316	1.258	1.200
4500.	1.307	1.251	1.194
5000.	1.298	1.244	1.188
5500.	1.289	1.237	1.181
6000.	1.279	1.230	1.175
6500.	1.270	1.222	1.168
7000.	1.260	1.215	1.161
7500.	1.249	1.208	1.157
8000.	1.239	1.200	1.153
8500.	1.228	1.192	1.148
9000.	1.218	1.184	1.144
9500.	1.206	1.176	1.139
10000.	1.195	1.168	1.135
10500.	1.185	1.160	1.130
11000.	1.175	1.152	1.125
11500.	1.166	1.145	1.121
12000.	1.158	1.138	1.116
12500.	1.153	1.132	1.111
13000.	1.149	1.127	1.107
13500.	1.145	1.123	1.104
14000.	1.142	1.120	1.100
14500.	1.139	1.117	1.098
15000.	1.136	1.115	1.095
15500.	1.134	1.113	1.094
16000.	1.131	1.111	1.092
16500.	1.129	1.110	1.091
17000.	1.127	1.108	1.090
17500.	1.125	1.107	1.090
18000.	1.123	1.106	1.089
18500.	1.121	1.104	1.089
19000.	1.118	1.103	1.088
20000.	1.114	1.100	1.088
22500.	1.103	1.093	1.086
25000.	1.093	1.087	1.084
27500.	1.093	1.083	1.082
30000.	1.094	1.082	1.080
32500.	1.097	1.080	1.078
35000.	1.098	1.079	1.076
37500.	1.098	1.077	1.074
40000.	1.097	1.076	1.071
42500.	1.095	1.077	1.069
45000.	1.093	1.077	1.067
47500.	1.090	1.076	1.064
50000.	1.085	1.073	1.062
52500.	1.079	1.071	1.061
55000.	1.071	1.068	1.060
57500.	1.063	1.063	1.059
60000.	1.053	1.058	1.058
62500.	1.044	1.052	1.065
65000.	1.046	1.045	1.076
67500.	1.053	1.053	1.087
70000.	1.068	1.067	1.098

Table B.15 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.04737	1.02488	0.99969
100.	1.02376	1.00321	0.98060
500.	1.02210	1.00254	0.98099
1000.	1.02416	1.00535	0.98438
1500.	1.02743	1.00913	0.98842
2000.	1.03100	1.01311	0.99249
2500.	1.03461	1.01707	0.99644
3000.	1.03828	1.02098	1.00024
3500.	1.04206	1.02490	1.00394
4000.	1.04598	1.02888	1.00759
4500.	1.05010	1.03297	1.01125
5000.	1.05443	1.03719	1.01494
5500.	1.05897	1.04155	1.01868
6000.	1.06371	1.04604	1.02249
6500.	1.06863	1.05067	1.02637
7000.	1.07376	1.05544	1.03033
7500.	1.07912	1.06036	1.03437
8000.	1.08475	1.06545	1.03852
8500.	1.09067	1.07075	1.04278
9000.	1.09691	1.07625	1.04715
9500.	1.10348	1.08194	1.05160
10000.	1.11028	1.08770	1.05603
10500.	1.11712	1.09338	1.06032
11000.	1.12380	1.09893	1.06444
11500.	1.13014	1.10419	1.06835
12000.	1.13611	1.10915	1.07205
12500.	1.14183	1.11388	1.07554
13000.	1.14736	1.11845	1.07886
13500.	1.15264	1.12279	1.08201
14000.	1.15758	1.12681	1.08495
14500.	1.16205	1.13041	1.08760
15000.	1.16580	1.13349	1.08991
15500.	1.16860	1.13595	1.09185
16000.	1.17033	1.13774	1.09335
16500.	1.17098	1.13883	1.09441
17000.	1.17057	1.13924	1.09505
17500.	1.16919	1.13894	1.09531
18000.	1.16695	1.13799	1.09518
18500.	1.16403	1.13643	1.09467
19000.	1.16057	1.13430	1.09377
19500.	1.15672	1.13170	1.09250
20000.	1.15260	1.12868	1.09088
20500.	1.14830	1.12532	1.08893
21000.	1.14375	1.12173	1.08671
21500.	1.13920	1.11795	1.08422
22000.	1.13464	1.11407	1.08151
22500.	1.13009	1.11005	1.07860
23000.	1.12556	1.10601	1.07554
23500.	1.12104	1.10197	1.07235
24000.	1.11651	1.09794	1.06906
24500.	1.11199	1.09390	1.06572
25000.	1.10746	1.08986	1.06233
27500.	1.08492	1.06999	1.04518
30000.	1.06243	1.05043	1.02838
32500.	1.03999	1.03120	1.01203
35000.	1.01762	1.01228	0.99615
37500.	0.99535	0.99369	0.98076
40000.	0.97326	0.97547	0.96586
42500.	0.95141	0.95764	0.95146
45000.	0.92991	0.94025	0.93760
47500.	0.90889	0.92335	0.92427
50000.	0.88845	0.90699	0.91149
52500.	0.86876	0.89124	0.89928
55000.	0.84993	0.87613	0.88764
57500.	0.83209	0.86173	0.87659
60000.	0.81538	0.84808	0.86611
62500.	0.79988	0.83521	0.85622
65000.	0.78567	0.82316	0.84691
67500.	0.77277	0.81194	0.83817
70000.	0.76120	0.80156	0.82999

Table B.16 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.389	1.377	1.371
100.	1.384	1.372	1.369
500.	1.378	1.367	1.365
1000.	1.371	1.360	1.362
1500.	1.363	1.353	1.357
2000.	1.354	1.346	1.353
2500.	1.346	1.338	1.348
3000.	1.337	1.330	1.343
3500.	1.328	1.324	1.338
4000.	1.319	1.317	1.333
4500.	1.310	1.311	1.328
5000.	1.301	1.305	1.323
5500.	1.292	1.298	1.318
6000.	1.282	1.292	1.313
6500.	1.273	1.285	1.308
7000.	1.264	1.279	1.303
7500.	1.254	1.272	1.298
8000.	1.245	1.266	1.293
8500.	1.235	1.260	1.288
9000.	1.226	1.254	1.284
9500.	1.216	1.248	1.279
10000.	1.210	1.242	1.274
10500.	1.202	1.235	1.268
11000.	1.193	1.226	1.262
11500.	1.183	1.217	1.255
12000.	1.171	1.206	1.247
12500.	1.158	1.195	1.238
13000.	1.149	1.183	1.229
13500.	1.144	1.172	1.220
14000.	1.139	1.163	1.211
14500.	1.133	1.159	1.203
15000.	1.128	1.155	1.194
15500.	1.123	1.151	1.186
16000.	1.119	1.146	1.179
16500.	1.116	1.142	1.174
17000.	1.112	1.137	1.171
17500.	1.110	1.132	1.167
18000.	1.107	1.128	1.163
18500.	1.105	1.124	1.159
19000.	1.104	1.120	1.156
19500.	1.102	1.117	1.152
20000.	1.101	1.114	1.149
20500.	1.100	1.111	1.146
21000.	1.099	1.108	1.143
21500.	1.098	1.106	1.141
22000.	1.097	1.103	1.138
22500.	1.096	1.101	1.136
23000.	1.095	1.099	1.134
23500.	1.094	1.098	1.132
24000.	1.093	1.096	1.130
24500.	1.092	1.095	1.128
25000.	1.091	1.093	1.126
27500.	1.086	1.090	1.118
30000.	1.083	1.087	1.110
32500.	1.079	1.083	1.103
35000.	1.076	1.080	1.098
37500.	1.072	1.077	1.096
40000.	1.069	1.073	1.094
42500.	1.065	1.070	1.099
45000.	1.061	1.066	1.108
47500.	1.059	1.064	1.118
50000.	1.060	1.061	1.129
52500.	1.060	1.059	1.140
55000.	1.057	1.057	1.151
57500.	1.054	1.061	1.163
60000.	1.048	1.077	1.175
62500.	1.053	1.092	1.186
65000.	1.073	1.107	1.198
67500.	1.091	1.122	1.209
70000.	1.108	1.136	1.219

Table B.17 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.09645	1.07204	1.04396
100.	1.07061	1.04817	1.02275
500.	1.06765	1.04615	1.02174
1000.	1.06823	1.04743	1.02358
1500.	1.07001	1.04972	1.02614
2000.	1.07209	1.05220	1.02878
2500.	1.07423	1.05469	1.03133
3000.	1.07642	1.05716	1.03377
3500.	1.07868	1.05962	1.03614
4000.	1.08105	1.06213	1.03846
4500.	1.08355	1.06471	1.04080
5000.	1.08621	1.06738	1.04316
5500.	1.08901	1.07016	1.04556
6000.	1.09196	1.07304	1.04801
6500.	1.09506	1.07603	1.05051
7000.	1.09831	1.07913	1.05308
7500.	1.10172	1.08235	1.05574
8000.	1.10531	1.08570	1.05849
8500.	1.10910	1.08920	1.06133
9000.	1.11314	1.09285	1.06427
9500.	1.11742	1.09666	1.06726
10000.	1.12188	1.10051	1.07021
10500.	1.12636	1.10427	1.07302
11000.	1.13077	1.10790	1.07565
11500.	1.13506	1.11133	1.07808
12000.	1.13923	1.11461	1.08032
12500.	1.14341	1.11784	1.08246
13000.	1.14778	1.12113	1.08455
13500.	1.15233	1.12451	1.08664
14000.	1.15693	1.12788	1.08871
14500.	1.16138	1.13114	1.09071
15000.	1.16542	1.13414	1.09254
15500.	1.16874	1.13673	1.09417
16000.	1.17110	1.13878	1.09553
16500.	1.17243	1.14022	1.09656
17000.	1.17269	1.14098	1.09723
17500.	1.17193	1.14108	1.09756
18000.	1.17025	1.14052	1.09755
18500.	1.16779	1.13932	1.09719
19000.	1.16472	1.13755	1.09647
19500.	1.16117	1.13526	1.09539
20000.	1.15728	1.13252	1.09396
20500.	1.15315	1.12940	1.09221
21000.	1.14885	1.12599	1.09015
21500.	1.14432	1.12236	1.08783
22000.	1.13980	1.11857	1.08527
22500.	1.13527	1.11469	1.08249
23000.	1.13076	1.11067	1.07954
23500.	1.12625	1.10665	1.07644
24000.	1.12173	1.10263	1.07323
24500.	1.11722	1.09861	1.06994
25000.	1.11271	1.09459	1.06659
25500.	1.10822	1.09063	1.06321
27500.	1.09028	1.07477	1.04949
30000.	1.06790	1.05525	1.03269
32500.	1.04556	1.03603	1.01631
35000.	1.02328	1.01713	1.00040
37500.	1.00110	0.99856	0.98496
40000.	0.97907	0.98033	0.97000
42500.	0.95725	0.96249	0.95553
45000.	0.93576	0.94506	0.94159
47500.	0.91470	0.92811	0.92817
50000.	0.89418	0.91167	0.91530
52500.	0.87435	0.89582	0.90298
55000.	0.85534	0.88059	0.89124
57500.	0.83729	0.86605	0.88006
60000.	0.82030	0.85223	0.86946
62500.	0.80449	0.83918	0.85944
65000.	0.78993	0.82693	0.84999
67500.	0.77667	0.81550	0.84112
70000.	0.76473	0.80490	0.83279

Table B.18 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.367	1.355	1.349
100.	1.362	1.350	1.346
500.	1.356	1.345	1.343
1000.	1.350	1.339	1.340
1500.	1.343	1.333	1.336
2000.	1.335	1.326	1.332
2500.	1.327	1.319	1.328
3000.	1.320	1.312	1.324
3500.	1.312	1.305	1.320
4000.	1.303	1.298	1.315
4500.	1.295	1.293	1.311
5000.	1.287	1.287	1.306
5500.	1.278	1.282	1.302
6000.	1.270	1.276	1.298
6500.	1.261	1.271	1.293
7000.	1.252	1.265	1.289
7500.	1.244	1.260	1.285
8000.	1.235	1.254	1.280
8500.	1.226	1.249	1.276
9000.	1.218	1.244	1.272
9500.	1.209	1.239	1.268
10000.	1.204	1.234	1.264
10500.	1.197	1.228	1.259
11000.	1.190	1.221	1.253
11500.	1.181	1.212	1.247
12000.	1.170	1.203	1.240
12500.	1.158	1.192	1.232
13000.	1.145	1.181	1.224
13500.	1.136	1.170	1.215
14000.	1.133	1.159	1.207
14500.	1.129	1.156	1.198
15000.	1.125	1.152	1.190
15500.	1.121	1.148	1.182
16000.	1.116	1.144	1.174
16500.	1.111	1.140	1.170
17000.	1.107	1.135	1.167
17500.	1.104	1.130	1.163
18000.	1.103	1.126	1.160
18500.	1.103	1.122	1.156
19000.	1.103	1.118	1.153
19500.	1.102	1.115	1.149
20000.	1.102	1.111	1.146
20500.	1.102	1.108	1.143
21000.	1.101	1.105	1.140
21500.	1.101	1.103	1.137
22000.	1.100	1.100	1.135
22500.	1.100	1.098	1.132
23000.	1.099	1.097	1.130
23500.	1.099	1.095	1.128
24000.	1.098	1.094	1.126
24500.	1.098	1.092	1.124
25000.	1.097	1.091	1.122
25500.	1.096	1.091	1.120
27500.	1.093	1.089	1.114
30000.	1.090	1.087	1.106
32500.	1.086	1.084	1.099
35000.	1.082	1.082	1.093
37500.	1.078	1.079	1.087
40000.	1.073	1.077	1.085
42500.	1.069	1.074	1.094
45000.	1.064	1.071	1.103
47500.	1.060	1.068	1.113
50000.	1.056	1.065	1.124
52500.	1.056	1.061	1.135
55000.	1.054	1.058	1.146
57500.	1.051	1.056	1.158
60000.	1.047	1.071	1.170
62500.	1.046	1.086	1.181
65000.	1.066	1.101	1.193
67500.	1.085	1.116	1.204
70000.	1.102	1.130	1.214

Table B.19 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.06555	1.04568	1.02157
100.	1.03978	1.02170	1.00012
500.	1.03710	1.01996	0.99940
1000.	1.03814	1.02176	1.00182
1500.	1.04058	1.02478	1.00516
2000.	1.04343	1.02811	1.00869
2500.	1.04643	1.03155	1.01221
3000.	1.04959	1.03504	1.01569
3500.	1.05292	1.03863	1.01913
4000.	1.05645	1.04233	1.02260
4500.	1.06020	1.04618	1.02612
5000.	1.06418	1.05020	1.02971
5500.	1.06837	1.05437	1.03337
6000.	1.07276	1.05870	1.03712
6500.	1.07736	1.06319	1.04096
7000.	1.08217	1.06784	1.04489
7500.	1.08724	1.07267	1.04896
8000.	1.09258	1.07771	1.05316
8500.	1.09824	1.08298	1.05750
9000.	1.10424	1.08847	1.06195
9500.	1.11052	1.09407	1.06640
10000.	1.11686	1.09957	1.07068
10500.	1.12314	1.10489	1.07474
11000.	1.12925	1.10997	1.07855
11500.	1.13525	1.11487	1.08213
12000.	1.14135	1.11977	1.08559
12500.	1.14775	1.12483	1.08904
13000.	1.15445	1.13007	1.09253
13500.	1.16122	1.13533	1.09603
14000.	1.16767	1.14045	1.09942
14500.	1.17341	1.14521	1.10263
15000.	1.17796	1.14936	1.10556
15500.	1.18111	1.15267	1.10813
16000.	1.18282	1.15506	1.11024
16500.	1.18314	1.15656	1.11189
17000.	1.18224	1.15712	1.11308
17500.	1.18035	1.15677	1.11379
18000.	1.17770	1.15556	1.11401
18500.	1.17450	1.15359	1.11370
19000.	1.17084	1.15101	1.11288
19500.	1.16684	1.14794	1.11157
20000.	1.16257	1.14451	1.10982
20500.	1.15811	1.14080	1.10766
21000.	1.15335	1.13688	1.10515
21500.	1.14859	1.13283	1.10234
22000.	1.14384	1.12858	1.09928
22500.	1.13908	1.12433	1.09602
23000.	1.13433	1.12008	1.09261
23500.	1.12958	1.11583	1.08911
24000.	1.12482	1.11157	1.08553
25000.	1.11532	1.10307	1.07817
27500.	1.09142	1.08203	1.05997
30000.	1.06734	1.06113	1.04211
32500.	1.04306	1.04036	1.02462
35000.	1.01860	1.01972	1.00750
37500.	0.99402	0.99925	0.99076
40000.	0.96937	0.97897	0.97441
42500.	0.94477	0.95894	0.95848
45000.	0.92037	0.93922	0.94300
47500.	0.89632	0.91989	0.92801
50000.	0.87283	0.90104	0.91354
52500.	0.85012	0.88277	0.89961
55000.	0.82840	0.86517	0.88626
57500.	0.80791	0.84836	0.87350
60000.	0.78882	0.83241	0.86136
62500.	0.77133	0.81740	0.84986
65000.	0.75553	0.80341	0.83902
67500.	0.74146	0.79048	0.82882
70000.	0.72913	0.77863	0.81928

Table B.20 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.374	1.336	1.340
100.	1.369	1.334	1.338
500.	1.364	1.330	1.335
1000.	1.357	1.325	1.332
1500.	1.350	1.320	1.328
2000.	1.343	1.315	1.324
2500.	1.336	1.309	1.319
3000.	1.329	1.303	1.315
3500.	1.321	1.298	1.310
4000.	1.314	1.292	1.305
4500.	1.306	1.286	1.301
5000.	1.298	1.280	1.296
5500.	1.290	1.274	1.291
6000.	1.282	1.268	1.286
6500.	1.274	1.261	1.281
7000.	1.266	1.255	1.276
7500.	1.258	1.249	1.271
8000.	1.249	1.243	1.267
8500.	1.241	1.238	1.262
9000.	1.232	1.232	1.257
9500.	1.224	1.226	1.252
10000.	1.215	1.220	1.247
10500.	1.206	1.211	1.240
11000.	1.198	1.202	1.233
11500.	1.189	1.190	1.224
12000.	1.180	1.178	1.215
12500.	1.170	1.165	1.205
13000.	1.161	1.152	1.196
13500.	1.152	1.142	1.186
14000.	1.143	1.135	1.176
14500.	1.135	1.130	1.167
15000.	1.127	1.125	1.157
15500.	1.121	1.121	1.149
16000.	1.116	1.116	1.146
16500.	1.113	1.111	1.142
17000.	1.111	1.107	1.138
17500.	1.109	1.102	1.134
18000.	1.107	1.099	1.130
18500.	1.106	1.097	1.126
19000.	1.104	1.095	1.123
19500.	1.103	1.094	1.120
20000.	1.102	1.093	1.116
20500.	1.101	1.092	1.114
21000.	1.100	1.091	1.111
21500.	1.099	1.091	1.109
22000.	1.098	1.090	1.106
22500.	1.097	1.090	1.104
23000.	1.096	1.089	1.102
23500.	1.095	1.089	1.100
24000.	1.095	1.088	1.099
25000.	1.093	1.087	1.095
27500.	1.089	1.084	1.090
30000.	1.085	1.082	1.089
32500.	1.080	1.080	1.087
35000.	1.075	1.078	1.086
37500.	1.071	1.075	1.084
40000.	1.066	1.073	1.082
42500.	1.067	1.070	1.080
45000.	1.070	1.067	1.078
47500.	1.071	1.063	1.075
50000.	1.071	1.060	1.073
52500.	1.069	1.056	1.070
55000.	1.065	1.053	1.068
57500.	1.061	1.050	1.068
60000.	1.057	1.047	1.078
62500.	1.051	1.044	1.089
65000.	1.043	1.042	1.099
67500.	1.049	1.057	1.110
70000.	1.066	1.072	1.120

Table B.21 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.06511	1.04520	1.02052
100.	1.03919	1.02108	0.99897
500.	1.03633	1.01918	0.99813
1000.	1.03714	1.02081	1.00041
1500.	1.03932	1.02365	1.00360
2000.	1.04192	1.02681	1.00699
2500.	1.04467	1.03007	1.01037
3000.	1.04759	1.03339	1.01373
3500.	1.05071	1.03683	1.01709
4000.	1.05402	1.04041	1.02048
4500.	1.05750	1.04409	1.02392
5000.	1.06115	1.04788	1.02739
5500.	1.06497	1.05178	1.03089
6000.	1.06900	1.05581	1.03444
6500.	1.07323	1.06001	1.03806
7000.	1.07771	1.06438	1.04179
7500.	1.08246	1.06897	1.04564
8000.	1.08752	1.07381	1.04965
8500.	1.09294	1.07891	1.05382
9000.	1.09868	1.08420	1.05809
9500.	1.10454	1.08946	1.06228
10000.	1.11028	1.09451	1.06626
10500.	1.11577	1.09926	1.06997
11000.	1.12092	1.10368	1.07338
11500.	1.12591	1.10794	1.07656
12000.	1.13104	1.11225	1.07962
12500.	1.13645	1.11670	1.08268
13000.	1.14207	1.12122	1.08577
13500.	1.14775	1.12567	1.08883
14000.	1.15334	1.13000	1.09175
14500.	1.15867	1.13409	1.09451
15000.	1.16353	1.13787	1.09707
15500.	1.16790	1.14132	1.09939
16000.	1.17159	1.14446	1.10146
16500.	1.17446	1.14722	1.10329
17000.	1.17645	1.14950	1.10488
17500.	1.17739	1.15119	1.10623
18000.	1.17717	1.15221	1.10734
18500.	1.17583	1.15245	1.10819
19000.	1.17358	1.15186	1.10870
19500.	1.17066	1.15044	1.10881
20000.	1.16721	1.14832	1.10846
20500.	1.16333	1.14561	1.10764
21000.	1.15913	1.14242	1.10636
21500.	1.15468	1.13887	1.10465
22000.	1.14989	1.13506	1.10255
22500.	1.14510	1.13106	1.10009
23000.	1.14024	1.12693	1.09732
23500.	1.13537	1.12260	1.09429
24000.	1.13051	1.11827	1.09106
24500.	1.12564	1.11394	1.08767
25000.	1.12078	1.10961	1.08418
25500.	1.11591	1.10533	1.08062
27500.	1.09643	1.08822	1.06595
30000.	1.07185	1.06696	1.04794
32500.	1.04706	1.04581	1.03027
35000.	1.02207	1.02479	1.01296
37500.	0.99692	1.00391	0.99603
40000.	0.97170	0.98322	0.97949
42500.	0.94652	0.96276	0.96337
45000.	0.92152	0.94261	0.94769
47500.	0.89690	0.92284	0.93250
50000.	0.87286	0.90356	0.91782
52500.	0.84964	0.88487	0.90370
55000.	0.82746	0.86687	0.89014
57500.	0.80657	0.84967	0.87719
60000.	0.78718	0.83337	0.86486
62500.	0.76946	0.81805	0.85318
65000.	0.75352	0.80379	0.84215
67500.	0.73941	0.79063	0.83179
70000.	0.72710	0.77861	0.82210

Table B.22 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.379	1.355	1.351
100.	1.374	1.353	1.349
500.	1.369	1.349	1.347
1000.	1.363	1.346	1.344
1500.	1.357	1.341	1.341
2000.	1.350	1.336	1.337
2500.	1.343	1.331	1.333
3000.	1.336	1.325	1.329
3500.	1.328	1.320	1.324
4000.	1.321	1.314	1.320
4500.	1.313	1.308	1.315
5000.	1.305	1.302	1.310
5500.	1.298	1.296	1.306
6000.	1.290	1.290	1.301
6500.	1.282	1.284	1.296
7000.	1.274	1.279	1.291
7500.	1.266	1.273	1.287
8000.	1.258	1.267	1.282
8500.	1.250	1.262	1.278
9000.	1.241	1.257	1.274
9500.	1.233	1.251	1.269
10000.	1.224	1.244	1.263
10500.	1.216	1.235	1.256
11000.	1.207	1.224	1.249
11500.	1.199	1.212	1.240
12000.	1.190	1.200	1.230
12500.	1.181	1.187	1.220
13000.	1.172	1.174	1.211
13500.	1.164	1.161	1.201
14000.	1.155	1.152	1.191
14500.	1.147	1.148	1.182
15000.	1.140	1.143	1.173
15500.	1.133	1.137	1.166
16000.	1.127	1.131	1.161
16500.	1.121	1.126	1.156
17000.	1.116	1.120	1.151
17500.	1.113	1.114	1.147
18000.	1.111	1.109	1.142
18500.	1.109	1.104	1.137
19000.	1.107	1.101	1.132
19500.	1.106	1.098	1.128
20000.	1.104	1.096	1.124
20500.	1.103	1.094	1.120
21000.	1.102	1.093	1.117
21500.	1.101	1.092	1.114
22000.	1.100	1.092	1.111
22500.	1.099	1.091	1.108
23000.	1.098	1.091	1.106
23500.	1.097	1.090	1.104
24000.	1.097	1.090	1.101
24500.	1.096	1.089	1.099
25000.	1.095	1.089	1.098
25500.	1.094	1.089	1.096
27500.	1.091	1.087	1.091
30000.	1.086	1.084	1.090
32500.	1.082	1.082	1.088
35000.	1.077	1.080	1.087
37500.	1.072	1.077	1.085
40000.	1.069	1.074	1.083
42500.	1.073	1.071	1.080
45000.	1.075	1.068	1.078
47500.	1.075	1.065	1.076
50000.	1.073	1.061	1.073
52500.	1.072	1.057	1.071
55000.	1.069	1.054	1.068
57500.	1.064	1.051	1.068
60000.	1.058	1.047	1.078
62500.	1.051	1.044	1.089
65000.	1.042	1.048	1.100
67500.	1.059	1.064	1.111
70000.	1.077	1.079	1.122

Table B.23 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.04024	1.02209	0.99807
100.	1.01454	0.99810	0.97659
500.	1.01185	0.99640	0.97602
1000.	1.01290	0.99833	0.97873
1500.	1.01537	1.00152	0.98239
2000.	1.01827	1.00506	0.98627
2500.	1.02133	1.00870	0.99016
3000.	1.02458	1.01243	0.99401
3500.	1.02805	1.01629	0.99788
4000.	1.03174	1.02031	1.00180
4500.	1.03562	1.02446	1.00577
5000.	1.03971	1.02873	1.00978
5500.	1.04400	1.03314	1.01383
6000.	1.04852	1.03770	1.01794
6500.	1.05327	1.04245	1.02214
7000.	1.05827	1.04739	1.02644
7500.	1.06356	1.05255	1.03089
8000.	1.06916	1.05797	1.03550
8500.	1.07512	1.06366	1.04028
9000.	1.08144	1.06960	1.04520
9500.	1.08805	1.07564	1.05011
10000.	1.09470	1.08155	1.05483
10500.	1.10126	1.08726	1.05931
11000.	1.10758	1.09268	1.06351
11500.	1.11370	1.09789	1.06746
12000.	1.11987	1.10306	1.07128
12500.	1.12639	1.10841	1.07508
13000.	1.13339	1.11399	1.07894
13500.	1.14077	1.11972	1.08282
14000.	1.14829	1.12549	1.08664
14500.	1.15551	1.13122	1.09033
15000.	1.16202	1.13673	1.09388
15500.	1.16736	1.14176	1.09723
16000.	1.17125	1.14610	1.10035
16500.	1.17365	1.14961	1.10318
17000.	1.17463	1.15221	1.10569
17500.	1.17444	1.15385	1.10783
18000.	1.17329	1.15443	1.10957
18500.	1.17134	1.15395	1.11084
19000.	1.16873	1.15253	1.11158
19500.	1.16560	1.15036	1.11171
20000.	1.16202	1.14763	1.11120
20500.	1.15803	1.14447	1.11009
21000.	1.15370	1.14095	1.10841
21500.	1.14911	1.13714	1.10625
22000.	1.14416	1.13312	1.10367
22500.	1.13921	1.12894	1.10076
23000.	1.13416	1.12448	1.09759
23500.	1.12912	1.12002	1.09421
24000.	1.12407	1.11557	1.09068
24500.	1.11903	1.11111	1.08706
25000.	1.11398	1.10665	1.08337
27500.	1.08860	1.08451	1.06440
30000.	1.06283	1.06236	1.04581
32500.	1.03668	1.04020	1.02751
35000.	1.01017	1.01805	1.00952
37500.	0.98336	0.99592	0.99185
40000.	0.95635	0.97389	0.97451
42500.	0.92929	0.95200	0.95754
45000.	0.90239	0.93036	0.94099
47500.	0.87589	0.90909	0.92489
50000.	0.85008	0.88830	0.90930
52500.	0.82526	0.86815	0.89426
55000.	0.80176	0.84879	0.87980
57500.	0.77988	0.83035	0.86597
60000.	0.75986	0.81299	0.85280
62500.	0.74191	0.79680	0.84033
65000.	0.72609	0.78188	0.82859
67500.	0.71242	0.76830	0.81759
70000.	0.70077	0.75606	0.80734

Table B.24 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.479	1.415	1.333
100.	1.475	1.410	1.328
500.	1.469	1.405	1.323
1000.	1.462	1.398	1.317
1500.	1.454	1.391	1.313
2000.	1.446	1.384	1.309
2500.	1.437	1.377	1.304
3000.	1.429	1.370	1.300
3500.	1.420	1.362	1.295
4000.	1.411	1.355	1.290
4500.	1.402	1.347	1.285
5000.	1.393	1.339	1.280
5500.	1.383	1.332	1.275
6000.	1.374	1.324	1.270
6500.	1.364	1.316	1.265
7000.	1.355	1.308	1.260
7500.	1.345	1.301	1.255
8000.	1.335	1.293	1.250
8500.	1.325	1.285	1.245
9000.	1.315	1.277	1.241
9500.	1.305	1.269	1.236
10000.	1.295	1.261	1.230
10500.	1.285	1.253	1.224
11000.	1.274	1.245	1.216
11500.	1.264	1.237	1.209
12000.	1.253	1.229	1.204
12500.	1.243	1.221	1.198
13000.	1.232	1.213	1.193
13500.	1.221	1.204	1.187
14000.	1.210	1.196	1.182
14500.	1.200	1.188	1.176
15000.	1.190	1.181	1.171
15500.	1.181	1.174	1.166
16000.	1.174	1.167	1.162
16500.	1.170	1.161	1.157
17000.	1.167	1.155	1.153
17500.	1.163	1.150	1.149
18000.	1.160	1.146	1.145
18500.	1.157	1.142	1.141
19000.	1.154	1.139	1.138
19500.	1.152	1.138	1.135
20000.	1.149	1.136	1.132
20500.	1.147	1.135	1.130
21000.	1.145	1.133	1.128
21500.	1.143	1.132	1.126
22000.	1.141	1.131	1.125
22500.	1.139	1.130	1.124
23000.	1.137	1.129	1.123
23500.	1.136	1.128	1.122
24000.	1.134	1.126	1.121
24500.	1.133	1.125	1.121
25000.	1.131	1.124	1.120
27500.	1.122	1.119	1.117
30000.	1.113	1.114	1.114
32500.	1.104	1.109	1.111
35000.	1.094	1.103	1.108
37500.	1.085	1.098	1.104
40000.	1.086	1.092	1.101
42500.	1.088	1.087	1.098
45000.	1.088	1.081	1.095
47500.	1.088	1.076	1.092
50000.	1.085	1.071	1.089
52500.	1.081	1.067	1.087
55000.	1.077	1.065	1.084
57500.	1.071	1.062	1.081
60000.	1.063	1.058	1.078
62500.	1.055	1.055	1.075
65000.	1.046	1.053	1.074
67500.	1.049	1.053	1.085
70000.	1.066	1.064	1.097

Table B.25 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.02450	1.00750	0.98364
100.	0.99896	0.98361	0.96229
500.	0.99663	0.98240	0.96239
1000.	0.99838	0.98520	0.96617
1500.	1.00157	0.98929	0.97088
2000.	1.00518	0.99370	0.97578
2500.	1.00900	0.99824	0.98067
3000.	1.01308	1.00293	0.98555
3500.	1.01745	1.00782	0.99048
4000.	1.02206	1.01288	0.99545
4500.	1.02691	1.01807	1.00046
5000.	1.03200	1.02344	1.00552
5500.	1.03738	1.02900	1.01064
6000.	1.04306	1.03480	1.01586
6500.	1.04908	1.04087	1.02124
7000.	1.05548	1.04723	1.02680
7500.	1.06229	1.05392	1.03255
8000.	1.06953	1.06094	1.03849
8500.	1.07719	1.06821	1.04452
9000.	1.08516	1.07551	1.05045
9500.	1.09317	1.08264	1.05614
10000.	1.10104	1.08948	1.06151
10500.	1.10864	1.09599	1.06656
11000.	1.11619	1.10235	1.07135
11500.	1.12396	1.10871	1.07600
12000.	1.13195	1.11503	1.08048
12500.	1.14010	1.12129	1.08476
13000.	1.14813	1.12744	1.08882
13500.	1.15564	1.13340	1.09263
14000.	1.16228	1.13914	1.09623
14500.	1.16775	1.14458	1.09965
15000.	1.17176	1.14948	1.10294
15500.	1.17422	1.15357	1.10609
16000.	1.17530	1.15663	1.10902
16500.	1.17521	1.15857	1.11163
17000.	1.17409	1.15924	1.11384
17500.	1.17209	1.15868	1.11552
18000.	1.16938	1.15708	1.11655
18500.	1.16611	1.15469	1.11685
19000.	1.16234	1.15174	1.11640
19500.	1.15812	1.14833	1.11524
20000.	1.15351	1.14455	1.11345
20500.	1.14863	1.14047	1.11111
21000.	1.14332	1.13617	1.10833
21500.	1.13801	1.13152	1.10518
22000.	1.13269	1.12686	1.10176
22500.	1.12738	1.12221	1.09815
23000.	1.12204	1.11754	1.09441
25000.	1.10066	1.09885	1.07867
27500.	1.07356	1.07555	1.05926
30000.	1.04603	1.05223	1.04016
32500.	1.01808	1.02890	1.02141
35000.	0.98979	1.00560	1.00300
37500.	0.96129	0.98237	0.98496
40000.	0.93273	0.95930	0.96732
42500.	0.90437	0.93651	0.95011
45000.	0.87650	0.91411	0.93339
47500.	0.84945	0.89227	0.91721
50000.	0.82358	0.87116	0.90162
52500.	0.79926	0.85093	0.88666
55000.	0.77682	0.83177	0.87237
57500.	0.75653	0.81383	0.85880
60000.	0.73856	0.79722	0.84598
62500.	0.72296	0.78204	0.83395
65000.	0.70966	0.76834	0.82271
67500.	0.69851	0.75612	0.81227
70000.	0.68929	0.74535	0.80262

Table B.26 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.504	1.427	1.324
100.	1.499	1.422	1.318
500.	1.492	1.416	1.313
1000.	1.484	1.408	1.307
1500.	1.474	1.400	1.301
2000.	1.464	1.391	1.295
2500.	1.454	1.383	1.289
3000.	1.444	1.374	1.283
3500.	1.433	1.365	1.277
4000.	1.422	1.356	1.271
4500.	1.411	1.347	1.265
5000.	1.400	1.338	1.259
5500.	1.388	1.329	1.253
6000.	1.377	1.320	1.248
6500.	1.365	1.311	1.242
7000.	1.353	1.302	1.236
7500.	1.341	1.293	1.231
8000.	1.329	1.283	1.225
8500.	1.317	1.274	1.220
9000.	1.305	1.265	1.214
9500.	1.293	1.255	1.208
10000.	1.281	1.246	1.202
10500.	1.268	1.236	1.196
11000.	1.256	1.227	1.190
11500.	1.243	1.217	1.184
12000.	1.231	1.208	1.178
12500.	1.218	1.198	1.172
13000.	1.207	1.190	1.166
13500.	1.195	1.181	1.161
14000.	1.185	1.173	1.156
14500.	1.175	1.165	1.151
15000.	1.172	1.157	1.146
15500.	1.176	1.150	1.141
16000.	1.177	1.144	1.136
16500.	1.176	1.138	1.132
17000.	1.174	1.133	1.127
17500.	1.172	1.128	1.123
18000.	1.168	1.126	1.119
18500.	1.165	1.123	1.116
19000.	1.162	1.121	1.113
19500.	1.159	1.119	1.111
20000.	1.156	1.118	1.108
20500.	1.153	1.116	1.107
21000.	1.151	1.114	1.105
21500.	1.148	1.113	1.104
22000.	1.145	1.111	1.103
22500.	1.143	1.110	1.102
23000.	1.141	1.109	1.101
25000.	1.131	1.103	1.099
27500.	1.118	1.097	1.095
30000.	1.120	1.092	1.092
32500.	1.123	1.094	1.088
35000.	1.124	1.096	1.085
37500.	1.124	1.098	1.082
40000.	1.123	1.099	1.079
42500.	1.120	1.100	1.077
45000.	1.115	1.098	1.075
47500.	1.110	1.096	1.073
50000.	1.104	1.092	1.071
52500.	1.096	1.088	1.069
55000.	1.086	1.083	1.067
57500.	1.075	1.078	1.065
60000.	1.064	1.071	1.064
62500.	1.053	1.064	1.073
65000.	1.053	1.055	1.084
67500.	1.064	1.062	1.095
70000.	1.078	1.077	1.106

Table B.27 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.09399	1.08054	1.05953
100.	1.06584	1.05387	1.03528
500.	1.06348	1.05241	1.03482
1000.	1.06574	1.05541	1.03833
1500.	1.06960	1.05985	1.04291
2000.	1.07387	1.06460	1.04763
2500.	1.07838	1.06948	1.05228
3000.	1.08314	1.07449	1.05689
3500.	1.08823	1.07968	1.06150
4000.	1.09373	1.08514	1.06618
4500.	1.09967	1.09090	1.07095
5000.	1.10605	1.09697	1.07588
5500.	1.11286	1.10334	1.08097
6000.	1.12013	1.11002	1.08622
6500.	1.12790	1.11703	1.09162
7000.	1.13628	1.12444	1.09722
7500.	1.14532	1.13229	1.10305
8000.	1.15513	1.14064	1.10915
8500.	1.16579	1.14956	1.11554
9000.	1.17726	1.15903	1.12215
9500.	1.18911	1.16881	1.12877
10000.	1.20037	1.17840	1.13518
10500.	1.21003	1.18717	1.14120
11000.	1.21731	1.19445	1.14661
11500.	1.22178	1.19991	1.15127
12000.	1.22364	1.20343	1.15512
12500.	1.22343	1.20504	1.15808
13000.	1.22171	1.20490	1.16006
13500.	1.21890	1.20335	1.16100
14000.	1.21527	1.20075	1.16093
14500.	1.21104	1.19740	1.15992
15000.	1.20640	1.19351	1.15808
15500.	1.20150	1.18926	1.15555
16000.	1.19623	1.18478	1.15247
16500.	1.19096	1.18017	1.14899
17000.	1.18568	1.17536	1.14524
17500.	1.18041	1.17055	1.14130
18000.	1.17513	1.16577	1.13726
20000.	1.15401	1.14663	1.12055
22500.	1.12737	1.12295	1.10006
25000.	1.10032	1.09930	1.07997
27500.	1.07283	1.07566	1.06026
30000.	1.04488	1.05199	1.04090
32500.	1.01653	1.02832	1.02189
35000.	0.98786	1.00468	1.00324
37500.	0.95901	0.98115	0.98497
40000.	0.93017	0.95782	0.96712
42500.	0.90160	0.93479	0.94974
45000.	0.87362	0.91223	0.93288
47500.	0.84658	0.89030	0.91659
50000.	0.82085	0.86916	0.90093
52500.	0.79680	0.84900	0.88593
55000.	0.77475	0.82998	0.87165
57500.	0.75493	0.81225	0.85812
60000.	0.73750	0.79593	0.84539
62500.	0.72246	0.78109	0.83347
65000.	0.70972	0.76777	0.82238
67500.	0.69908	0.75594	0.81211
70000.	0.69031	0.74557	0.80266

Table B.28 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.424	1.358	1.272
100.	1.422	1.354	1.267
500.	1.416	1.349	1.263
1000.	1.408	1.342	1.258
1500.	1.400	1.335	1.252
2000.	1.391	1.328	1.247
2500.	1.382	1.320	1.242
3000.	1.373	1.313	1.237
3500.	1.364	1.305	1.232
4000.	1.354	1.298	1.227
4500.	1.344	1.290	1.222
5000.	1.334	1.282	1.217
5500.	1.324	1.274	1.212
6000.	1.313	1.265	1.207
6500.	1.302	1.257	1.201
7000.	1.291	1.249	1.196
7500.	1.280	1.240	1.191
8000.	1.268	1.231	1.186
8500.	1.257	1.223	1.181
9000.	1.244	1.214	1.176
9500.	1.232	1.205	1.171
10000.	1.220	1.196	1.165
10500.	1.209	1.187	1.160
11000.	1.199	1.178	1.154
11500.	1.190	1.170	1.149
12000.	1.183	1.164	1.143
12500.	1.178	1.158	1.138
13000.	1.174	1.153	1.134
13500.	1.170	1.149	1.130
14000.	1.167	1.146	1.127
14500.	1.164	1.143	1.124
15000.	1.161	1.141	1.122
15500.	1.158	1.139	1.120
16000.	1.156	1.137	1.118
16500.	1.154	1.135	1.117
17000.	1.151	1.133	1.116
17500.	1.149	1.132	1.115
18000.	1.146	1.130	1.115
20000.	1.136	1.124	1.112
22500.	1.124	1.116	1.109
25000.	1.112	1.107	1.105
27500.	1.115	1.100	1.102
30000.	1.117	1.093	1.098
32500.	1.119	1.090	1.094
35000.	1.119	1.092	1.091
37500.	1.118	1.093	1.087
40000.	1.116	1.094	1.083
42500.	1.113	1.093	1.079
45000.	1.109	1.091	1.076
47500.	1.104	1.088	1.072
50000.	1.097	1.085	1.070
52500.	1.089	1.082	1.067
55000.	1.079	1.077	1.066
57500.	1.068	1.071	1.064
60000.	1.056	1.063	1.065
62500.	1.045	1.056	1.076
65000.	1.052	1.050	1.087
67500.	1.064	1.065	1.098
70000.	1.077	1.078	1.108

Table B.29 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.12530	1.10304	1.07734
100.	1.09853	1.07818	1.05507
500.	1.09489	1.07534	1.05306
1000.	1.09465	1.07563	1.05373
1500.	1.09558	1.07691	1.05513
2000.	1.09680	1.07839	1.05661
2500.	1.09807	1.07987	1.05801
3000.	1.09936	1.08129	1.05929
3500.	1.10068	1.08268	1.06049
4000.	1.10207	1.08408	1.06163
4500.	1.10355	1.08552	1.06276
5000.	1.10516	1.08704	1.06389
5500.	1.10688	1.08863	1.06506
6000.	1.10874	1.09031	1.06626
6500.	1.11072	1.09208	1.06751
7000.	1.11284	1.09395	1.06883
7500.	1.11509	1.09593	1.07021
8000.	1.11749	1.09800	1.07167
8500.	1.12003	1.10017	1.07322
9000.	1.12276	1.10248	1.07484
9500.	1.12568	1.10492	1.07653
10000.	1.12881	1.10749	1.07827
10500.	1.13207	1.11008	1.07997
11000.	1.13532	1.11258	1.08155
11500.	1.13847	1.11492	1.08295
12000.	1.14145	1.11707	1.08415
12500.	1.14425	1.11900	1.08517
13000.	1.14698	1.12082	1.08602
13500.	1.14976	1.12261	1.08679
14000.	1.15265	1.12444	1.08752
14500.	1.15565	1.12633	1.08824
15000.	1.15869	1.12824	1.08896
15500.	1.16163	1.13013	1.08967
16000.	1.16434	1.13195	1.09034
16500.	1.16662	1.13360	1.09095
17000.	1.16835	1.13501	1.09149
17500.	1.16937	1.13606	1.09193
18000.	1.16965	1.13671	1.09224
18500.	1.16917	1.13688	1.09238
19000.	1.16794	1.13657	1.09232
19500.	1.16602	1.13576	1.09202
20000.	1.16352	1.13447	1.09147
20500.	1.16055	1.13270	1.09066
21000.	1.15720	1.13051	1.08958
21500.	1.15357	1.12793	1.08825
22000.	1.14970	1.12505	1.08666
22500.	1.14565	1.12191	1.08482
23000.	1.14146	1.11858	1.08275
23500.	1.13718	1.11508	1.08047
24000.	1.13272	1.11146	1.07799
24500.	1.12825	1.10774	1.07533
25000.	1.12379	1.10395	1.07254
25500.	1.11936	1.10012	1.06963
26000.	1.11493	1.09625	1.06662
26500.	1.11049	1.09230	1.06353
27000.	1.10606	1.08834	1.06038
27500.	1.10163	1.08439	1.05718
28000.	1.09722	1.08052	1.05395
28500.	1.09280	1.07665	1.05069
29000.	1.08839	1.07277	1.04742
29500.	1.08397	1.06890	1.04414
30000.	1.07956	1.06503	1.04086
30500.	1.07515	1.06122	1.03758
31000.	1.07074	1.05740	1.03430
32500.	1.05752	1.04596	1.02447
35000.	1.03551	1.02716	1.00856
37500.	1.01356	1.00866	0.99307
40000.	0.99170	0.99047	0.97804
42500.	0.97001	0.97262	0.96348
45000.	0.94856	0.95516	0.94940
47500.	0.92744	0.93811	0.93582
50000.	0.90677	0.92153	0.92276
52500.	0.88667	0.90547	0.91024
55000.	0.86727	0.88999	0.89826
57500.	0.84871	0.87513	0.88683
60000.	0.83110	0.86095	0.87596
62500.	0.81457	0.84749	0.86565
65000.	0.79921	0.83478	0.85590
67500.	0.78509	0.82285	0.84670
70000.	0.77225	0.81173	0.83805

Table B.30 [] Hot Uncontrolled LPF

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.337	1.330	1.313
100.	1.332	1.325	1.314
500.	1.327	1.321	1.320
1000.	1.322	1.317	1.326
1500.	1.317	1.312	1.330
2000.	1.311	1.307	1.332
2500.	1.304	1.302	1.332
3000.	1.298	1.296	1.332
3500.	1.292	1.291	1.331
4000.	1.285	1.286	1.330
4500.	1.279	1.280	1.328
5000.	1.272	1.275	1.325
5500.	1.266	1.270	1.322
6000.	1.259	1.265	1.319
6500.	1.252	1.259	1.316
7000.	1.246	1.254	1.312
7500.	1.239	1.248	1.308
8000.	1.232	1.243	1.303
8500.	1.225	1.238	1.299
9000.	1.219	1.232	1.295
9500.	1.212	1.227	1.290
10000.	1.206	1.222	1.285
10500.	1.199	1.217	1.280
11000.	1.192	1.211	1.275
11500.	1.185	1.204	1.269
12000.	1.176	1.198	1.263
12500.	1.167	1.190	1.256
13000.	1.158	1.183	1.248
13500.	1.148	1.175	1.240
14000.	1.142	1.166	1.232
14500.	1.137	1.158	1.225
15000.	1.132	1.150	1.217
15500.	1.127	1.142	1.209
16000.	1.122	1.134	1.201
16500.	1.117	1.126	1.194
17000.	1.112	1.118	1.186
17500.	1.108	1.111	1.179
18000.	1.104	1.107	1.172
18500.	1.104	1.104	1.166
19000.	1.104	1.101	1.159
19500.	1.104	1.098	1.153
20000.	1.104	1.096	1.148
20500.	1.104	1.095	1.143
21000.	1.104	1.096	1.138
21500.	1.104	1.096	1.134
22000.	1.104	1.096	1.129
22500.	1.104	1.096	1.126
23000.	1.104	1.096	1.122
23500.	1.103	1.096	1.119
24000.	1.102	1.096	1.117
24500.	1.102	1.096	1.114
25000.	1.101	1.095	1.112
25500.	1.100	1.095	1.110
26000.	1.099	1.094	1.108
26500.	1.099	1.093	1.107
27000.	1.098	1.093	1.105
27500.	1.097	1.092	1.104
28000.	1.096	1.091	1.103
28500.	1.095	1.091	1.102
29000.	1.095	1.090	1.101
29500.	1.094	1.090	1.100
30000.	1.093	1.089	1.099
30500.	1.092	1.088	1.098
31000.	1.091	1.088	1.098
32500.	1.089	1.086	1.097
35000.	1.084	1.082	1.097
37500.	1.079	1.079	1.098
40000.	1.075	1.076	1.100
42500.	1.069	1.072	1.105
45000.	1.066	1.069	1.110
47500.	1.062	1.065	1.117
50000.	1.058	1.063	1.125
52500.	1.058	1.060	1.134
55000.	1.059	1.058	1.143
57500.	1.059	1.056	1.153
60000.	1.058	1.060	1.164
62500.	1.055	1.075	1.174
65000.	1.051	1.089	1.185
67500.	1.069	1.104	1.196
70000.	1.087	1.118	1.206

Table B.31 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.09380	1.07608	1.05438
100.	1.06707	1.05109	1.03187
500.	1.06378	1.04862	1.03027
1000.	1.06406	1.04952	1.03162
1500.	1.06567	1.05157	1.03385
2000.	1.06766	1.05391	1.03626
2500.	1.06977	1.05632	1.03863
3000.	1.07197	1.05873	1.04092
3500.	1.07428	1.06118	1.04315
4000.	1.07672	1.06369	1.04535
4500.	1.07934	1.06630	1.04759
5000.	1.08214	1.06904	1.04986
5500.	1.08512	1.07190	1.05217
6000.	1.08828	1.07489	1.05455
6500.	1.09161	1.07801	1.05700
7000.	1.09513	1.08128	1.05953
7500.	1.09884	1.08468	1.06217
8000.	1.10278	1.08824	1.06492
8500.	1.10695	1.09198	1.06778
9000.	1.11141	1.09591	1.07074
9500.	1.11614	1.10001	1.07378
10000.	1.12103	1.10411	1.07675
10500.	1.12587	1.10807	1.07954
11000.	1.13056	1.11179	1.08208
11500.	1.13498	1.11521	1.08434
12000.	1.13921	1.11841	1.08635
12500.	1.14349	1.12154	1.08820
13000.	1.14796	1.12476	1.09000
13500.	1.15266	1.12812	1.09181
14000.	1.15754	1.13161	1.09367
14500.	1.16237	1.13518	1.09556
15000.	1.16693	1.13872	1.09747
15500.	1.17098	1.14206	1.09934
16000.	1.17423	1.14508	1.10114
16500.	1.17655	1.14765	1.10282
17000.	1.17780	1.14960	1.10434
17500.	1.17802	1.15083	1.10561
18000.	1.17732	1.15134	1.10659
18500.	1.17584	1.15112	1.10722
19000.	1.17373	1.15023	1.10746
19500.	1.17109	1.14873	1.10731
20000.	1.16802	1.14668	1.10676
20500.	1.16461	1.14419	1.10582
21000.	1.16091	1.14134	1.10451
21500.	1.15695	1.13820	1.10286
22000.	1.15277	1.13483	1.10087
22500.	1.14842	1.13127	1.09859
23000.	1.14395	1.12754	1.09606
23500.	1.13923	1.12369	1.09331
24000.	1.13452	1.11974	1.09038
24500.	1.12980	1.11571	1.08732
25000.	1.12508	1.11163	1.08414
25500.	1.12038	1.10744	1.08086
26000.	1.11568	1.10324	1.07751
26500.	1.11097	1.09905	1.07411
27000.	1.10627	1.09485	1.07066
27500.	1.10157	1.09066	1.06717
28000.	1.09684	1.08653	1.06367
28500.	1.09211	1.08240	1.06016
29000.	1.08737	1.07828	1.05664
30000.	1.07791	1.07002	1.04949
32500.	1.05404	1.04948	1.03204
35000.	1.02997	1.02905	1.01497
37500.	1.00573	1.00875	0.99826
40000.	0.98139	0.98861	0.98191
42500.	0.95702	0.96868	0.96595
45000.	0.93274	0.94901	0.95042
47500.	0.90871	0.92967	0.93533
50000.	0.88510	0.91074	0.92074
52500.	0.86211	0.89232	0.90666
55000.	0.83997	0.87449	0.89312
57500.	0.81888	0.85736	0.88015
60000.	0.79906	0.84103	0.86777
62500.	0.78070	0.82556	0.85600
65000.	0.76394	0.81105	0.84485
67500.	0.74887	0.79755	0.83435
70000.	0.73553	0.78509	0.82448

Table B.32 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.326	1.332	1.325
100.	1.322	1.328	1.321
500.	1.317	1.323	1.316
1000.	1.312	1.317	1.310
1500.	1.306	1.311	1.304
2000.	1.300	1.305	1.298
2500.	1.294	1.299	1.292
3000.	1.288	1.292	1.286
3500.	1.281	1.286	1.284
4000.	1.275	1.279	1.282
4500.	1.268	1.272	1.281
5000.	1.261	1.265	1.279
5500.	1.254	1.258	1.277
6000.	1.247	1.252	1.274
6500.	1.240	1.245	1.271
7000.	1.233	1.238	1.268
7500.	1.226	1.231	1.265
8000.	1.218	1.223	1.262
8500.	1.210	1.216	1.258
9000.	1.203	1.212	1.255
9500.	1.195	1.209	1.251
10000.	1.187	1.204	1.248
10500.	1.179	1.199	1.243
11000.	1.172	1.192	1.237
11500.	1.165	1.183	1.231
12000.	1.159	1.174	1.223
12500.	1.152	1.164	1.215
13000.	1.146	1.159	1.206
13500.	1.140	1.153	1.197
14000.	1.133	1.148	1.188
14500.	1.127	1.142	1.179
15000.	1.121	1.137	1.170
15500.	1.118	1.131	1.161
16000.	1.117	1.126	1.153
16500.	1.116	1.121	1.144
17000.	1.115	1.119	1.136
17500.	1.114	1.118	1.129
18000.	1.113	1.116	1.121
18500.	1.112	1.115	1.120
19000.	1.110	1.113	1.119
19500.	1.109	1.112	1.118
20000.	1.108	1.110	1.117
20500.	1.106	1.109	1.117
21000.	1.104	1.108	1.116
21500.	1.102	1.106	1.115
22000.	1.100	1.105	1.114
22500.	1.098	1.103	1.114
23000.	1.096	1.101	1.113
23500.	1.095	1.100	1.112
24000.	1.095	1.098	1.112
24500.	1.094	1.096	1.111
25000.	1.094	1.095	1.110
25500.	1.093	1.093	1.109
26000.	1.092	1.091	1.108
26500.	1.092	1.090	1.108
27000.	1.091	1.088	1.107
27500.	1.090	1.086	1.106
28000.	1.089	1.085	1.105
28500.	1.088	1.084	1.104
29000.	1.088	1.082	1.103
30000.	1.086	1.080	1.102
32500.	1.082	1.077	1.097
35000.	1.078	1.074	1.094
37500.	1.074	1.071	1.090
40000.	1.069	1.068	1.087
42500.	1.067	1.064	1.085
45000.	1.069	1.061	1.083
47500.	1.073	1.058	1.081
50000.	1.075	1.054	1.080
52500.	1.076	1.052	1.079
55000.	1.075	1.051	1.078
57500.	1.073	1.050	1.079
60000.	1.070	1.048	1.079
62500.	1.064	1.046	1.084
65000.	1.057	1.044	1.093
67500.	1.048	1.047	1.103
70000.	1.054	1.062	1.113

Table B.33 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.09552	1.07796	1.05572
100.	1.06856	1.05274	1.03303
500.	1.06516	1.05018	1.03136
1000.	1.06534	1.05101	1.03267
1500.	1.06685	1.05301	1.03487
2000.	1.06874	1.05530	1.03724
2500.	1.07074	1.05766	1.03959
3000.	1.07281	1.06000	1.04184
3500.	1.07500	1.06237	1.04405
4000.	1.07732	1.06482	1.04623
4500.	1.07976	1.06734	1.04842
5000.	1.08234	1.06994	1.05063
5500.	1.08510	1.07266	1.05287
6000.	1.08808	1.07552	1.05517
6500.	1.09129	1.07855	1.05756
7000.	1.09472	1.08176	1.06004
7500.	1.09836	1.08513	1.06264
8000.	1.10221	1.08867	1.06536
8500.	1.10633	1.09240	1.06821
9000.	1.11076	1.09635	1.07116
9500.	1.11544	1.10042	1.07417
10000.	1.12012	1.10439	1.07705
10500.	1.12461	1.10812	1.07971
11000.	1.12873	1.11150	1.08209
11500.	1.13245	1.11451	1.08416
12000.	1.13599	1.11732	1.08598
12500.	1.13961	1.12011	1.08766
13000.	1.14345	1.12300	1.08930
13500.	1.14756	1.12603	1.09096
14000.	1.15190	1.12918	1.09266
14500.	1.15641	1.13241	1.09440
15000.	1.16105	1.13566	1.09614
15500.	1.16568	1.13892	1.09784
16000.	1.17004	1.14211	1.09949
16500.	1.17386	1.14513	1.10108
17000.	1.17695	1.14782	1.10258
17500.	1.17910	1.15004	1.10397
18000.	1.18018	1.15175	1.10519
18500.	1.18014	1.15283	1.10619
19000.	1.17900	1.15320	1.10691
19500.	1.17691	1.15281	1.10736
20000.	1.17408	1.15168	1.10749
20500.	1.17071	1.14988	1.10729
21000.	1.16692	1.14749	1.10672
21500.	1.16282	1.14461	1.10576
22000.	1.15849	1.14135	1.10440
22500.	1.15399	1.13780	1.10266
23000.	1.14919	1.13403	1.10059
23500.	1.14439	1.13010	1.09821
24000.	1.13959	1.12606	1.09557
24500.	1.13479	1.12194	1.09270
25000.	1.12999	1.11769	1.08965
25500.	1.12520	1.11342	1.08645
26000.	1.12040	1.10916	1.08313
26500.	1.11561	1.10489	1.07973
27000.	1.11081	1.10063	1.07626
27500.	1.10602	1.09636	1.07275
28000.	1.10118	1.09215	1.06922
28500.	1.09634	1.08794	1.06567
30000.	1.08182	1.07532	1.05483
32500.	1.05739	1.05438	1.03720
35000.	1.03274	1.03355	1.01994
37500.	1.00791	1.01282	1.00302
40000.	0.98295	0.99224	0.98648
42500.	0.95796	0.97187	0.97032
45000.	0.93307	0.95175	0.95458
47500.	0.90844	0.93197	0.93930
50000.	0.88427	0.91261	0.92451
52500.	0.86077	0.89377	0.91024
55000.	0.83816	0.87555	0.89652
57500.	0.81670	0.85805	0.88337
60000.	0.79660	0.84138	0.87082
62500.	0.77806	0.82563	0.85889
65000.	0.76122	0.81088	0.84759
67500.	0.74617	0.79719	0.83695
70000.	0.73292	0.78460	0.82696

Table B.34 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.364	1.362	1.344
100.	1.359	1.358	1.340
500.	1.354	1.353	1.335
1000.	1.349	1.347	1.329
1500.	1.343	1.340	1.323
2000.	1.336	1.334	1.316
2500.	1.330	1.327	1.310
3000.	1.323	1.320	1.305
3500.	1.316	1.313	1.303
4000.	1.310	1.306	1.302
4500.	1.302	1.299	1.300
5000.	1.295	1.292	1.298
5500.	1.288	1.285	1.295
6000.	1.281	1.278	1.292
6500.	1.273	1.271	1.289
7000.	1.265	1.263	1.286
7500.	1.258	1.256	1.283
8000.	1.250	1.248	1.279
8500.	1.241	1.242	1.276
9000.	1.233	1.238	1.272
9500.	1.225	1.234	1.269
10000.	1.216	1.229	1.264
10500.	1.208	1.223	1.259
11000.	1.201	1.214	1.253
11500.	1.195	1.204	1.245
12000.	1.188	1.193	1.237
12500.	1.182	1.187	1.228
13000.	1.176	1.182	1.219
13500.	1.170	1.176	1.210
14000.	1.163	1.171	1.201
14500.	1.156	1.165	1.192
15000.	1.149	1.159	1.182
15500.	1.142	1.153	1.173
16000.	1.135	1.147	1.165
16500.	1.134	1.141	1.156
17000.	1.134	1.135	1.147
17500.	1.134	1.134	1.139
18000.	1.133	1.133	1.132
18500.	1.132	1.131	1.130
19000.	1.131	1.130	1.129
19500.	1.129	1.128	1.128
20000.	1.127	1.126	1.128
20500.	1.125	1.125	1.127
21000.	1.123	1.123	1.126
21500.	1.120	1.121	1.125
22000.	1.118	1.119	1.124
22500.	1.115	1.117	1.124
23000.	1.114	1.115	1.123
23500.	1.112	1.113	1.122
24000.	1.111	1.111	1.121
24500.	1.109	1.109	1.120
25000.	1.108	1.107	1.119
25500.	1.107	1.105	1.118
26000.	1.106	1.103	1.117
26500.	1.105	1.100	1.115
27000.	1.104	1.098	1.114
27500.	1.103	1.096	1.113
28000.	1.102	1.095	1.112
28500.	1.101	1.094	1.111
30000.	1.098	1.090	1.108
32500.	1.092	1.086	1.103
35000.	1.086	1.082	1.099
37500.	1.080	1.077	1.095
40000.	1.077	1.073	1.091
42500.	1.078	1.069	1.088
45000.	1.079	1.064	1.085
47500.	1.081	1.060	1.083
50000.	1.082	1.056	1.081
52500.	1.082	1.053	1.080
55000.	1.080	1.054	1.079
57500.	1.076	1.054	1.079
60000.	1.070	1.053	1.080
62500.	1.063	1.051	1.085
65000.	1.055	1.048	1.095
67500.	1.047	1.054	1.106
70000.	1.066	1.069	1.116

Table B.35 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.06981	1.05429	1.03330
100.	1.04304	1.02915	1.01061
500.	1.03984	1.02682	1.00922
1000.	1.04029	1.02799	1.01098
1500.	1.04213	1.03038	1.01367
2000.	1.04436	1.03309	1.01654
2500.	1.04671	1.03586	1.01939
3000.	1.04917	1.03865	1.02216
3500.	1.05177	1.04149	1.02487
4000.	1.05451	1.04442	1.02758
4500.	1.05741	1.04744	1.03031
5000.	1.06048	1.05056	1.03306
5500.	1.06376	1.05382	1.03585
6000.	1.06728	1.05725	1.03871
6500.	1.07106	1.06088	1.04166
7000.	1.07508	1.06470	1.04473
7500.	1.07933	1.06870	1.04792
8000.	1.08382	1.07288	1.05125
8500.	1.08858	1.07726	1.05471
9000.	1.09366	1.08188	1.05829
9500.	1.09908	1.08671	1.06197
10000.	1.10469	1.09157	1.06558
10500.	1.11027	1.09628	1.06900
11000.	1.11566	1.10074	1.07217
11500.	1.12073	1.10485	1.07503
12000.	1.12558	1.10872	1.07762
12500.	1.13050	1.11253	1.08005
13000.	1.13568	1.11645	1.08243
13500.	1.14123	1.12056	1.08485
14000.	1.14709	1.12485	1.08732
14500.	1.15306	1.12927	1.08984
15000.	1.15896	1.13375	1.09237
15500.	1.16451	1.13818	1.09489
16000.	1.16930	1.14242	1.09738
16500.	1.17301	1.14629	1.09980
17000.	1.17551	1.14956	1.10211
17500.	1.17681	1.15204	1.10425
18000.	1.17694	1.15366	1.10610
18500.	1.17603	1.15440	1.10763
19000.	1.17421	1.15426	1.10877
19500.	1.17169	1.15325	1.10948
20000.	1.16859	1.15146	1.10972
20500.	1.16504	1.14905	1.10947
21000.	1.16110	1.14614	1.10871
21500.	1.15685	1.14287	1.10746
22000.	1.15237	1.13931	1.10576
22500.	1.14771	1.13551	1.10364
23000.	1.14272	1.13154	1.10117
23500.	1.13774	1.12742	1.09840
24000.	1.13275	1.12321	1.09540
24500.	1.12777	1.11879	1.09222
25000.	1.12278	1.11438	1.08889
25500.	1.11778	1.10997	1.08545
26000.	1.11279	1.10556	1.08193
26500.	1.10779	1.10115	1.07834
27000.	1.10280	1.09674	1.07471
27500.	1.09780	1.09233	1.07105
30000.	1.07243	1.07042	1.05242
32500.	1.04667	1.04849	1.03421
35000.	1.02053	1.02654	1.01627
37500.	0.99405	1.00460	0.99862
40000.	0.96733	0.98271	0.98129
42500.	0.94048	0.96093	0.96431
45000.	0.91368	0.93935	0.94771
47500.	0.88715	0.91807	0.93154
50000.	0.86116	0.89720	0.91584
52500.	0.83600	0.87688	0.90066
55000.	0.81198	0.85727	0.88604
57500.	0.78942	0.83849	0.87201
60000.	0.76858	0.82071	0.85862
62500.	0.74970	0.80403	0.84590
65000.	0.73290	0.78856	0.83388
67500.	0.71823	0.77437	0.82258
70000.	0.70563	0.76152	0.81202

Table B.36 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.329	1.323	1.320
100.	1.326	1.319	1.317
500.	1.322	1.314	1.312
1000.	1.318	1.309	1.306
1500.	1.312	1.302	1.300
2000.	1.307	1.296	1.294
2500.	1.301	1.290	1.287
3000.	1.295	1.283	1.281
3500.	1.289	1.276	1.274
4000.	1.282	1.270	1.268
4500.	1.276	1.263	1.264
5000.	1.269	1.256	1.262
5500.	1.262	1.249	1.259
6000.	1.255	1.242	1.256
6500.	1.248	1.235	1.253
7000.	1.242	1.228	1.249
7500.	1.238	1.220	1.246
8000.	1.234	1.213	1.242
8500.	1.229	1.206	1.238
9000.	1.225	1.198	1.235
9500.	1.221	1.191	1.231
10000.	1.216	1.185	1.227
10500.	1.211	1.180	1.221
11000.	1.207	1.173	1.215
11500.	1.204	1.170	1.208
12000.	1.200	1.167	1.200
12500.	1.197	1.165	1.191
13000.	1.195	1.163	1.182
13500.	1.192	1.161	1.173
14000.	1.189	1.159	1.163
14500.	1.186	1.157	1.154
15000.	1.182	1.155	1.145
15500.	1.178	1.153	1.135
16000.	1.174	1.150	1.130
16500.	1.169	1.147	1.126
17000.	1.164	1.144	1.121
17500.	1.159	1.141	1.117
18000.	1.154	1.138	1.116
18500.	1.149	1.135	1.114
19000.	1.145	1.132	1.112
19500.	1.142	1.129	1.111
20000.	1.139	1.126	1.109
20500.	1.136	1.124	1.108
21000.	1.133	1.122	1.106
21500.	1.131	1.120	1.105
22000.	1.129	1.118	1.104
22500.	1.127	1.117	1.103
23000.	1.125	1.116	1.102
23500.	1.123	1.114	1.101
24000.	1.122	1.113	1.100
24500.	1.120	1.112	1.099
25000.	1.118	1.111	1.099
25500.	1.116	1.110	1.099
26000.	1.114	1.109	1.098
26500.	1.113	1.108	1.098
27000.	1.111	1.107	1.098
27500.	1.109	1.106	1.097
30000.	1.100	1.101	1.096
32500.	1.091	1.096	1.094
35000.	1.082	1.091	1.093
37500.	1.074	1.086	1.091
40000.	1.080	1.081	1.089
42500.	1.085	1.076	1.087
45000.	1.089	1.071	1.085
47500.	1.091	1.066	1.083
50000.	1.091	1.063	1.081
52500.	1.090	1.064	1.078
55000.	1.086	1.065	1.076
57500.	1.080	1.064	1.074
60000.	1.073	1.061	1.071
62500.	1.064	1.058	1.069
65000.	1.054	1.053	1.069
67500.	1.043	1.048	1.080
70000.	1.057	1.055	1.091

Table B.37 [] Hot Uncontrolled k_{∞}

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.02318	1.00840	0.98904
100.	0.99852	0.98543	0.96855
500.	0.99669	0.98461	0.96882
1000.	0.99889	0.98769	0.97258
1500.	1.00261	0.99210	0.97732
2000.	1.00677	0.99688	0.98228
2500.	1.01115	1.00180	0.98725
3000.	1.01582	1.00689	0.99222
3500.	1.02080	1.01219	0.99724
4000.	1.02610	1.01772	1.00235
4500.	1.03171	1.02346	1.00755
5000.	1.03766	1.02943	1.01283
5500.	1.04395	1.03565	1.01822
6000.	1.05058	1.04212	1.02373
6500.	1.05756	1.04886	1.02938
7000.	1.06491	1.05587	1.03520
7500.	1.07269	1.06319	1.04120
8000.	1.08093	1.07086	1.04740
8500.	1.08969	1.07891	1.05380
9000.	1.09897	1.08733	1.06039
9500.	1.10874	1.09602	1.06706
10000.	1.11881	1.10478	1.07367
10500.	1.12901	1.11349	1.08012
11000.	1.13915	1.12201	1.08635
11500.	1.14910	1.13022	1.09229
12000.	1.15888	1.13811	1.09791
12500.	1.16837	1.14561	1.10314
13000.	1.17741	1.15264	1.10795
13500.	1.18566	1.15905	1.11231
14000.	1.19272	1.16472	1.11617
14500.	1.19839	1.16962	1.11949
15000.	1.20246	1.17375	1.12229
15500.	1.20490	1.17713	1.12465
16000.	1.20577	1.17969	1.12665
16500.	1.20513	1.18128	1.12835
17000.	1.20321	1.18183	1.12974
17500.	1.20035	1.18134	1.13077
18000.	1.19684	1.17985	1.13141
18500.	1.19286	1.17748	1.13160
19000.	1.18852	1.17440	1.13129
19500.	1.18392	1.17079	1.13045
20000.	1.17901	1.16683	1.12908
20500.	1.17393	1.16263	1.12720
21000.	1.16885	1.15810	1.12486
21500.	1.16376	1.15357	1.12212
22000.	1.15868	1.14904	1.11903
22500.	1.15360	1.14451	1.11569
23000.	1.14850	1.14000	1.11216
23500.	1.14341	1.13549	1.10851
25000.	1.12812	1.12195	1.09695
27500.	1.10219	1.09938	1.07785
30000.	1.07576	1.07675	1.05902
32500.	1.04883	1.05404	1.04046
35000.	1.02142	1.03125	1.02218
37500.	0.99358	1.00840	1.00417
40000.	0.96543	0.98555	0.98647
42500.	0.93712	0.96278	0.96911
45000.	0.90887	0.94018	0.95214
47500.	0.88097	0.91789	0.93559
50000.	0.85374	0.89605	0.91953
52500.	0.82755	0.87482	0.90399
55000.	0.80277	0.85440	0.88903
57500.	0.77976	0.83494	0.87469
60000.	0.75881	0.81661	0.86101
62500.	0.74014	0.79957	0.84804
65000.	0.72385	0.78390	0.83581
67500.	0.70990	0.76969	0.82434
70000.	0.69817	0.75696	0.81365

Table B.38 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.460	1.368	1.341
100.	1.455	1.363	1.336
500.	1.448	1.357	1.330
1000.	1.439	1.351	1.324
1500.	1.430	1.343	1.318
2000.	1.420	1.335	1.315
2500.	1.410	1.327	1.311
3000.	1.399	1.319	1.307
3500.	1.388	1.311	1.302
4000.	1.377	1.302	1.297
4500.	1.365	1.293	1.292
5000.	1.354	1.284	1.286
5500.	1.342	1.276	1.280
6000.	1.330	1.267	1.274
6500.	1.318	1.257	1.268
7000.	1.309	1.250	1.261
7500.	1.302	1.245	1.255
8000.	1.294	1.239	1.248
8500.	1.287	1.233	1.241
9000.	1.279	1.227	1.235
9500.	1.271	1.221	1.227
10000.	1.262	1.215	1.219
10500.	1.255	1.210	1.210
11000.	1.247	1.204	1.200
11500.	1.240	1.199	1.189
12000.	1.233	1.194	1.178
12500.	1.227	1.190	1.166
13000.	1.221	1.185	1.154
13500.	1.216	1.181	1.143
14000.	1.211	1.178	1.138
14500.	1.207	1.175	1.136
15000.	1.202	1.172	1.134
15500.	1.197	1.169	1.132
16000.	1.192	1.166	1.130
16500.	1.187	1.163	1.129
17000.	1.183	1.160	1.127
17500.	1.179	1.157	1.126
18000.	1.176	1.155	1.124
18500.	1.172	1.152	1.123
19000.	1.169	1.150	1.122
19500.	1.167	1.148	1.120
20000.	1.164	1.146	1.119
20500.	1.162	1.145	1.118
21000.	1.159	1.143	1.117
21500.	1.157	1.142	1.116
22000.	1.154	1.141	1.116
22500.	1.152	1.139	1.115
23000.	1.149	1.138	1.114
23500.	1.147	1.136	1.114
25000.	1.139	1.132	1.113
27500.	1.127	1.124	1.111
30000.	1.114	1.117	1.109
32500.	1.102	1.110	1.107
35000.	1.089	1.103	1.104
37500.	1.089	1.096	1.102
40000.	1.092	1.089	1.099
42500.	1.093	1.082	1.097
45000.	1.094	1.076	1.094
47500.	1.094	1.072	1.091
50000.	1.093	1.073	1.088
52500.	1.089	1.073	1.086
55000.	1.084	1.072	1.083
57500.	1.076	1.069	1.080
60000.	1.068	1.066	1.078
62500.	1.058	1.061	1.075
65000.	1.048	1.055	1.073
67500.	1.053	1.055	1.078
70000.	1.059	1.057	1.089

Table B.39 [] Hot Uncontrolled k_{∞}

Exposure MWd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.08066	1.06894	1.05221
100.	1.05371	1.04350	1.02913
500.	1.05228	1.04291	1.02928
1000.	1.05563	1.04689	1.03340
1500.	1.06067	1.05238	1.03864
2000.	1.06623	1.05826	1.04409
2500.	1.07214	1.06434	1.04952
3000.	1.07845	1.07065	1.05495
3500.	1.08526	1.07726	1.06045
4000.	1.09265	1.08424	1.06608
4500.	1.10062	1.09163	1.07187
5000.	1.10918	1.09941	1.07786
5500.	1.11836	1.10760	1.08402
6000.	1.12827	1.11622	1.09038
6500.	1.13900	1.12536	1.09695
7000.	1.15064	1.13507	1.10377
7500.	1.16313	1.14536	1.11089
8000.	1.17617	1.15618	1.11829
8500.	1.18924	1.16737	1.12597
9000.	1.20166	1.17857	1.13386
9500.	1.21271	1.18928	1.14180
10000.	1.22195	1.19891	1.14944
10500.	1.22910	1.20691	1.15640
11000.	1.23416	1.21300	1.16241
11500.	1.23726	1.21703	1.16723
12000.	1.23849	1.21905	1.17075
12500.	1.23802	1.21933	1.17297
13000.	1.23620	1.21826	1.17402
13500.	1.23335	1.21619	1.17400
14000.	1.22975	1.21339	1.17307
14500.	1.22562	1.21003	1.17137
15000.	1.22112	1.20625	1.16905
15500.	1.21638	1.20217	1.16626
16000.	1.21150	1.19787	1.16310
16500.	1.20634	1.19343	1.15966
17000.	1.20118	1.18890	1.15602
17500.	1.19602	1.18422	1.15222
18000.	1.19086	1.17952	1.14831
18500.	1.18570	1.17482	1.14433
19000.	1.18055	1.17012	1.14031
19500.	1.17539	1.16542	1.13626
20000.	1.17023	1.16072	1.13220
22500.	1.14431	1.13752	1.11177
25000.	1.11795	1.11433	1.09187
27500.	1.09111	1.09109	1.07230
30000.	1.06375	1.06776	1.05305
32500.	1.03587	1.04436	1.03408
35000.	1.00753	1.02089	1.01542
37500.	0.97883	0.99741	0.99707
40000.	0.94993	0.97400	0.97907
42500.	0.92103	0.95074	0.96147
45000.	0.89244	0.92779	0.94430
47500.	0.86447	0.90528	0.92763
50000.	0.83752	0.88339	0.91151
52500.	0.81198	0.86233	0.89600
55000.	0.78823	0.84227	0.88115
57500.	0.76659	0.82338	0.86700
60000.	0.74730	0.80584	0.85360
62500.	0.73047	0.78974	0.84099
65000.	0.71607	0.77517	0.82920
67500.	0.70397	0.76215	0.81823
70000.	0.69395	0.75066	0.80809

Table B.40 [] Hot Uncontrolled LPF

Exposure Mwd/MTU	0.00 Void History	0.40 Void History	0.80 Void History
0.	1.323	1.300	1.289
100.	1.321	1.298	1.287
500.	1.315	1.293	1.282
1000.	1.308	1.286	1.277
1500.	1.300	1.279	1.271
2000.	1.292	1.271	1.265
2500.	1.283	1.262	1.258
3000.	1.273	1.253	1.251
3500.	1.264	1.244	1.244
4000.	1.253	1.235	1.237
4500.	1.243	1.226	1.230
5000.	1.232	1.216	1.223
5500.	1.221	1.206	1.217
6000.	1.210	1.196	1.211
6500.	1.198	1.186	1.204
7000.	1.186	1.175	1.198
7500.	1.173	1.165	1.190
8000.	1.161	1.156	1.183
8500.	1.148	1.152	1.176
9000.	1.142	1.147	1.168
9500.	1.140	1.144	1.161
10000.	1.138	1.140	1.154
10500.	1.137	1.137	1.146
11000.	1.136	1.135	1.139
11500.	1.136	1.134	1.134
12000.	1.135	1.133	1.132
12500.	1.134	1.132	1.131
13000.	1.133	1.131	1.130
13500.	1.132	1.130	1.129
14000.	1.131	1.129	1.129
14500.	1.129	1.127	1.128
15000.	1.127	1.126	1.127
15500.	1.125	1.124	1.126
16000.	1.123	1.122	1.125
16500.	1.121	1.120	1.124
17000.	1.118	1.118	1.123
17500.	1.116	1.117	1.122
18000.	1.114	1.115	1.121
18500.	1.111	1.113	1.120
19000.	1.109	1.111	1.119
19500.	1.106	1.109	1.117
20000.	1.104	1.107	1.116
22500.	1.092	1.097	1.110
25000.	1.086	1.087	1.104
27500.	1.088	1.078	1.099
30000.	1.091	1.074	1.093
32500.	1.093	1.073	1.088
35000.	1.095	1.072	1.083
37500.	1.096	1.072	1.079
40000.	1.096	1.072	1.076
42500.	1.097	1.072	1.073
45000.	1.096	1.073	1.070
47500.	1.093	1.074	1.068
50000.	1.089	1.073	1.066
52500.	1.082	1.070	1.065
55000.	1.074	1.067	1.065
57500.	1.065	1.063	1.065
60000.	1.054	1.057	1.066
62500.	1.044	1.051	1.069
65000.	1.042	1.044	1.080
67500.	1.054	1.055	1.090
70000.	1.068	1.069	1.100

Appendix C Enriched Lattice Isotopic Data Tables

The results in this appendix are based on hot operating and equilibrium xenon conditions.

**Table C.1 [] Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.327	43.320	0.000	956.353	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.327	43.200	0.023	956.298	0.000	0.000	0.020	0.000	0.000	0.000
500.0	0.325	42.723	0.113	956.075	0.002	0.000	0.199	0.002	0.000	0.000
1000.0	0.323	42.135	0.225	955.796	0.004	0.000	0.430	0.007	0.000	0.000
1500.0	0.321	41.556	0.334	955.518	0.006	0.000	0.651	0.016	0.001	0.000
2000.0	0.319	40.985	0.442	955.239	0.008	0.000	0.861	0.027	0.003	0.000
2500.0	0.318	40.422	0.548	954.961	0.011	0.000	1.062	0.042	0.005	0.000
3000.0	0.316	39.867	0.652	954.682	0.014	0.000	1.252	0.059	0.008	0.000
3500.0	0.314	39.320	0.754	954.404	0.017	0.001	1.434	0.077	0.012	0.000
4000.0	0.312	38.779	0.855	954.126	0.020	0.001	1.607	0.098	0.017	0.000
4500.0	0.310	38.245	0.954	953.848	0.024	0.001	1.772	0.120	0.024	0.001
5000.0	0.308	37.717	1.052	953.571	0.027	0.001	1.930	0.143	0.031	0.001
5500.0	0.306	37.196	1.149	953.293	0.031	0.001	2.080	0.167	0.039	0.001
6000.0	0.305	36.681	1.243	953.016	0.035	0.002	2.223	0.193	0.049	0.002
6500.0	0.303	36.171	1.337	952.739	0.039	0.002	2.359	0.220	0.059	0.003
7000.0	0.301	35.667	1.429	952.463	0.043	0.003	2.488	0.247	0.070	0.003
7500.0	0.299	35.169	1.520	952.187	0.047	0.003	2.611	0.275	0.082	0.004
8000.0	0.298	34.676	1.610	951.911	0.052	0.003	2.728	0.304	0.094	0.005
8500.0	0.296	34.188	1.698	951.636	0.056	0.004	2.840	0.333	0.108	0.006
9000.0	0.294	33.705	1.785	951.361	0.061	0.005	2.945	0.363	0.122	0.008
9500.0	0.292	33.227	1.871	951.086	0.065	0.005	3.045	0.393	0.136	0.009
10000.0	0.291	32.753	1.956	950.812	0.070	0.006	3.140	0.424	0.151	0.011
10500.0	0.289	32.284	2.040	950.539	0.075	0.007	3.230	0.455	0.167	0.013
11000.0	0.287	31.819	2.122	950.266	0.080	0.007	3.315	0.487	0.183	0.015
11500.0	0.286	31.359	2.203	949.993	0.085	0.008	3.395	0.519	0.199	0.017
12000.0	0.284	30.903	2.284	949.721	0.091	0.009	3.472	0.551	0.216	0.019
12500.0	0.282	30.451	2.363	949.449	0.096	0.010	3.543	0.583	0.232	0.022
13000.0	0.281	30.003	2.441	949.177	0.101	0.011	3.611	0.616	0.250	0.024
13500.0	0.279	29.559	2.518	948.906	0.107	0.012	3.675	0.648	0.267	0.027
14000.0	0.277	29.119	2.595	948.634	0.112	0.013	3.736	0.681	0.284	0.030
14500.0	0.276	28.682	2.670	948.363	0.118	0.014	3.792	0.714	0.302	0.034
15000.0	0.274	28.250	2.744	948.092	0.123	0.015	3.846	0.747	0.320	0.037
15500.0	0.273	27.820	2.818	947.821	0.129	0.016	3.896	0.780	0.338	0.041
16000.0	0.271	27.395	2.890	947.550	0.135	0.017	3.944	0.813	0.356	0.045
16500.0	0.269	26.972	2.962	947.279	0.141	0.019	3.989	0.846	0.374	0.049
17000.0	0.268	26.554	3.033	947.007	0.147	0.020	4.031	0.879	0.392	0.053
17500.0	0.266	26.139	3.103	946.734	0.153	0.021	4.071	0.911	0.410	0.058
18000.0	0.265	25.727	3.172	946.460	0.159	0.023	4.109	0.944	0.428	0.063
18500.0	0.263	25.319	3.240	946.186	0.165	0.024	4.144	0.977	0.446	0.068
19000.0	0.262	24.915	3.307	945.910	0.171	0.026	4.178	1.010	0.464	0.073
19500.0	0.260	24.514	3.374	945.633	0.177	0.028	4.210	1.042	0.482	0.078
20000.0	0.258	24.116	3.439	945.355	0.183	0.029	4.240	1.074	0.501	0.084
20500.0	0.257	23.723	3.504	945.076	0.190	0.031	4.268	1.106	0.519	0.090
21000.0	0.255	23.333	3.568	944.795	0.196	0.033	4.295	1.139	0.537	0.096
22500.0	0.251	22.183	3.756	943.945	0.216	0.039	4.367	1.234	0.591	0.115
25000.0	0.243	20.338	4.051	942.498	0.249	0.050	4.460	1.388	0.681	0.153
27500.0	0.235	18.581	4.327	941.013	0.284	0.063	4.522	1.537	0.766	0.196
30000.0	0.227	16.911	4.582	939.488	0.320	0.078	4.558	1.679	0.846	0.245
32500.0	0.220	15.329	4.817	937.922	0.356	0.095	4.573	1.816	0.920	0.299
35000.0	0.212	13.833	5.033	936.313	0.393	0.114	4.568	1.945	0.987	0.359
37500.0	0.205	12.424	5.228	934.657	0.430	0.134	4.548	2.066	1.048	0.425
40000.0	0.197	11.102	5.405	932.953	0.466	0.157	4.515	2.180	1.101	0.495
42500.0	0.190	9.868	5.561	931.200	0.503	0.180	4.471	2.284	1.147	0.571
45000.0	0.182	8.721	5.699	929.394	0.538	0.206	4.420	2.380	1.186	0.651
47500.0	0.175	7.662	5.817	927.535	0.573	0.232	4.363	2.467	1.218	0.735
50000.0	0.168	6.689	5.916	925.620	0.606	0.259	4.303	2.545	1.244	0.822
52500.0	0.161	5.803	5.997	923.650	0.638	0.286	4.241	2.614	1.264	0.913
55000.0	0.154	5.001	6.060	921.623	0.669	0.314	4.178	2.674	1.279	1.007
57500.0	0.147	4.281	6.106	919.539	0.697	0.341	4.117	2.726	1.289	1.103
60000.0	0.141	3.641	6.135	917.400	0.724	0.368	4.057	2.770	1.296	1.201
62500.0	0.134	3.076	6.148	915.206	0.748	0.394	4.001	2.806	1.298	1.300
65000.0	0.128	2.583	6.148	912.962	0.770	0.419	3.948	2.835	1.298	1.399
67500.0	0.122	2.157	6.133	910.669	0.790	0.442	3.900	2.858	1.296	1.499
70000.0	0.116	1.791	6.107	908.331	0.807	0.464	3.855	2.875	1.293	1.598

**Table C.2 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.327	43.320	0.000	956.353	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.327	43.200	0.024	956.290	0.000	0.000	0.022	0.000	0.000	0.000
500.0	0.325	42.725	0.118	956.037	0.002	0.000	0.225	0.002	0.000	0.000
1000.0	0.323	42.141	0.233	955.719	0.004	0.000	0.487	0.008	0.000	0.000
1500.0	0.321	41.566	0.347	955.402	0.007	0.000	0.736	0.018	0.001	0.000
2000.0	0.318	41.001	0.458	955.086	0.010	0.000	0.973	0.031	0.003	0.000
2500.0	0.316	40.445	0.567	954.770	0.013	0.000	1.199	0.047	0.006	0.000
3000.0	0.314	39.898	0.674	954.454	0.016	0.001	1.414	0.065	0.010	0.000
3500.0	0.312	39.358	0.779	954.138	0.020	0.001	1.619	0.086	0.016	0.000
4000.0	0.310	38.827	0.883	953.823	0.024	0.001	1.815	0.108	0.022	0.001
4500.0	0.308	38.302	0.985	953.508	0.028	0.001	2.001	0.132	0.030	0.001
5000.0	0.306	37.785	1.085	953.193	0.032	0.002	2.179	0.157	0.039	0.001
5500.0	0.304	37.275	1.183	952.879	0.037	0.002	2.349	0.183	0.049	0.002
6000.0	0.302	36.771	1.280	952.565	0.041	0.002	2.511	0.210	0.061	0.002
6500.0	0.300	36.273	1.375	952.252	0.046	0.003	2.666	0.239	0.073	0.003
7000.0	0.298	35.782	1.469	951.939	0.051	0.003	2.813	0.268	0.086	0.004
7500.0	0.296	35.296	1.561	951.627	0.056	0.004	2.954	0.298	0.101	0.005
8000.0	0.294	34.816	1.652	951.315	0.061	0.005	3.088	0.328	0.116	0.006
8500.0	0.292	34.342	1.741	951.003	0.067	0.005	3.216	0.359	0.132	0.008
9000.0	0.290	33.873	1.829	950.692	0.072	0.006	3.337	0.391	0.148	0.009
9500.0	0.288	33.410	1.915	950.382	0.078	0.007	3.453	0.423	0.165	0.011
10000.0	0.287	32.951	2.001	950.072	0.083	0.008	3.563	0.456	0.183	0.013
10500.0	0.285	32.497	2.085	949.763	0.089	0.009	3.667	0.488	0.201	0.015
11000.0	0.283	32.048	2.168	949.455	0.095	0.010	3.767	0.522	0.220	0.017
11500.0	0.281	31.604	2.249	949.147	0.101	0.011	3.861	0.555	0.239	0.020
12000.0	0.279	31.164	2.330	948.839	0.108	0.012	3.951	0.589	0.258	0.022
12500.0	0.277	30.728	2.409	948.532	0.114	0.013	4.036	0.623	0.278	0.025
13000.0	0.276	30.297	2.487	948.225	0.120	0.014	4.117	0.657	0.298	0.028
13500.0	0.274	29.870	2.564	947.918	0.127	0.015	4.194	0.692	0.318	0.032
14000.0	0.272	29.447	2.640	947.612	0.133	0.017	4.266	0.726	0.338	0.035
14500.0	0.270	29.028	2.715	947.306	0.140	0.018	4.336	0.761	0.358	0.039
15000.0	0.269	28.612	2.789	947.000	0.146	0.020	4.401	0.795	0.379	0.043
15500.0	0.267	28.201	2.862	946.694	0.153	0.021	4.463	0.830	0.399	0.047
16000.0	0.265	27.793	2.934	946.389	0.159	0.023	4.522	0.865	0.420	0.051
16500.0	0.263	27.390	3.005	946.082	0.166	0.024	4.578	0.899	0.440	0.055
17000.0	0.262	26.989	3.075	945.776	0.173	0.026	4.631	0.934	0.461	0.060
17500.0	0.260	26.593	3.144	945.469	0.180	0.028	4.681	0.969	0.482	0.065
18000.0	0.258	26.200	3.212	945.162	0.187	0.030	4.729	1.003	0.502	0.070
18500.0	0.257	25.811	3.280	944.854	0.194	0.032	4.775	1.038	0.523	0.076
19000.0	0.255	25.425	3.346	944.545	0.201	0.034	4.818	1.072	0.544	0.081
19500.0	0.253	25.043	3.412	944.236	0.208	0.036	4.860	1.106	0.564	0.087
20000.0	0.252	24.664	3.476	943.925	0.215	0.038	4.899	1.140	0.585	0.093
20500.0	0.250	24.289	3.540	943.613	0.222	0.041	4.937	1.174	0.606	0.099
21000.0	0.248	23.918	3.603	943.300	0.229	0.043	4.972	1.208	0.626	0.105
21500.0	0.247	23.550	3.665	942.986	0.237	0.045	5.007	1.242	0.647	0.112
22000.0	0.245	23.186	3.726	942.670	0.244	0.048	5.039	1.275	0.667	0.119
22500.0	0.243	22.825	3.787	942.354	0.252	0.050	5.070	1.308	0.688	0.126
25000.0	0.235	21.075	4.076	940.749	0.290	0.065	5.204	1.471	0.789	0.164
27500.0	0.227	19.411	4.343	939.110	0.329	0.081	5.306	1.628	0.887	0.208
30000.0	0.219	17.832	4.591	937.435	0.369	0.100	5.379	1.780	0.979	0.257
32500.0	0.212	16.337	4.818	935.724	0.409	0.120	5.429	1.925	1.066	0.311
35000.0	0.204	14.925	5.026	933.976	0.449	0.143	5.458	2.063	1.146	0.369
37500.0	0.197	13.593	5.214	932.188	0.489	0.168	5.468	2.193	1.219	0.433
40000.0	0.189	12.341	5.384	930.362	0.529	0.195	5.464	2.316	1.286	0.500
42500.0	0.182	11.168	5.536	928.496	0.568	0.224	5.448	2.432	1.346	0.571
45000.0	0.175	10.072	5.669	926.588	0.606	0.254	5.420	2.539	1.399	0.645
47500.0	0.168	9.051	5.786	924.640	0.642	0.285	5.385	2.638	1.445	0.723
50000.0	0.162	8.105	5.885	922.650	0.678	0.318	5.343	2.728	1.485	0.803
52500.0	0.155	7.231	5.968	920.618	0.712	0.351	5.297	2.811	1.520	0.886
55000.0	0.149	6.428	6.034	918.545	0.744	0.384	5.247	2.885	1.548	0.971
57500.0	0.143	5.693	6.086	916.430	0.774	0.418	5.195	2.952	1.572	1.057
60000.0	0.137	5.023	6.123	914.276	0.803	0.452	5.142	3.011	1.591	1.145
62500.0	0.131	4.416	6.146	912.082	0.830	0.485	5.090	3.063	1.605	1.234
65000.0	0.126	3.869	6.157	909.851	0.854	0.517	5.038	3.109	1.616	1.324
67500.0	0.120	3.378	6.155	907.584	0.877	0.548	4.988	3.148	1.624	1.413
70000.0	0.115	2.940	6.142	905.282	0.897	0.579	4.940	3.181	1.629	1.503

**Table C.3 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.327	43.320	0.000	956.353	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.327	43.201	0.025	956.280	0.000	0.000	0.025	0.000	0.000	0.000
500.0	0.325	42.729	0.124	955.987	0.002	0.000	0.257	0.002	0.000	0.000
1000.0	0.322	42.151	0.245	955.621	0.005	0.000	0.556	0.009	0.001	0.000
1500.0	0.320	41.583	0.363	955.256	0.008	0.000	0.840	0.020	0.002	0.000
2000.0	0.317	41.026	0.479	954.891	0.012	0.000	1.111	0.034	0.004	0.000
2500.0	0.315	40.479	0.592	954.526	0.016	0.000	1.370	0.052	0.008	0.000
3000.0	0.312	39.941	0.704	954.162	0.020	0.001	1.616	0.072	0.014	0.000
3500.0	0.310	39.412	0.813	953.799	0.024	0.001	1.852	0.093	0.020	0.000
4000.0	0.308	38.891	0.920	953.436	0.029	0.001	2.078	0.117	0.029	0.001
4500.0	0.305	38.379	1.025	953.073	0.034	0.002	2.293	0.142	0.038	0.001
5000.0	0.303	37.874	1.128	952.711	0.039	0.002	2.499	0.169	0.050	0.002
5500.0	0.301	37.376	1.230	952.350	0.045	0.003	2.697	0.196	0.062	0.002
6000.0	0.298	36.885	1.329	951.988	0.050	0.003	2.886	0.225	0.075	0.003
6500.0	0.296	36.401	1.427	951.628	0.056	0.004	3.067	0.255	0.090	0.004
7000.0	0.294	35.924	1.523	951.267	0.062	0.005	3.241	0.286	0.106	0.005
7500.0	0.292	35.453	1.617	950.908	0.068	0.006	3.407	0.317	0.123	0.006
8000.0	0.289	34.988	1.710	950.549	0.075	0.006	3.566	0.349	0.140	0.007
8500.0	0.287	34.529	1.801	950.190	0.081	0.007	3.718	0.382	0.159	0.009
9000.0	0.285	34.076	1.891	949.832	0.088	0.009	3.864	0.415	0.178	0.011
9500.0	0.283	33.629	1.979	949.475	0.095	0.010	4.004	0.449	0.197	0.013
10000.0	0.281	33.186	2.066	949.118	0.102	0.011	4.137	0.483	0.217	0.015
10500.0	0.279	32.749	2.152	948.762	0.109	0.012	4.265	0.518	0.238	0.017
11000.0	0.277	32.317	2.236	948.407	0.116	0.013	4.387	0.553	0.259	0.019
11500.0	0.275	31.890	2.319	948.052	0.123	0.015	4.505	0.588	0.281	0.022
12000.0	0.273	31.468	2.400	947.697	0.131	0.016	4.617	0.624	0.303	0.025
12500.0	0.271	31.051	2.480	947.343	0.138	0.018	4.724	0.660	0.325	0.028
13000.0	0.269	30.638	2.559	946.990	0.146	0.020	4.827	0.696	0.347	0.031
13500.0	0.267	30.229	2.637	946.636	0.153	0.022	4.925	0.733	0.370	0.035
14000.0	0.265	29.825	2.714	946.283	0.161	0.023	5.019	0.770	0.393	0.038
14500.0	0.263	29.425	2.789	945.930	0.168	0.025	5.109	0.807	0.415	0.042
15000.0	0.261	29.029	2.863	945.578	0.176	0.027	5.195	0.844	0.438	0.046
15500.0	0.259	28.637	2.937	945.225	0.184	0.030	5.277	0.881	0.461	0.050
16000.0	0.257	28.250	3.009	944.873	0.192	0.032	5.356	0.918	0.485	0.055
16500.0	0.255	27.866	3.080	944.520	0.200	0.034	5.432	0.955	0.508	0.059
17000.0	0.254	27.486	3.150	944.167	0.208	0.037	5.504	0.993	0.531	0.064
17500.0	0.252	27.110	3.219	943.814	0.216	0.039	5.574	1.030	0.554	0.069
18000.0	0.250	26.737	3.287	943.461	0.224	0.042	5.641	1.067	0.577	0.074
18500.0	0.248	26.369	3.354	943.107	0.232	0.044	5.705	1.105	0.600	0.080
19000.0	0.246	26.004	3.420	942.753	0.241	0.047	5.766	1.142	0.624	0.085
19500.0	0.244	25.642	3.485	942.398	0.249	0.050	5.825	1.179	0.647	0.091
20000.0	0.243	25.285	3.549	942.043	0.257	0.053	5.882	1.216	0.670	0.097
20500.0	0.241	24.931	3.612	941.687	0.265	0.056	5.936	1.253	0.693	0.103
21000.0	0.239	24.580	3.675	941.330	0.274	0.059	5.989	1.290	0.716	0.110
21500.0	0.237	24.233	3.736	940.972	0.282	0.062	6.040	1.327	0.739	0.116
22000.0	0.236	23.890	3.797	940.613	0.291	0.066	6.088	1.364	0.762	0.123
22500.0	0.234	23.549	3.856	940.253	0.299	0.069	6.135	1.400	0.784	0.130
23000.0	0.232	23.213	3.915	939.892	0.307	0.073	6.181	1.437	0.807	0.137
23500.0	0.230	22.880	3.973	939.529	0.316	0.076	6.224	1.473	0.830	0.144
24000.0	0.229	22.551	4.030	939.166	0.324	0.080	6.266	1.509	0.852	0.151
24500.0	0.227	22.225	4.086	938.802	0.333	0.084	6.307	1.545	0.875	0.159
25000.0	0.225	21.902	4.141	938.436	0.342	0.088	6.346	1.581	0.897	0.167
25500.0	0.224	21.583	4.196	938.069	0.350	0.092	6.384	1.616	0.919	0.175
27500.0	0.217	20.339	4.405	936.588	0.385	0.109	6.522	1.756	1.007	0.208
30000.0	0.209	18.859	4.648	934.709	0.428	0.133	6.668	1.926	1.114	0.254
32500.0	0.201	17.459	4.870	932.797	0.471	0.160	6.787	2.090	1.216	0.303
35000.0	0.193	16.136	5.074	930.853	0.514	0.189	6.883	2.249	1.312	0.357
37500.0	0.186	14.890	5.258	928.878	0.557	0.220	6.958	2.401	1.404	0.413
40000.0	0.179	13.716	5.424	926.870	0.599	0.253	7.015	2.546	1.489	0.473
42500.0	0.172	12.614	5.572	924.831	0.640	0.289	7.057	2.685	1.568	0.536
45000.0	0.165	11.580	5.703	922.760	0.680	0.326	7.085	2.816	1.642	0.602
47500.0	0.158	10.613	5.818	920.658	0.718	0.365	7.102	2.941	1.710	0.669
50000.0	0.152	9.710	5.916	918.526	0.756	0.405	7.109	3.058	1.772	0.739
52500.0	0.146	8.869	6.000	916.363	0.791	0.446	7.108	3.168	1.829	0.811
55000.0	0.140	8.088	6.069	914.172	0.825	0.489	7.100	3.271	1.881	0.885
57500.0	0.135	7.363	6.125	911.952	0.858	0.531	7.086	3.367	1.928	0.961
60000.0	0.130	6.693	6.167	909.705	0.888	0.574	7.068	3.456	1.971	1.037
62500.0	0.125	6.074	6.197	907.431	0.917	0.617	7.047	3.539	2.009	1.115
65000.0	0.120	5.504	6.216	905.132	0.943	0.660	7.023	3.615	2.043	1.195
67500.0	0.116	4.981	6.224	902.810	0.967	0.702	6.996	3.686	2.073	1.275
70000.0	0.111	4.502	6.222	900.465	0.990	0.743	6.969	3.750	2.100	1.356

**Table C.4 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.330	43.785	0.000	955.885	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.330	43.665	0.023	955.831	0.000	0.000	0.019	0.000	0.000	0.000
500.0	0.328	43.187	0.113	955.615	0.002	0.000	0.193	0.001	0.000	0.000
1000.0	0.326	42.598	0.224	955.345	0.003	0.000	0.418	0.007	0.000	0.000
1500.0	0.325	42.018	0.333	955.074	0.006	0.000	0.633	0.015	0.001	0.000
2000.0	0.323	41.446	0.440	954.803	0.008	0.000	0.837	0.026	0.002	0.000
2500.0	0.321	40.882	0.546	954.532	0.011	0.000	1.033	0.040	0.004	0.000
3000.0	0.319	40.325	0.650	954.260	0.013	0.000	1.219	0.056	0.008	0.000
3500.0	0.317	39.775	0.752	953.989	0.016	0.001	1.398	0.075	0.011	0.000
4000.0	0.315	39.231	0.853	953.717	0.019	0.001	1.568	0.094	0.016	0.000
4500.0	0.313	38.695	0.953	953.446	0.023	0.001	1.730	0.116	0.022	0.001
5000.0	0.312	38.165	1.050	953.174	0.026	0.001	1.885	0.138	0.029	0.001
5500.0	0.310	37.640	1.147	952.902	0.030	0.001	2.033	0.162	0.037	0.001
6000.0	0.308	37.122	1.242	952.631	0.034	0.002	2.174	0.187	0.046	0.002
6500.0	0.306	36.610	1.336	952.359	0.038	0.002	2.309	0.213	0.056	0.002
7000.0	0.305	36.103	1.429	952.087	0.042	0.002	2.438	0.240	0.066	0.003
7500.0	0.303	35.601	1.520	951.815	0.046	0.003	2.560	0.267	0.078	0.004
8000.0	0.301	35.105	1.610	951.543	0.050	0.003	2.677	0.295	0.090	0.005
8500.0	0.299	34.614	1.699	951.272	0.055	0.004	2.789	0.324	0.103	0.006
9000.0	0.298	34.127	1.786	951.000	0.059	0.004	2.895	0.354	0.116	0.007
9500.0	0.296	33.646	1.873	950.728	0.064	0.005	2.996	0.383	0.130	0.009
10000.0	0.294	33.169	1.958	950.457	0.069	0.006	3.092	0.414	0.145	0.010
10500.0	0.292	32.697	2.042	950.185	0.074	0.006	3.183	0.444	0.160	0.012
11000.0	0.291	32.230	2.125	949.914	0.079	0.007	3.269	0.475	0.176	0.014
11500.0	0.289	31.766	2.207	949.643	0.084	0.008	3.351	0.507	0.192	0.016
12000.0	0.287	31.307	2.288	949.372	0.089	0.009	3.429	0.538	0.209	0.018
12500.0	0.286	30.853	2.368	949.101	0.094	0.009	3.503	0.570	0.225	0.021
13000.0	0.284	30.402	2.447	948.830	0.100	0.010	3.573	0.602	0.242	0.023
13500.0	0.282	29.955	2.525	948.559	0.105	0.011	3.639	0.634	0.260	0.026
14000.0	0.281	29.512	2.601	948.288	0.111	0.012	3.702	0.667	0.277	0.029
14500.0	0.279	29.073	2.677	948.017	0.116	0.013	3.761	0.699	0.295	0.032
15000.0	0.277	28.638	2.752	947.747	0.122	0.015	3.816	0.732	0.312	0.036
15500.0	0.276	28.206	2.826	947.476	0.128	0.016	3.869	0.765	0.330	0.039
16000.0	0.274	27.778	2.899	947.205	0.134	0.017	3.918	0.797	0.348	0.043
16500.0	0.273	27.353	2.971	946.934	0.140	0.018	3.965	0.830	0.366	0.047
17000.0	0.271	26.932	3.043	946.663	0.145	0.020	4.008	0.863	0.384	0.051
17500.0	0.269	26.515	3.113	946.391	0.151	0.021	4.050	0.895	0.402	0.056
18000.0	0.268	26.101	3.183	946.118	0.157	0.022	4.089	0.928	0.420	0.061
18500.0	0.266	25.690	3.252	945.845	0.164	0.024	4.126	0.961	0.438	0.065
19000.0	0.265	25.283	3.320	945.570	0.170	0.025	4.161	0.993	0.456	0.070
19500.0	0.263	24.880	3.387	945.294	0.176	0.027	4.194	1.025	0.474	0.076
20000.0	0.262	24.480	3.453	945.017	0.182	0.029	4.226	1.058	0.492	0.081
20500.0	0.260	24.083	3.518	944.739	0.189	0.031	4.255	1.090	0.511	0.087
21000.0	0.258	23.691	3.583	944.460	0.195	0.032	4.283	1.122	0.529	0.093
21500.0	0.257	23.301	3.647	944.179	0.201	0.034	4.310	1.153	0.547	0.099
22500.0	0.254	22.533	3.772	943.613	0.215	0.038	4.358	1.217	0.583	0.112
25000.0	0.246	20.675	4.070	942.173	0.248	0.049	4.455	1.371	0.672	0.149
27500.0	0.238	18.904	4.348	940.695	0.283	0.062	4.522	1.520	0.758	0.191
30000.0	0.230	17.221	4.606	939.178	0.319	0.077	4.562	1.663	0.838	0.239
32500.0	0.223	15.624	4.844	937.620	0.356	0.094	4.579	1.799	0.913	0.293
35000.0	0.215	14.114	5.063	936.019	0.392	0.113	4.577	1.929	0.981	0.352
37500.0	0.207	12.690	5.261	934.373	0.430	0.133	4.559	2.051	1.042	0.417
40000.0	0.200	11.353	5.440	932.679	0.466	0.156	4.528	2.165	1.096	0.486
42500.0	0.192	10.103	5.600	930.936	0.503	0.179	4.486	2.271	1.143	0.561
45000.0	0.185	8.941	5.740	929.141	0.539	0.204	4.436	2.368	1.183	0.640
47500.0	0.178	7.865	5.862	927.292	0.574	0.231	4.380	2.456	1.216	0.723
50000.0	0.171	6.877	5.964	925.389	0.608	0.258	4.320	2.535	1.243	0.810
52500.0	0.164	5.974	6.048	923.430	0.640	0.285	4.258	2.606	1.264	0.900
55000.0	0.157	5.156	6.113	921.415	0.670	0.313	4.195	2.667	1.279	0.993
57500.0	0.150	4.421	6.162	919.344	0.699	0.340	4.133	2.720	1.290	1.089
60000.0	0.143	3.765	6.194	917.216	0.726	0.368	4.073	2.765	1.297	1.186
62500.0	0.137	3.186	6.209	915.035	0.751	0.394	4.016	2.802	1.300	1.285
65000.0	0.130	2.680	6.211	912.801	0.773	0.419	3.962	2.832	1.301	1.384
67500.0	0.124	2.240	6.198	910.519	0.794	0.443	3.913	2.856	1.299	1.484
70000.0	0.118	1.862	6.174	908.191	0.812	0.465	3.867	2.874	1.295	1.583

**Table C.5 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.330	43.785	0.000	955.885	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.330	43.665	0.024	955.824	0.000	0.000	0.021	0.000	0.000	0.000
500.0	0.328	43.190	0.117	955.578	0.002	0.000	0.218	0.002	0.000	0.000
1000.0	0.326	42.604	0.232	955.270	0.004	0.000	0.472	0.008	0.000	0.000
1500.0	0.324	42.028	0.345	954.962	0.007	0.000	0.715	0.017	0.001	0.000
2000.0	0.322	41.462	0.456	954.654	0.009	0.000	0.946	0.030	0.003	0.000
2500.0	0.320	40.904	0.565	954.346	0.013	0.000	1.166	0.045	0.006	0.000
3000.0	0.318	40.354	0.672	954.038	0.016	0.000	1.376	0.063	0.010	0.000
3500.0	0.316	39.812	0.777	953.730	0.019	0.001	1.577	0.083	0.015	0.000
4000.0	0.313	39.278	0.881	953.422	0.023	0.001	1.769	0.104	0.021	0.001
4500.0	0.311	38.751	0.982	953.114	0.027	0.001	1.953	0.128	0.028	0.001
5000.0	0.309	38.231	1.083	952.806	0.031	0.001	2.128	0.152	0.037	0.001
5500.0	0.307	37.717	1.181	952.498	0.036	0.002	2.296	0.178	0.047	0.002
6000.0	0.305	37.210	1.278	952.190	0.040	0.002	2.456	0.204	0.058	0.002
6500.0	0.303	36.709	1.374	951.883	0.045	0.003	2.609	0.232	0.069	0.003
7000.0	0.302	36.214	1.468	951.575	0.050	0.003	2.755	0.260	0.082	0.004
7500.0	0.300	35.726	1.560	951.268	0.055	0.004	2.895	0.290	0.096	0.005
8000.0	0.298	35.242	1.652	950.960	0.060	0.004	3.029	0.320	0.111	0.006
8500.0	0.296	34.764	1.741	950.653	0.065	0.005	3.156	0.350	0.126	0.007
9000.0	0.294	34.292	1.830	950.346	0.070	0.006	3.278	0.381	0.142	0.009
9500.0	0.292	33.825	1.917	950.039	0.076	0.007	3.394	0.413	0.159	0.010
10000.0	0.290	33.363	2.003	949.732	0.082	0.007	3.505	0.445	0.176	0.012
10500.0	0.288	32.905	2.087	949.426	0.088	0.008	3.611	0.477	0.194	0.014
11000.0	0.286	32.453	2.171	949.120	0.094	0.009	3.711	0.510	0.212	0.016
11500.0	0.284	32.005	2.253	948.814	0.100	0.010	3.807	0.543	0.231	0.019
12000.0	0.283	31.562	2.334	948.508	0.106	0.011	3.899	0.576	0.250	0.021
12500.0	0.281	31.123	2.414	948.202	0.112	0.012	3.986	0.609	0.269	0.024
13000.0	0.279	30.689	2.493	947.896	0.118	0.014	4.069	0.643	0.289	0.027
13500.0	0.277	30.259	2.570	947.590	0.125	0.015	4.148	0.677	0.309	0.030
14000.0	0.275	29.833	2.647	947.285	0.131	0.016	4.223	0.711	0.329	0.034
14500.0	0.274	29.411	2.723	946.979	0.138	0.018	4.294	0.745	0.349	0.037
15000.0	0.272	28.993	2.797	946.674	0.145	0.019	4.362	0.780	0.369	0.041
15500.0	0.270	28.579	2.871	946.369	0.151	0.021	4.426	0.814	0.390	0.045
16000.0	0.268	28.168	2.943	946.063	0.158	0.022	4.487	0.848	0.410	0.049
16500.0	0.267	27.762	3.015	945.758	0.165	0.024	4.545	0.883	0.431	0.053
17000.0	0.265	27.359	3.086	945.452	0.172	0.026	4.600	0.917	0.452	0.058
17500.0	0.263	26.960	3.156	945.146	0.178	0.027	4.652	0.952	0.472	0.063
18000.0	0.262	26.564	3.224	944.839	0.185	0.029	4.702	0.986	0.493	0.068
18500.0	0.260	26.172	3.292	944.532	0.192	0.031	4.749	1.020	0.513	0.073
19000.0	0.258	25.784	3.359	944.224	0.199	0.033	4.794	1.054	0.534	0.078
19500.0	0.257	25.399	3.426	943.915	0.206	0.035	4.837	1.089	0.555	0.084
20000.0	0.255	25.018	3.491	943.606	0.214	0.038	4.878	1.122	0.575	0.090
20500.0	0.253	24.640	3.555	943.295	0.221	0.040	4.917	1.156	0.596	0.096
21000.0	0.252	24.266	3.619	942.983	0.228	0.042	4.954	1.190	0.616	0.102
21500.0	0.250	23.896	3.681	942.670	0.236	0.045	4.989	1.224	0.637	0.109
22000.0	0.248	23.529	3.743	942.356	0.243	0.047	5.023	1.257	0.657	0.116
22500.0	0.247	23.165	3.804	942.040	0.250	0.050	5.055	1.290	0.678	0.122
23000.0	0.245	22.806	3.864	941.723	0.258	0.052	5.086	1.323	0.698	0.130
25000.0	0.238	21.401	4.096	940.442	0.289	0.064	5.194	1.453	0.779	0.160
27500.0	0.230	19.723	4.367	938.810	0.328	0.080	5.301	1.610	0.876	0.203
30000.0	0.222	18.131	4.617	937.142	0.368	0.098	5.378	1.762	0.969	0.251
32500.0	0.215	16.623	4.847	935.438	0.408	0.119	5.432	1.907	1.057	0.304
35000.0	0.207	15.196	5.057	933.697	0.449	0.142	5.463	2.046	1.137	0.362
37500.0	0.199	13.851	5.249	931.917	0.489	0.167	5.477	2.177	1.212	0.425
40000.0	0.192	12.585	5.421	930.099	0.529	0.194	5.475	2.301	1.279	0.491
42500.0	0.185	11.398	5.576	928.241	0.568	0.222	5.460	2.417	1.340	0.561
45000.0	0.178	10.288	5.712	926.342	0.606	0.252	5.435	2.525	1.394	0.635
47500.0	0.171	9.253	5.831	924.402	0.643	0.284	5.401	2.625	1.441	0.712
50000.0	0.164	8.293	5.933	922.421	0.679	0.316	5.360	2.717	1.482	0.792
52500.0	0.157	7.406	6.018	920.398	0.713	0.350	5.314	2.801	1.517	0.874
55000.0	0.151	6.589	6.087	918.334	0.746	0.383	5.264	2.877	1.547	0.958
57500.0	0.145	5.841	6.141	916.229	0.777	0.417	5.213	2.945	1.571	1.045
60000.0	0.139	5.159	6.180	914.083	0.806	0.451	5.160	3.005	1.591	1.132
62500.0	0.133	4.539	6.206	911.899	0.833	0.485	5.107	3.058	1.606	1.221
65000.0	0.128	3.981	6.218	909.676	0.858	0.517	5.055	3.104	1.618	1.310
67500.0	0.122	3.479	6.218	907.417	0.881	0.549	5.004	3.144	1.626	1.400
70000.0	0.117	3.030	6.206	905.124	0.902	0.579	4.955	3.178	1.631	1.489

**Table C.6 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.330	43.785	0.000	955.885	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.330	43.666	0.025	955.814	0.000	0.000	0.024	0.000	0.000	0.000
500.0	0.328	43.194	0.123	955.530	0.002	0.000	0.249	0.002	0.000	0.000
1000.0	0.325	42.614	0.243	955.174	0.005	0.000	0.539	0.009	0.001	0.000
1500.0	0.323	42.045	0.361	954.819	0.008	0.000	0.816	0.019	0.002	0.000
2000.0	0.320	41.487	0.477	954.463	0.012	0.000	1.080	0.033	0.004	0.000
2500.0	0.318	40.937	0.590	954.108	0.015	0.000	1.333	0.050	0.008	0.000
3000.0	0.316	40.397	0.701	953.753	0.019	0.001	1.574	0.069	0.013	0.000
3500.0	0.313	39.866	0.810	953.398	0.024	0.001	1.804	0.091	0.019	0.000
4000.0	0.311	39.342	0.917	953.043	0.028	0.001	2.025	0.114	0.027	0.001
4500.0	0.309	38.827	1.022	952.688	0.033	0.002	2.237	0.138	0.036	0.001
5000.0	0.306	38.319	1.125	952.334	0.038	0.002	2.440	0.164	0.047	0.001
5500.0	0.304	37.818	1.227	951.979	0.043	0.003	2.635	0.191	0.059	0.002
6000.0	0.302	37.324	1.327	951.625	0.049	0.003	2.821	0.219	0.072	0.003
6500.0	0.300	36.837	1.425	951.270	0.055	0.004	3.000	0.248	0.086	0.004
7000.0	0.297	36.356	1.521	950.916	0.061	0.005	3.172	0.278	0.101	0.005
7500.0	0.295	35.882	1.616	950.562	0.067	0.005	3.337	0.309	0.117	0.006
8000.0	0.293	35.413	1.709	950.209	0.073	0.006	3.495	0.341	0.134	0.007
8500.0	0.291	34.951	1.801	949.855	0.080	0.007	3.647	0.373	0.152	0.008
9000.0	0.289	34.494	1.891	949.502	0.086	0.008	3.792	0.405	0.171	0.010
9500.0	0.287	34.042	1.980	949.149	0.093	0.009	3.932	0.439	0.190	0.012
10000.0	0.285	33.597	2.067	948.796	0.100	0.010	4.066	0.472	0.210	0.014
10500.0	0.282	33.156	2.153	948.443	0.107	0.012	4.194	0.506	0.230	0.016
11000.0	0.280	32.720	2.238	948.091	0.114	0.013	4.318	0.541	0.251	0.018
11500.0	0.278	32.289	2.322	947.739	0.121	0.014	4.436	0.576	0.272	0.021
12000.0	0.276	31.864	2.404	947.387	0.129	0.016	4.549	0.611	0.293	0.024
12500.0	0.274	31.442	2.485	947.035	0.136	0.018	4.658	0.647	0.315	0.027
13000.0	0.272	31.026	2.565	946.683	0.143	0.019	4.763	0.682	0.337	0.030
13500.0	0.270	30.614	2.643	946.331	0.151	0.021	4.863	0.718	0.360	0.033
14000.0	0.268	30.206	2.720	945.979	0.159	0.023	4.959	0.755	0.382	0.037
14500.0	0.266	29.803	2.797	945.628	0.166	0.025	5.051	0.791	0.405	0.041
15000.0	0.264	29.404	2.872	945.276	0.174	0.027	5.139	0.828	0.428	0.044
15500.0	0.263	29.009	2.945	944.924	0.182	0.029	5.224	0.864	0.451	0.049
16000.0	0.261	28.618	3.018	944.573	0.190	0.031	5.305	0.901	0.474	0.053
16500.0	0.259	28.231	3.090	944.221	0.198	0.033	5.383	0.938	0.497	0.057
17000.0	0.257	27.848	3.161	943.869	0.206	0.036	5.457	0.975	0.520	0.062
17500.0	0.255	27.469	3.230	943.517	0.214	0.038	5.529	1.012	0.543	0.067
18000.0	0.253	27.094	3.299	943.165	0.222	0.041	5.598	1.049	0.566	0.072
18500.0	0.251	26.722	3.367	942.812	0.231	0.043	5.664	1.086	0.589	0.077
19000.0	0.250	26.355	3.434	942.458	0.239	0.046	5.727	1.123	0.612	0.083
19500.0	0.248	25.990	3.499	942.104	0.247	0.049	5.788	1.160	0.635	0.088
20000.0	0.246	25.630	3.564	941.750	0.255	0.052	5.846	1.197	0.658	0.094
20500.0	0.244	25.273	3.628	941.395	0.264	0.055	5.902	1.234	0.681	0.100
21000.0	0.242	24.919	3.691	941.039	0.272	0.058	5.956	1.271	0.704	0.107
21500.0	0.241	24.570	3.753	940.682	0.281	0.061	6.009	1.307	0.727	0.113
22000.0	0.239	24.223	3.814	940.324	0.289	0.065	6.059	1.344	0.750	0.119
22500.0	0.237	23.881	3.874	939.965	0.298	0.068	6.107	1.380	0.773	0.126
23000.0	0.235	23.541	3.934	939.605	0.306	0.072	6.154	1.417	0.795	0.133
23500.0	0.234	23.205	3.992	939.244	0.315	0.075	6.199	1.453	0.818	0.140
24000.0	0.232	22.873	4.050	938.882	0.323	0.079	6.242	1.489	0.840	0.148
24500.0	0.230	22.544	4.106	938.518	0.332	0.083	6.284	1.525	0.863	0.155
25000.0	0.228	22.219	4.162	938.154	0.340	0.087	6.324	1.560	0.885	0.163
25500.0	0.227	21.897	4.217	937.788	0.349	0.091	6.363	1.596	0.907	0.171
26000.0	0.225	21.578	4.271	937.421	0.358	0.095	6.401	1.631	0.929	0.179
27500.0	0.220	20.642	4.429	936.313	0.383	0.108	6.506	1.736	0.995	0.204
30000.0	0.212	19.148	4.675	934.439	0.427	0.132	6.656	1.906	1.102	0.249
32500.0	0.204	17.734	4.900	932.534	0.471	0.158	6.780	2.071	1.204	0.298
35000.0	0.196	16.399	5.106	930.597	0.514	0.187	6.879	2.229	1.301	0.350
37500.0	0.188	15.139	5.294	928.629	0.557	0.218	6.958	2.382	1.393	0.406
40000.0	0.181	13.952	5.462	926.628	0.599	0.251	7.018	2.528	1.479	0.466
42500.0	0.174	12.837	5.613	924.596	0.640	0.287	7.062	2.667	1.559	0.528
45000.0	0.167	11.790	5.747	922.532	0.681	0.324	7.093	2.800	1.633	0.593
47500.0	0.161	10.811	5.864	920.437	0.720	0.363	7.112	2.925	1.702	0.660
50000.0	0.154	9.896	5.965	918.311	0.757	0.403	7.120	3.043	1.765	0.730
52500.0	0.148	9.043	6.050	916.156	0.793	0.445	7.121	3.155	1.823	0.801
55000.0	0.143	8.250	6.122	913.971	0.828	0.487	7.114	3.259	1.876	0.875
57500.0	0.137	7.514	6.179	911.757	0.861	0.530	7.101	3.356	1.923	0.950
60000.0	0.132	6.833	6.224	909.517	0.891	0.573	7.083	3.446	1.967	1.026
62500.0	0.127	6.204	6.256	907.250	0.920	0.616	7.062	3.530	2.005	1.104
65000.0	0.122	5.625	6.276	904.957	0.947	0.659	7.038	3.607	2.040	1.183
67500.0	0.117	5.092	6.285	902.641	0.972	0.702	7.012	3.679	2.071	1.263
70000.0	0.113	4.604	6.285	900.302	0.995	0.744	6.985	3.744	2.098	1.343

**Table C.7 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.336	44.488	0.000	955.176	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.335	44.368	0.022	955.126	0.000	0.000	0.016	0.000	0.000	0.000
500.0	0.334	43.889	0.111	954.924	0.002	0.000	0.176	0.001	0.000	0.000
1000.0	0.332	43.298	0.221	954.671	0.003	0.000	0.387	0.006	0.000	0.000
1500.0	0.330	42.715	0.330	954.418	0.005	0.000	0.589	0.013	0.001	0.000
2000.0	0.328	42.139	0.436	954.165	0.007	0.000	0.781	0.024	0.002	0.000
2500.0	0.327	41.571	0.541	953.912	0.010	0.000	0.965	0.037	0.004	0.000
3000.0	0.325	41.009	0.644	953.659	0.012	0.000	1.141	0.051	0.006	0.000
3500.0	0.323	40.454	0.746	953.405	0.015	0.000	1.308	0.068	0.010	0.000
4000.0	0.321	39.905	0.847	953.152	0.018	0.001	1.468	0.087	0.014	0.000
4500.0	0.320	39.362	0.946	952.899	0.021	0.001	1.621	0.107	0.019	0.001
5000.0	0.318	38.825	1.044	952.646	0.024	0.001	1.767	0.128	0.025	0.001
5500.0	0.316	38.293	1.140	952.393	0.028	0.001	1.906	0.150	0.032	0.001
6000.0	0.314	37.767	1.235	952.140	0.031	0.002	2.039	0.174	0.040	0.002
6500.0	0.313	37.247	1.329	951.887	0.035	0.002	2.165	0.198	0.048	0.002
7000.0	0.311	36.732	1.422	951.635	0.039	0.002	2.286	0.223	0.058	0.003
7500.0	0.309	36.221	1.513	951.382	0.043	0.003	2.401	0.249	0.068	0.003
8000.0	0.308	35.716	1.604	951.130	0.046	0.003	2.510	0.276	0.079	0.004
8500.0	0.306	35.215	1.693	950.878	0.051	0.003	2.614	0.303	0.090	0.005
9000.0	0.304	34.719	1.781	950.627	0.055	0.004	2.712	0.331	0.102	0.006
9500.0	0.303	34.228	1.868	950.375	0.059	0.004	2.806	0.360	0.115	0.007
10000.0	0.301	33.741	1.954	950.124	0.063	0.005	2.895	0.389	0.128	0.009
10500.0	0.299	33.258	2.038	949.873	0.068	0.005	2.979	0.418	0.142	0.010
11000.0	0.298	32.779	2.122	949.623	0.073	0.006	3.059	0.448	0.156	0.012
11500.0	0.296	32.305	2.205	949.373	0.077	0.007	3.134	0.478	0.170	0.014
12000.0	0.295	31.834	2.286	949.123	0.082	0.007	3.205	0.508	0.185	0.016
12500.0	0.293	31.368	2.367	948.873	0.087	0.008	3.273	0.539	0.200	0.018
13000.0	0.291	30.905	2.447	948.623	0.092	0.009	3.336	0.570	0.215	0.020
13500.0	0.290	30.445	2.526	948.374	0.097	0.010	3.396	0.601	0.231	0.023
14000.0	0.288	29.989	2.603	948.125	0.102	0.011	3.452	0.632	0.246	0.025
14500.0	0.287	29.537	2.680	947.876	0.107	0.012	3.505	0.663	0.262	0.028
15000.0	0.285	29.088	2.756	947.628	0.112	0.013	3.555	0.694	0.278	0.031
15500.0	0.284	28.643	2.832	947.379	0.117	0.014	3.601	0.726	0.294	0.034
16000.0	0.282	28.201	2.906	947.130	0.123	0.015	3.645	0.757	0.310	0.038
16500.0	0.280	27.762	2.979	946.881	0.128	0.016	3.687	0.789	0.327	0.041
17000.0	0.279	27.327	3.052	946.631	0.133	0.017	3.726	0.820	0.343	0.045
17500.0	0.277	26.895	3.124	946.380	0.139	0.018	3.762	0.852	0.359	0.049
18000.0	0.276	26.467	3.195	946.129	0.144	0.019	3.797	0.883	0.376	0.053
18500.0	0.274	26.042	3.265	945.876	0.150	0.021	3.830	0.915	0.393	0.058
19000.0	0.273	25.620	3.335	945.622	0.156	0.022	3.861	0.946	0.409	0.062
19500.0	0.271	25.202	3.403	945.367	0.161	0.023	3.890	0.977	0.426	0.067
20000.0	0.270	24.787	3.471	945.111	0.167	0.025	3.917	1.009	0.443	0.072
20500.0	0.268	24.375	3.538	944.854	0.173	0.026	3.943	1.040	0.459	0.077
21000.0	0.267	23.968	3.605	944.595	0.179	0.028	3.967	1.071	0.476	0.083
22500.0	0.262	22.765	3.799	943.810	0.197	0.033	4.031	1.163	0.526	0.101
25000.0	0.254	20.828	4.107	942.472	0.229	0.043	4.112	1.313	0.609	0.134
27500.0	0.247	18.978	4.395	941.096	0.261	0.054	4.163	1.458	0.688	0.174
30000.0	0.239	17.215	4.664	939.679	0.295	0.067	4.188	1.599	0.762	0.220
32500.0	0.231	15.539	4.912	938.219	0.329	0.081	4.192	1.733	0.831	0.272
35000.0	0.223	13.951	5.141	936.712	0.364	0.098	4.177	1.861	0.893	0.329
37500.0	0.216	12.453	5.350	935.156	0.399	0.116	4.148	1.981	0.948	0.392
40000.0	0.208	11.046	5.539	933.548	0.435	0.135	4.106	2.093	0.996	0.461
42500.0	0.200	9.732	5.708	931.883	0.470	0.156	4.055	2.197	1.038	0.536
45000.0	0.193	8.511	5.857	930.160	0.504	0.179	3.996	2.292	1.072	0.615
47500.0	0.185	7.387	5.985	928.374	0.538	0.202	3.933	2.377	1.100	0.700
50000.0	0.177	6.358	6.092	926.524	0.570	0.226	3.868	2.454	1.122	0.789
52500.0	0.170	5.426	6.180	924.608	0.601	0.251	3.801	2.521	1.138	0.883
55000.0	0.162	4.590	6.247	922.624	0.631	0.275	3.736	2.578	1.149	0.979
57500.0	0.155	3.848	6.296	920.572	0.659	0.300	3.672	2.627	1.155	1.079
60000.0	0.147	3.197	6.326	918.452	0.684	0.324	3.613	2.667	1.158	1.182
62500.0	0.140	2.633	6.338	916.267	0.708	0.347	3.557	2.699	1.157	1.286
65000.0	0.133	2.150	6.334	914.021	0.729	0.369	3.507	2.724	1.155	1.391
67500.0	0.126	1.743	6.316	911.717	0.748	0.389	3.461	2.742	1.150	1.496
70000.0	0.120	1.403	6.284	909.360	0.764	0.408	3.421	2.755	1.145	1.601

**Table C.8 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.336	44.488	0.000	955.176	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.335	44.368	0.023	955.119	0.000	0.000	0.019	0.000	0.000	0.000
500.0	0.334	43.891	0.116	954.888	0.002	0.000	0.200	0.001	0.000	0.000
1000.0	0.332	43.303	0.230	954.598	0.004	0.000	0.440	0.007	0.000	0.000
1500.0	0.330	42.724	0.342	954.309	0.006	0.000	0.669	0.015	0.001	0.000
2000.0	0.328	42.154	0.452	954.019	0.009	0.000	0.887	0.027	0.003	0.000
2500.0	0.326	41.591	0.560	953.730	0.012	0.000	1.096	0.041	0.005	0.000
3000.0	0.324	41.036	0.667	953.441	0.015	0.000	1.295	0.058	0.008	0.000
3500.0	0.322	40.488	0.772	953.152	0.018	0.001	1.485	0.076	0.013	0.000
4000.0	0.320	39.948	0.875	952.864	0.022	0.001	1.666	0.097	0.018	0.000
4500.0	0.318	39.414	0.976	952.575	0.025	0.001	1.839	0.118	0.025	0.001
5000.0	0.316	38.886	1.076	952.287	0.029	0.001	2.005	0.142	0.032	0.001
5500.0	0.314	38.365	1.175	951.999	0.033	0.002	2.163	0.166	0.041	0.001
6000.0	0.312	37.850	1.272	951.712	0.037	0.002	2.314	0.191	0.051	0.002
6500.0	0.310	37.341	1.367	951.424	0.042	0.002	2.457	0.217	0.061	0.003
7000.0	0.308	36.838	1.461	951.137	0.046	0.003	2.595	0.245	0.073	0.003
7500.0	0.306	36.340	1.554	950.850	0.051	0.003	2.726	0.272	0.085	0.004
8000.0	0.304	35.847	1.646	950.564	0.055	0.004	2.850	0.301	0.099	0.005
8500.0	0.302	35.360	1.736	950.278	0.060	0.004	2.969	0.330	0.112	0.006
9000.0	0.301	34.877	1.825	949.992	0.065	0.005	3.083	0.360	0.127	0.008
9500.0	0.299	34.400	1.912	949.707	0.071	0.006	3.190	0.390	0.142	0.009
10000.0	0.297	33.927	1.999	949.422	0.076	0.007	3.293	0.421	0.158	0.011
10500.0	0.295	33.459	2.084	949.138	0.081	0.007	3.390	0.452	0.174	0.012
11000.0	0.293	32.995	2.168	948.854	0.087	0.008	3.482	0.483	0.191	0.014
11500.0	0.292	32.536	2.251	948.570	0.092	0.009	3.570	0.515	0.208	0.016
12000.0	0.290	32.081	2.332	948.287	0.098	0.010	3.654	0.547	0.225	0.019
12500.0	0.288	31.631	2.413	948.004	0.104	0.011	3.733	0.580	0.243	0.021
13000.0	0.286	31.184	2.493	947.721	0.110	0.012	3.808	0.612	0.261	0.024
13500.0	0.285	30.741	2.571	947.438	0.116	0.013	3.879	0.645	0.279	0.027
14000.0	0.283	30.303	2.649	947.156	0.122	0.014	3.946	0.678	0.298	0.030
14500.0	0.281	29.868	2.725	946.874	0.128	0.015	4.009	0.711	0.316	0.033
15000.0	0.280	29.436	2.801	946.593	0.134	0.017	4.069	0.744	0.335	0.036
15500.0	0.278	29.009	2.876	946.311	0.140	0.018	4.126	0.777	0.354	0.040
16000.0	0.276	28.585	2.949	946.029	0.146	0.019	4.180	0.811	0.373	0.044
16500.0	0.275	28.164	3.022	945.748	0.152	0.021	4.230	0.844	0.392	0.048
17000.0	0.273	27.747	3.094	945.466	0.159	0.022	4.278	0.877	0.410	0.052
17500.0	0.271	27.334	3.165	945.183	0.165	0.024	4.323	0.910	0.429	0.056
18000.0	0.270	26.924	3.236	944.900	0.171	0.025	4.366	0.943	0.449	0.061
18500.0	0.268	26.517	3.305	944.616	0.178	0.027	4.407	0.977	0.468	0.066
19000.0	0.266	26.114	3.373	944.332	0.184	0.029	4.446	1.010	0.487	0.071
19500.0	0.265	25.715	3.441	944.046	0.191	0.031	4.483	1.043	0.506	0.076
20000.0	0.263	25.319	3.508	943.759	0.198	0.033	4.518	1.075	0.525	0.082
20500.0	0.261	24.926	3.574	943.471	0.204	0.035	4.551	1.108	0.544	0.087
21000.0	0.260	24.537	3.639	943.182	0.211	0.037	4.582	1.141	0.563	0.093
21500.0	0.258	24.151	3.703	942.892	0.218	0.039	4.612	1.173	0.582	0.099
22000.0	0.257	23.769	3.767	942.600	0.225	0.041	4.640	1.206	0.601	0.106
22500.0	0.255	23.391	3.829	942.307	0.232	0.043	4.667	1.238	0.620	0.112
25000.0	0.247	21.549	4.130	940.821	0.268	0.055	4.781	1.395	0.714	0.148
27500.0	0.239	19.794	4.410	939.300	0.305	0.069	4.863	1.548	0.805	0.189
30000.0	0.231	18.124	4.670	937.742	0.343	0.086	4.917	1.696	0.891	0.236
32500.0	0.223	16.538	4.910	936.147	0.381	0.104	4.947	1.837	0.971	0.288
35000.0	0.215	15.036	5.130	934.511	0.420	0.124	4.958	1.971	1.045	0.345
37500.0	0.208	13.617	5.331	932.834	0.458	0.146	4.950	2.099	1.112	0.407
40000.0	0.200	12.281	5.513	931.114	0.497	0.170	4.929	2.219	1.172	0.473
42500.0	0.193	11.029	5.676	929.349	0.534	0.195	4.895	2.331	1.225	0.544
45000.0	0.185	9.858	5.820	927.538	0.571	0.222	4.852	2.434	1.271	0.619
47500.0	0.178	8.770	5.946	925.680	0.607	0.250	4.802	2.529	1.311	0.698
50000.0	0.171	7.763	6.053	923.773	0.641	0.279	4.746	2.615	1.344	0.781
52500.0	0.164	6.836	6.143	921.817	0.675	0.308	4.687	2.693	1.371	0.866
55000.0	0.157	5.988	6.215	919.811	0.706	0.339	4.625	2.762	1.392	0.955
57500.0	0.150	5.218	6.271	917.755	0.736	0.369	4.563	2.823	1.409	1.045
60000.0	0.144	4.522	6.310	915.650	0.764	0.398	4.501	2.876	1.420	1.137
62500.0	0.137	3.898	6.334	913.496	0.790	0.428	4.441	2.920	1.428	1.231
65000.0	0.131	3.343	6.344	911.295	0.814	0.456	4.384	2.958	1.432	1.326
67500.0	0.125	2.853	6.340	909.050	0.836	0.483	4.329	2.989	1.434	1.421
70000.0	0.120	2.422	6.323	906.762	0.855	0.509	4.278	3.014	1.433	1.516

**Table C.9 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.336	44.488	0.000	955.176	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.335	44.369	0.024	955.109	0.000	0.000	0.021	0.000	0.000	0.000
500.0	0.333	43.895	0.122	954.839	0.002	0.000	0.231	0.002	0.000	0.000
1000.0	0.331	43.312	0.242	954.502	0.005	0.000	0.508	0.008	0.000	0.000
1500.0	0.329	42.740	0.359	954.164	0.008	0.000	0.772	0.018	0.002	0.000
2000.0	0.326	42.176	0.474	953.827	0.011	0.000	1.024	0.031	0.004	0.000
2500.0	0.324	41.622	0.587	953.490	0.014	0.000	1.264	0.047	0.007	0.000
3000.0	0.322	41.076	0.697	953.154	0.018	0.001	1.494	0.065	0.011	0.000
3500.0	0.319	40.539	0.806	952.818	0.022	0.001	1.714	0.085	0.017	0.000
4000.0	0.317	40.009	0.913	952.482	0.027	0.001	1.925	0.107	0.024	0.001
4500.0	0.315	39.486	1.018	952.146	0.031	0.002	2.126	0.130	0.033	0.001
5000.0	0.313	38.971	1.122	951.811	0.036	0.002	2.319	0.155	0.042	0.001
5500.0	0.310	38.463	1.223	951.476	0.041	0.002	2.504	0.181	0.053	0.002
6000.0	0.308	37.961	1.323	951.142	0.046	0.003	2.680	0.208	0.065	0.002
6500.0	0.306	37.466	1.421	950.808	0.052	0.003	2.849	0.236	0.078	0.003
7000.0	0.304	36.977	1.518	950.474	0.057	0.004	3.011	0.265	0.093	0.004
7500.0	0.302	36.493	1.613	950.141	0.063	0.005	3.166	0.294	0.108	0.005
8000.0	0.300	36.016	1.707	949.808	0.069	0.006	3.315	0.324	0.123	0.006
8500.0	0.297	35.544	1.799	949.476	0.075	0.006	3.457	0.355	0.140	0.008
9000.0	0.295	35.078	1.889	949.144	0.081	0.007	3.593	0.387	0.157	0.009
9500.0	0.293	34.617	1.979	948.813	0.088	0.008	3.723	0.419	0.175	0.011
10000.0	0.291	34.161	2.067	948.482	0.094	0.009	3.847	0.452	0.194	0.012
10500.0	0.289	33.710	2.153	948.152	0.101	0.010	3.966	0.485	0.213	0.014
11000.0	0.287	33.264	2.239	947.822	0.107	0.012	4.079	0.518	0.232	0.017
11500.0	0.285	32.823	2.323	947.492	0.114	0.013	4.188	0.552	0.252	0.019
12000.0	0.283	32.387	2.406	947.163	0.121	0.014	4.291	0.586	0.273	0.022
12500.0	0.281	31.954	2.487	946.834	0.128	0.016	4.391	0.620	0.293	0.024
13000.0	0.279	31.527	2.568	946.505	0.135	0.017	4.485	0.655	0.314	0.027
13500.0	0.277	31.103	2.647	946.177	0.142	0.019	4.576	0.690	0.335	0.030
14000.0	0.276	30.684	2.725	945.849	0.149	0.020	4.662	0.725	0.356	0.034
14500.0	0.274	30.269	2.802	945.521	0.157	0.022	4.745	0.761	0.378	0.037
15000.0	0.272	29.858	2.878	945.193	0.164	0.024	4.823	0.796	0.399	0.041
15500.0	0.270	29.451	2.953	944.865	0.171	0.026	4.898	0.832	0.421	0.045
16000.0	0.268	29.048	3.027	944.538	0.179	0.028	4.970	0.868	0.443	0.049
16500.0	0.266	28.649	3.100	944.210	0.187	0.030	5.038	0.903	0.464	0.053
17000.0	0.264	28.253	3.172	943.883	0.194	0.032	5.103	0.939	0.486	0.057
17500.0	0.263	27.861	3.243	943.555	0.202	0.034	5.165	0.975	0.508	0.062
18000.0	0.261	27.473	3.312	943.227	0.209	0.036	5.225	1.011	0.530	0.067
18500.0	0.259	27.088	3.381	942.899	0.217	0.039	5.281	1.047	0.552	0.072
19000.0	0.257	26.707	3.449	942.570	0.225	0.041	5.336	1.083	0.573	0.077
19500.0	0.255	26.330	3.516	942.240	0.233	0.044	5.387	1.119	0.595	0.083
20000.0	0.254	25.956	3.582	941.910	0.241	0.046	5.437	1.155	0.617	0.088
20500.0	0.252	25.585	3.648	941.579	0.249	0.049	5.485	1.190	0.639	0.094
21000.0	0.250	25.218	3.712	941.247	0.257	0.052	5.530	1.226	0.660	0.100
21500.0	0.248	24.855	3.775	940.914	0.265	0.054	5.574	1.261	0.682	0.106
22000.0	0.247	24.495	3.838	940.580	0.273	0.057	5.616	1.297	0.704	0.112
22500.0	0.245	24.138	3.900	940.245	0.281	0.060	5.656	1.332	0.725	0.119
23000.0	0.243	23.785	3.960	939.909	0.289	0.064	5.695	1.367	0.747	0.126
23500.0	0.241	23.436	4.020	939.571	0.297	0.067	5.732	1.402	0.768	0.133
24000.0	0.240	23.090	4.079	939.233	0.305	0.070	5.768	1.437	0.789	0.140
24500.0	0.238	22.747	4.138	938.893	0.313	0.074	5.802	1.472	0.810	0.147
25000.0	0.236	22.408	4.195	938.552	0.321	0.077	5.835	1.506	0.832	0.154
27500.0	0.228	20.762	4.469	936.826	0.363	0.096	5.979	1.675	0.936	0.194
30000.0	0.220	19.199	4.723	935.068	0.405	0.117	6.093	1.839	1.037	0.239
32500.0	0.212	17.716	4.957	933.277	0.447	0.141	6.181	1.998	1.133	0.288
35000.0	0.204	16.314	5.171	931.452	0.489	0.167	6.246	2.151	1.223	0.341
37500.0	0.196	14.988	5.366	929.593	0.531	0.195	6.290	2.297	1.307	0.398
40000.0	0.189	13.739	5.542	927.700	0.572	0.225	6.317	2.436	1.386	0.458
42500.0	0.181	12.565	5.700	925.772	0.612	0.257	6.329	2.568	1.458	0.522
45000.0	0.174	11.463	5.840	923.808	0.652	0.291	6.329	2.693	1.524	0.589
47500.0	0.168	10.432	5.962	921.810	0.690	0.327	6.317	2.811	1.584	0.659
50000.0	0.161	9.470	6.068	919.776	0.728	0.363	6.297	2.920	1.638	0.731
52500.0	0.154	8.575	6.158	917.708	0.763	0.401	6.269	3.022	1.686	0.806
55000.0	0.148	7.745	6.232	915.605	0.797	0.439	6.235	3.117	1.729	0.883
57500.0	0.142	6.978	6.292	913.469	0.829	0.478	6.197	3.203	1.766	0.962
60000.0	0.136	6.272	6.337	911.299	0.860	0.517	6.156	3.283	1.799	1.042
62500.0	0.131	5.623	6.369	909.098	0.888	0.556	6.113	3.355	1.827	1.124
65000.0	0.126	5.029	6.389	906.865	0.914	0.595	6.068	3.420	1.851	1.208
67500.0	0.121	4.488	6.396	904.603	0.938	0.632	6.023	3.478	1.872	1.292
70000.0	0.116	3.996	6.393	902.312	0.960	0.669	5.978	3.531	1.888	1.377

**Table C.10 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.333	44.167	0.000	955.500	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.333	44.047	0.022	955.450	0.000	0.000	0.016	0.000	0.000	0.000
500.0	0.331	43.569	0.111	955.251	0.001	0.000	0.174	0.001	0.000	0.000
1000.0	0.330	42.978	0.220	955.002	0.003	0.000	0.382	0.006	0.000	0.000
1500.0	0.328	42.395	0.328	954.752	0.005	0.000	0.581	0.013	0.001	0.000
2000.0	0.326	41.819	0.434	954.502	0.007	0.000	0.771	0.024	0.002	0.000
2500.0	0.324	41.250	0.538	954.252	0.010	0.000	0.952	0.036	0.004	0.000
3000.0	0.323	40.688	0.641	954.001	0.012	0.000	1.125	0.051	0.006	0.000
3500.0	0.321	40.132	0.743	953.751	0.015	0.000	1.291	0.068	0.010	0.000
4000.0	0.319	39.583	0.843	953.501	0.018	0.001	1.449	0.086	0.014	0.000
4500.0	0.317	39.040	0.942	953.251	0.021	0.001	1.600	0.106	0.019	0.001
5000.0	0.316	38.503	1.039	953.000	0.024	0.001	1.744	0.127	0.025	0.001
5500.0	0.314	37.971	1.135	952.750	0.027	0.001	1.881	0.149	0.031	0.001
6000.0	0.312	37.445	1.230	952.500	0.031	0.001	2.012	0.172	0.039	0.001
6500.0	0.310	36.924	1.323	952.250	0.034	0.002	2.137	0.196	0.047	0.002
7000.0	0.309	36.408	1.416	952.000	0.038	0.002	2.256	0.222	0.057	0.003
7500.0	0.307	35.898	1.507	951.749	0.042	0.002	2.370	0.248	0.067	0.003
8000.0	0.305	35.392	1.597	951.500	0.046	0.003	2.477	0.274	0.077	0.004
8500.0	0.304	34.891	1.686	951.250	0.050	0.003	2.580	0.301	0.088	0.005
9000.0	0.302	34.395	1.773	951.000	0.054	0.004	2.677	0.329	0.100	0.006
9500.0	0.301	33.903	1.860	950.751	0.058	0.004	2.770	0.358	0.113	0.007
10000.0	0.299	33.416	1.946	950.502	0.063	0.005	2.857	0.386	0.126	0.009
10500.0	0.297	32.933	2.030	950.253	0.067	0.005	2.941	0.416	0.139	0.010
11000.0	0.296	32.454	2.113	950.004	0.072	0.006	3.019	0.445	0.153	0.012
11500.0	0.294	31.979	2.196	949.755	0.076	0.007	3.094	0.475	0.167	0.014
12000.0	0.292	31.509	2.277	949.507	0.081	0.007	3.164	0.506	0.182	0.016
12500.0	0.291	31.042	2.358	949.258	0.086	0.008	3.231	0.536	0.197	0.018
13000.0	0.289	30.579	2.437	949.010	0.091	0.009	3.294	0.567	0.212	0.020
13500.0	0.288	30.120	2.516	948.761	0.096	0.010	3.353	0.598	0.227	0.023
14000.0	0.286	29.664	2.593	948.513	0.101	0.011	3.408	0.629	0.243	0.025
14500.0	0.285	29.213	2.670	948.265	0.106	0.011	3.460	0.660	0.259	0.028
15000.0	0.283	28.764	2.746	948.017	0.111	0.012	3.509	0.692	0.274	0.031
15500.0	0.282	28.319	2.820	947.769	0.116	0.013	3.555	0.723	0.290	0.035
16000.0	0.280	27.877	2.895	947.521	0.121	0.014	3.598	0.755	0.306	0.038
16500.0	0.278	27.439	2.968	947.273	0.127	0.015	3.638	0.787	0.322	0.042
17000.0	0.277	27.004	3.040	947.025	0.132	0.017	3.676	0.818	0.339	0.045
17500.0	0.275	26.573	3.112	946.776	0.137	0.018	3.711	0.850	0.355	0.050
18000.0	0.274	26.144	3.183	946.526	0.143	0.019	3.744	0.882	0.371	0.054
18500.0	0.272	25.719	3.253	946.276	0.148	0.020	3.775	0.913	0.387	0.058
19000.0	0.271	25.298	3.322	946.024	0.154	0.022	3.804	0.945	0.403	0.063
19500.0	0.269	24.880	3.390	945.772	0.160	0.023	3.832	0.976	0.420	0.068
20000.0	0.268	24.465	3.458	945.518	0.165	0.024	3.857	1.007	0.436	0.073
20500.0	0.266	24.054	3.525	945.263	0.171	0.026	3.881	1.039	0.452	0.078
21000.0	0.265	23.646	3.591	945.007	0.177	0.027	3.903	1.070	0.469	0.083
21500.0	0.263	23.241	3.656	944.750	0.183	0.029	3.924	1.101	0.485	0.089
22500.0	0.260	22.442	3.784	944.230	0.195	0.032	3.962	1.162	0.517	0.101
25000.0	0.253	20.505	4.091	942.906	0.225	0.042	4.034	1.312	0.598	0.135
27500.0	0.245	18.654	4.378	941.541	0.257	0.053	4.078	1.458	0.675	0.175
30000.0	0.237	16.890	4.646	940.135	0.290	0.065	4.097	1.598	0.747	0.221
32500.0	0.230	15.214	4.894	938.684	0.324	0.080	4.096	1.732	0.814	0.273
35000.0	0.222	13.628	5.122	937.185	0.358	0.096	4.077	1.858	0.874	0.331
37500.0	0.214	12.132	5.330	935.634	0.393	0.113	4.043	1.978	0.927	0.395
40000.0	0.207	10.729	5.518	934.030	0.427	0.132	3.998	2.089	0.974	0.465
42500.0	0.199	9.420	5.685	932.367	0.462	0.153	3.945	2.192	1.013	0.540
45000.0	0.191	8.208	5.832	930.643	0.495	0.175	3.885	2.285	1.046	0.621
47500.0	0.183	7.092	5.958	928.854	0.528	0.197	3.820	2.369	1.072	0.707
50000.0	0.176	6.076	6.064	926.999	0.560	0.221	3.754	2.444	1.092	0.797
52500.0	0.168	5.158	6.149	925.074	0.590	0.245	3.688	2.509	1.106	0.892
55000.0	0.161	4.338	6.214	923.079	0.619	0.268	3.623	2.565	1.116	0.990
57500.0	0.153	3.614	6.259	921.014	0.646	0.292	3.561	2.612	1.121	1.092
60000.0	0.146	2.983	6.286	918.880	0.671	0.315	3.502	2.650	1.123	1.195
62500.0	0.138	2.439	6.296	916.678	0.694	0.337	3.449	2.680	1.122	1.301
65000.0	0.131	1.978	6.289	914.414	0.714	0.358	3.400	2.704	1.119	1.407
67500.0	0.125	1.591	6.268	912.092	0.732	0.377	3.357	2.720	1.114	1.514
70000.0	0.118	1.271	6.234	909.717	0.748	0.394	3.319	2.732	1.109	1.620

**Table C.11 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.333	44.167	0.000	955.500	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.333	44.047	0.023	955.443	0.000	0.000	0.018	0.000	0.000	0.000
500.0	0.331	43.570	0.115	955.214	0.002	0.000	0.198	0.001	0.000	0.000
1000.0	0.329	42.983	0.229	954.927	0.004	0.000	0.435	0.007	0.000	0.000
1500.0	0.327	42.404	0.340	954.640	0.006	0.000	0.662	0.015	0.001	0.000
2000.0	0.325	41.833	0.450	954.354	0.009	0.000	0.878	0.027	0.003	0.000
2500.0	0.323	41.271	0.558	954.067	0.012	0.000	1.085	0.041	0.005	0.000
3000.0	0.321	40.716	0.664	953.781	0.015	0.000	1.282	0.058	0.008	0.000
3500.0	0.319	40.168	0.768	953.494	0.018	0.001	1.470	0.076	0.013	0.000
4000.0	0.317	39.628	0.871	953.208	0.021	0.001	1.650	0.096	0.018	0.000
4500.0	0.315	39.094	0.972	952.922	0.025	0.001	1.821	0.118	0.024	0.001
5000.0	0.313	38.566	1.071	952.636	0.029	0.001	1.985	0.141	0.032	0.001
5500.0	0.311	38.045	1.169	952.350	0.033	0.002	2.142	0.165	0.041	0.001
6000.0	0.310	37.530	1.266	952.064	0.037	0.002	2.291	0.190	0.050	0.002
6500.0	0.308	37.021	1.361	951.779	0.041	0.002	2.433	0.216	0.061	0.003
7000.0	0.306	36.517	1.455	951.494	0.046	0.003	2.569	0.243	0.072	0.003
7500.0	0.304	36.019	1.547	951.209	0.050	0.003	2.699	0.271	0.084	0.004
8000.0	0.302	35.527	1.639	950.924	0.055	0.004	2.822	0.300	0.097	0.005
8500.0	0.300	35.039	1.728	950.640	0.060	0.004	2.940	0.329	0.111	0.006
9000.0	0.298	34.557	1.817	950.356	0.065	0.005	3.052	0.358	0.126	0.008
9500.0	0.297	34.079	1.904	950.073	0.070	0.006	3.159	0.389	0.141	0.009
10000.0	0.295	33.607	1.990	949.789	0.075	0.006	3.260	0.419	0.156	0.011
10500.0	0.293	33.139	2.075	949.507	0.081	0.007	3.356	0.450	0.172	0.012
11000.0	0.291	32.675	2.159	949.224	0.086	0.008	3.448	0.482	0.189	0.014
11500.0	0.290	32.216	2.241	948.941	0.092	0.009	3.535	0.513	0.206	0.016
12000.0	0.288	31.762	2.323	948.659	0.097	0.010	3.617	0.546	0.223	0.019
12500.0	0.286	31.312	2.403	948.377	0.103	0.011	3.696	0.578	0.241	0.021
13000.0	0.284	30.865	2.482	948.095	0.109	0.012	3.770	0.610	0.259	0.024
13500.0	0.283	30.423	2.560	947.813	0.115	0.013	3.840	0.643	0.277	0.027
14000.0	0.281	29.985	2.638	947.532	0.121	0.014	3.906	0.676	0.295	0.030
14500.0	0.279	29.550	2.714	947.250	0.127	0.015	3.969	0.709	0.314	0.033
15000.0	0.278	29.120	2.789	946.969	0.133	0.017	4.028	0.742	0.332	0.037
15500.0	0.276	28.693	2.864	946.688	0.139	0.018	4.084	0.775	0.351	0.040
16000.0	0.274	28.270	2.937	946.407	0.145	0.019	4.137	0.809	0.370	0.044
16500.0	0.273	27.850	3.010	946.126	0.151	0.021	4.187	0.842	0.389	0.048
17000.0	0.271	27.434	3.081	945.844	0.158	0.022	4.233	0.875	0.407	0.053
17500.0	0.269	27.021	3.152	945.563	0.164	0.024	4.278	0.909	0.426	0.057
18000.0	0.268	26.612	3.222	945.281	0.170	0.025	4.319	0.942	0.445	0.062
18500.0	0.266	26.206	3.291	944.999	0.177	0.027	4.358	0.975	0.464	0.067
19000.0	0.264	25.804	3.359	944.716	0.183	0.029	4.395	1.009	0.483	0.072
19500.0	0.263	25.405	3.426	944.432	0.190	0.030	4.430	1.042	0.501	0.077
20000.0	0.261	25.009	3.493	944.147	0.196	0.032	4.462	1.075	0.520	0.082
20500.0	0.260	24.617	3.558	943.862	0.203	0.034	4.493	1.107	0.539	0.088
21000.0	0.258	24.228	3.623	943.575	0.209	0.036	4.523	1.140	0.558	0.094
21500.0	0.256	23.843	3.687	943.288	0.216	0.038	4.550	1.173	0.576	0.100
22000.0	0.255	23.461	3.750	942.998	0.223	0.040	4.576	1.205	0.595	0.107
22500.0	0.253	23.083	3.812	942.708	0.230	0.043	4.601	1.237	0.613	0.113
23000.0	0.251	22.708	3.874	942.417	0.237	0.045	4.624	1.270	0.632	0.120
25000.0	0.245	21.243	4.112	941.236	0.265	0.055	4.704	1.396	0.705	0.149
27500.0	0.237	19.488	4.390	939.727	0.301	0.069	4.776	1.548	0.794	0.191
30000.0	0.229	17.819	4.649	938.181	0.339	0.084	4.822	1.695	0.878	0.238
32500.0	0.222	16.234	4.888	936.596	0.377	0.102	4.845	1.835	0.956	0.290
35000.0	0.214	14.734	5.107	934.970	0.414	0.122	4.849	1.969	1.028	0.348
37500.0	0.206	13.318	5.307	933.302	0.452	0.143	4.836	2.095	1.093	0.411
40000.0	0.199	11.985	5.487	931.589	0.490	0.167	4.809	2.213	1.151	0.478
42500.0	0.191	10.737	5.649	929.830	0.527	0.192	4.771	2.324	1.201	0.550
45000.0	0.184	9.571	5.792	928.024	0.563	0.218	4.725	2.425	1.245	0.626
47500.0	0.177	8.489	5.916	926.169	0.598	0.245	4.671	2.518	1.283	0.706
50000.0	0.170	7.490	6.022	924.263	0.632	0.273	4.613	2.603	1.314	0.790
52500.0	0.163	6.572	6.110	922.306	0.665	0.302	4.551	2.678	1.338	0.876
55000.0	0.156	5.735	6.180	920.298	0.696	0.331	4.488	2.745	1.358	0.966
57500.0	0.149	4.976	6.234	918.238	0.725	0.360	4.425	2.803	1.372	1.057
60000.0	0.142	4.293	6.271	916.127	0.753	0.389	4.363	2.854	1.382	1.151
62500.0	0.136	3.683	6.293	913.967	0.778	0.417	4.303	2.896	1.388	1.246
65000.0	0.130	3.143	6.300	911.758	0.801	0.444	4.246	2.931	1.391	1.341
67500.0	0.124	2.668	6.293	909.503	0.822	0.470	4.192	2.960	1.391	1.438
70000.0	0.118	2.253	6.275	907.204	0.841	0.495	4.142	2.983	1.389	1.534

**Table C.12 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.333	44.167	0.000	955.500	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.333	44.048	0.024	955.433	0.000	0.000	0.021	0.000	0.000	0.000
500.0	0.331	43.575	0.121	955.164	0.002	0.000	0.230	0.002	0.000	0.000
1000.0	0.328	42.992	0.241	954.827	0.005	0.000	0.506	0.008	0.000	0.000
1500.0	0.326	42.420	0.357	954.490	0.008	0.000	0.769	0.018	0.002	0.000
2000.0	0.324	41.857	0.472	954.154	0.011	0.000	1.020	0.031	0.004	0.000
2500.0	0.321	41.304	0.585	953.818	0.015	0.000	1.260	0.046	0.007	0.000
3000.0	0.319	40.758	0.695	953.482	0.018	0.001	1.490	0.065	0.011	0.000
3500.0	0.317	40.221	0.803	953.146	0.022	0.001	1.709	0.085	0.017	0.000
4000.0	0.315	39.692	0.910	952.811	0.027	0.001	1.919	0.107	0.024	0.001
4500.0	0.312	39.170	1.015	952.476	0.031	0.002	2.119	0.130	0.033	0.001
5000.0	0.310	38.655	1.118	952.141	0.036	0.002	2.311	0.155	0.042	0.001
5500.0	0.308	38.147	1.219	951.807	0.041	0.002	2.495	0.181	0.053	0.002
6000.0	0.306	37.646	1.318	951.473	0.046	0.003	2.671	0.208	0.065	0.002
6500.0	0.304	37.152	1.416	951.139	0.052	0.003	2.840	0.236	0.078	0.003
7000.0	0.301	36.663	1.513	950.806	0.057	0.004	3.002	0.265	0.092	0.004
7500.0	0.299	36.181	1.607	950.473	0.063	0.005	3.156	0.294	0.107	0.005
8000.0	0.297	35.704	1.700	950.140	0.069	0.006	3.304	0.324	0.123	0.006
8500.0	0.295	35.233	1.792	949.808	0.075	0.006	3.445	0.355	0.140	0.008
9000.0	0.293	34.767	1.883	949.476	0.081	0.007	3.581	0.387	0.157	0.009
9500.0	0.291	34.307	1.971	949.145	0.088	0.008	3.710	0.419	0.175	0.011
10000.0	0.289	33.852	2.059	948.814	0.094	0.009	3.834	0.452	0.194	0.013
10500.0	0.287	33.402	2.145	948.484	0.101	0.011	3.952	0.485	0.213	0.015
11000.0	0.285	32.957	2.230	948.153	0.108	0.012	4.065	0.518	0.232	0.017
11500.0	0.283	32.517	2.314	947.823	0.114	0.013	4.174	0.552	0.252	0.019
12000.0	0.281	32.082	2.397	947.494	0.121	0.014	4.277	0.586	0.273	0.022
12500.0	0.279	31.651	2.478	947.164	0.128	0.016	4.376	0.620	0.293	0.025
13000.0	0.277	31.224	2.558	946.835	0.135	0.017	4.470	0.655	0.314	0.028
13500.0	0.275	30.802	2.637	946.506	0.142	0.019	4.561	0.690	0.335	0.031
14000.0	0.273	30.384	2.715	946.177	0.150	0.020	4.647	0.725	0.357	0.034
14500.0	0.271	29.970	2.791	945.848	0.157	0.022	4.729	0.761	0.378	0.038
15000.0	0.270	29.561	2.867	945.519	0.164	0.024	4.807	0.796	0.400	0.041
15500.0	0.268	29.155	2.942	945.191	0.172	0.026	4.882	0.832	0.422	0.045
16000.0	0.266	28.754	3.015	944.862	0.179	0.028	4.953	0.868	0.443	0.049
16500.0	0.264	28.356	3.087	944.534	0.187	0.030	5.021	0.904	0.465	0.054
17000.0	0.262	27.962	3.159	944.205	0.194	0.032	5.085	0.940	0.487	0.058
17500.0	0.260	27.572	3.229	943.877	0.202	0.034	5.147	0.976	0.509	0.063
18000.0	0.259	27.185	3.299	943.548	0.210	0.036	5.205	1.012	0.531	0.068
18500.0	0.257	26.802	3.367	943.219	0.217	0.039	5.261	1.048	0.553	0.073
19000.0	0.255	26.423	3.434	942.890	0.225	0.041	5.314	1.084	0.574	0.078
19500.0	0.253	26.047	3.501	942.560	0.233	0.044	5.365	1.120	0.596	0.084
20000.0	0.251	25.675	3.567	942.230	0.241	0.046	5.413	1.156	0.618	0.089
20500.0	0.250	25.306	3.631	941.899	0.249	0.049	5.459	1.192	0.639	0.095
21000.0	0.248	24.941	3.695	941.568	0.257	0.052	5.503	1.227	0.661	0.101
21500.0	0.246	24.579	3.758	941.236	0.265	0.055	5.545	1.263	0.682	0.107
22000.0	0.245	24.221	3.820	940.903	0.272	0.058	5.584	1.299	0.704	0.114
22500.0	0.243	23.866	3.882	940.569	0.280	0.061	5.623	1.334	0.725	0.121
23000.0	0.241	23.514	3.942	940.234	0.288	0.064	5.659	1.369	0.746	0.127
23500.0	0.239	23.166	4.001	939.898	0.297	0.067	5.694	1.404	0.768	0.134
24000.0	0.238	22.821	4.060	939.561	0.305	0.070	5.727	1.439	0.789	0.142
24500.0	0.236	22.480	4.118	939.222	0.313	0.074	5.759	1.474	0.810	0.149
25000.0	0.234	22.142	4.175	938.883	0.321	0.077	5.790	1.509	0.830	0.156
25500.0	0.233	21.807	4.231	938.542	0.329	0.081	5.819	1.543	0.851	0.164
27500.0	0.226	20.502	4.447	937.166	0.362	0.096	5.923	1.679	0.933	0.197
30000.0	0.218	18.944	4.699	935.415	0.403	0.117	6.028	1.842	1.033	0.242
32500.0	0.210	17.468	4.931	933.631	0.445	0.141	6.107	2.000	1.127	0.292
35000.0	0.202	16.070	5.144	931.813	0.487	0.166	6.163	2.152	1.216	0.345
37500.0	0.195	14.751	5.337	929.960	0.528	0.194	6.201	2.297	1.299	0.403
40000.0	0.187	13.507	5.511	928.073	0.569	0.224	6.221	2.435	1.376	0.464
42500.0	0.180	12.338	5.667	926.150	0.609	0.256	6.227	2.565	1.446	0.528
45000.0	0.173	11.243	5.806	924.191	0.648	0.289	6.221	2.688	1.510	0.596
47500.0	0.166	10.218	5.927	922.197	0.686	0.324	6.205	2.804	1.569	0.667
50000.0	0.160	9.262	6.031	920.167	0.723	0.360	6.180	2.911	1.621	0.740
52500.0	0.153	8.374	6.119	918.101	0.758	0.397	6.148	3.011	1.667	0.815
55000.0	0.147	7.552	6.192	916.001	0.791	0.435	6.111	3.103	1.708	0.893
57500.0	0.141	6.792	6.250	913.866	0.823	0.473	6.070	3.187	1.744	0.973
60000.0	0.135	6.093	6.294	911.698	0.853	0.512	6.026	3.264	1.774	1.054
62500.0	0.130	5.452	6.325	909.497	0.881	0.550	5.981	3.334	1.801	1.137
65000.0	0.124	4.867	6.343	907.264	0.907	0.587	5.934	3.396	1.823	1.221
67500.0	0.119	4.333	6.349	905.001	0.930	0.624	5.887	3.452	1.841	1.306
70000.0	0.114	3.850	6.344	902.710	0.952	0.660	5.841	3.502	1.857	1.392

**Table C.13 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.331	43.917	0.000	955.752	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.331	43.797	0.022	955.704	0.000	0.000	0.015	0.000	0.000	0.000
500.0	0.330	43.318	0.110	955.510	0.001	0.000	0.166	0.001	0.000	0.000
1000.0	0.328	42.726	0.219	955.268	0.003	0.000	0.368	0.006	0.000	0.000
1500.0	0.326	42.142	0.325	955.025	0.005	0.000	0.562	0.013	0.001	0.000
2000.0	0.325	41.565	0.431	954.782	0.007	0.000	0.747	0.023	0.002	0.000
2500.0	0.323	40.994	0.534	954.539	0.009	0.000	0.924	0.035	0.003	0.000
3000.0	0.321	40.431	0.637	954.296	0.012	0.000	1.093	0.050	0.006	0.000
3500.0	0.319	39.874	0.738	954.053	0.014	0.000	1.254	0.066	0.009	0.000
4000.0	0.318	39.323	0.837	953.811	0.017	0.001	1.408	0.084	0.013	0.000
4500.0	0.316	38.777	0.935	953.568	0.020	0.001	1.554	0.103	0.018	0.000
5000.0	0.314	38.238	1.032	953.325	0.023	0.001	1.694	0.124	0.023	0.001
5500.0	0.313	37.704	1.128	953.082	0.026	0.001	1.828	0.146	0.030	0.001
6000.0	0.311	37.176	1.222	952.839	0.030	0.001	1.955	0.169	0.037	0.001
6500.0	0.309	36.652	1.315	952.597	0.033	0.002	2.076	0.193	0.045	0.002
7000.0	0.308	36.134	1.407	952.354	0.036	0.002	2.191	0.217	0.054	0.002
7500.0	0.306	35.621	1.498	952.112	0.040	0.002	2.301	0.243	0.063	0.003
8000.0	0.305	35.112	1.588	951.870	0.044	0.003	2.405	0.269	0.073	0.004
8500.0	0.303	34.609	1.676	951.628	0.048	0.003	2.504	0.296	0.084	0.005
9000.0	0.301	34.110	1.763	951.386	0.052	0.004	2.597	0.324	0.096	0.006
9500.0	0.300	33.615	1.850	951.145	0.056	0.004	2.686	0.352	0.108	0.007
10000.0	0.298	33.124	1.935	950.903	0.060	0.004	2.770	0.380	0.120	0.008
10500.0	0.297	32.638	2.019	950.663	0.064	0.005	2.850	0.409	0.133	0.010
11000.0	0.295	32.156	2.103	950.422	0.068	0.006	2.925	0.439	0.146	0.011
11500.0	0.293	31.677	2.185	950.182	0.073	0.006	2.996	0.468	0.160	0.013
12000.0	0.292	31.203	2.266	949.941	0.077	0.007	3.063	0.498	0.174	0.015
12500.0	0.290	30.733	2.346	949.701	0.082	0.008	3.126	0.529	0.188	0.017
13000.0	0.289	30.266	2.426	949.462	0.086	0.008	3.185	0.559	0.203	0.019
13500.0	0.287	29.803	2.504	949.222	0.091	0.009	3.241	0.590	0.217	0.022
14000.0	0.286	29.343	2.582	948.983	0.096	0.010	3.293	0.621	0.232	0.024
14500.0	0.284	28.887	2.658	948.744	0.101	0.011	3.341	0.652	0.247	0.027
15000.0	0.283	28.434	2.734	948.505	0.106	0.012	3.387	0.683	0.263	0.030
15500.0	0.281	27.985	2.809	948.267	0.111	0.012	3.429	0.714	0.278	0.033
16000.0	0.280	27.538	2.883	948.028	0.116	0.013	3.468	0.746	0.293	0.037
16500.0	0.278	27.095	2.957	947.790	0.121	0.014	3.505	0.777	0.308	0.040
17000.0	0.277	26.656	3.029	947.550	0.126	0.015	3.540	0.808	0.324	0.044
17500.0	0.275	26.219	3.101	947.310	0.131	0.016	3.572	0.839	0.339	0.048
18000.0	0.274	25.786	3.172	947.070	0.136	0.018	3.602	0.871	0.355	0.052
18500.0	0.272	25.357	3.242	946.828	0.141	0.019	3.630	0.902	0.371	0.056
19000.0	0.271	24.930	3.311	946.585	0.146	0.020	3.657	0.933	0.386	0.061
19500.0	0.269	24.507	3.380	946.341	0.152	0.021	3.681	0.964	0.402	0.065
20000.0	0.268	24.088	3.448	946.096	0.157	0.023	3.704	0.995	0.418	0.070
20500.0	0.266	23.671	3.515	945.850	0.163	0.024	3.726	1.026	0.433	0.075
21000.0	0.265	23.258	3.581	945.603	0.168	0.025	3.745	1.057	0.449	0.081
21500.0	0.263	22.848	3.647	945.354	0.174	0.027	3.764	1.088	0.465	0.086
22500.0	0.260	22.039	3.776	944.851	0.185	0.030	3.797	1.148	0.496	0.098
25000.0	0.253	20.076	4.085	943.568	0.214	0.039	3.859	1.297	0.574	0.132
27500.0	0.245	18.200	4.374	942.244	0.245	0.049	3.893	1.441	0.648	0.171
30000.0	0.238	16.411	4.643	940.877	0.277	0.061	3.903	1.579	0.717	0.217
32500.0	0.230	14.712	4.893	939.462	0.309	0.074	3.894	1.712	0.780	0.269
35000.0	0.223	13.104	5.123	937.996	0.342	0.089	3.868	1.837	0.838	0.328
37500.0	0.215	11.590	5.333	936.476	0.376	0.105	3.829	1.955	0.888	0.392
40000.0	0.207	10.172	5.522	934.897	0.409	0.123	3.779	2.064	0.931	0.463
42500.0	0.199	8.852	5.689	933.255	0.443	0.142	3.722	2.164	0.967	0.540
45000.0	0.191	7.635	5.836	931.545	0.475	0.163	3.659	2.255	0.997	0.622
47500.0	0.184	6.521	5.961	929.765	0.507	0.184	3.594	2.337	1.020	0.710
50000.0	0.176	5.513	6.064	927.910	0.538	0.206	3.527	2.409	1.037	0.803
52500.0	0.168	4.611	6.146	925.978	0.568	0.228	3.462	2.471	1.048	0.901
55000.0	0.160	3.815	6.206	923.968	0.596	0.250	3.399	2.523	1.055	1.003
57500.0	0.152	3.121	6.246	921.880	0.621	0.272	3.340	2.566	1.059	1.108
60000.0	0.144	2.526	6.266	919.716	0.645	0.294	3.286	2.600	1.059	1.216
62500.0	0.137	2.024	6.269	917.480	0.667	0.314	3.237	2.626	1.056	1.325
65000.0	0.130	1.606	6.255	915.178	0.686	0.332	3.194	2.646	1.052	1.435
67500.0	0.122	1.264	6.226	912.815	0.703	0.350	3.157	2.659	1.048	1.545
70000.0	0.116	0.987	6.186	910.400	0.717	0.365	3.125	2.668	1.042	1.654

**Table C.14 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.331	43.917	0.000	955.752	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.331	43.797	0.023	955.696	0.000	0.000	0.017	0.000	0.000	0.000
500.0	0.329	43.319	0.114	955.473	0.002	0.000	0.190	0.001	0.000	0.000
1000.0	0.327	42.730	0.227	955.194	0.004	0.000	0.422	0.006	0.000	0.000
1500.0	0.326	42.150	0.338	954.914	0.006	0.000	0.644	0.015	0.001	0.000
2000.0	0.324	41.578	0.447	954.635	0.008	0.000	0.855	0.026	0.002	0.000
2500.0	0.322	41.014	0.554	954.356	0.011	0.000	1.057	0.040	0.005	0.000
3000.0	0.320	40.458	0.659	954.077	0.014	0.000	1.249	0.056	0.008	0.000
3500.0	0.318	39.908	0.763	953.798	0.017	0.001	1.433	0.074	0.012	0.000
4000.0	0.316	39.365	0.865	953.519	0.021	0.001	1.608	0.094	0.017	0.000
4500.0	0.314	38.829	0.965	953.241	0.024	0.001	1.775	0.116	0.023	0.001
5000.0	0.312	38.300	1.064	952.963	0.028	0.001	1.935	0.138	0.031	0.001
5500.0	0.310	37.776	1.162	952.685	0.031	0.002	2.087	0.162	0.039	0.001
6000.0	0.308	37.259	1.258	952.407	0.035	0.002	2.232	0.187	0.048	0.002
6500.0	0.307	36.747	1.352	952.130	0.040	0.002	2.370	0.213	0.058	0.002
7000.0	0.305	36.241	1.446	951.852	0.044	0.003	2.502	0.240	0.069	0.003
7500.0	0.303	35.740	1.538	951.576	0.048	0.003	2.627	0.267	0.081	0.004
8000.0	0.301	35.245	1.629	951.299	0.053	0.004	2.747	0.296	0.094	0.005
8500.0	0.299	34.755	1.718	951.023	0.057	0.004	2.860	0.325	0.107	0.006
9000.0	0.298	34.269	1.806	950.748	0.062	0.005	2.968	0.354	0.121	0.007
9500.0	0.296	33.789	1.893	950.473	0.067	0.005	3.070	0.384	0.135	0.009
10000.0	0.294	33.313	1.979	950.198	0.072	0.006	3.167	0.414	0.151	0.010
10500.0	0.292	32.842	2.063	949.924	0.077	0.007	3.260	0.445	0.166	0.012
11000.0	0.291	32.375	2.147	949.650	0.082	0.008	3.347	0.476	0.182	0.014
11500.0	0.289	31.913	2.229	949.376	0.088	0.008	3.429	0.508	0.199	0.016
12000.0	0.287	31.455	2.310	949.103	0.093	0.009	3.508	0.540	0.215	0.018
12500.0	0.286	31.001	2.390	948.830	0.099	0.010	3.582	0.572	0.233	0.021
13000.0	0.284	30.551	2.469	948.557	0.104	0.011	3.652	0.604	0.250	0.023
13500.0	0.282	30.105	2.547	948.285	0.110	0.012	3.718	0.636	0.268	0.026
14000.0	0.281	29.663	2.625	948.013	0.116	0.013	3.780	0.669	0.285	0.029
14500.0	0.279	29.225	2.701	947.742	0.121	0.014	3.838	0.702	0.303	0.032
15000.0	0.277	28.790	2.776	947.470	0.127	0.015	3.893	0.735	0.321	0.036
15500.0	0.276	28.359	2.850	947.199	0.133	0.017	3.944	0.768	0.339	0.039
16000.0	0.274	27.931	2.924	946.928	0.139	0.018	3.992	0.801	0.357	0.043
16500.0	0.272	27.507	2.996	946.658	0.145	0.019	4.037	0.834	0.375	0.047
17000.0	0.271	27.086	3.068	946.387	0.151	0.021	4.080	0.867	0.394	0.051
17500.0	0.269	26.669	3.138	946.116	0.157	0.022	4.119	0.900	0.412	0.056
18000.0	0.268	26.255	3.208	945.844	0.163	0.023	4.157	0.933	0.430	0.060
18500.0	0.266	25.844	3.277	945.572	0.169	0.025	4.192	0.966	0.448	0.065
19000.0	0.265	25.437	3.346	945.300	0.175	0.027	4.225	0.999	0.466	0.070
19500.0	0.263	25.033	3.413	945.026	0.181	0.028	4.256	1.032	0.484	0.075
20000.0	0.261	24.632	3.480	944.751	0.187	0.030	4.285	1.064	0.502	0.081
20500.0	0.260	24.235	3.546	944.475	0.194	0.032	4.312	1.097	0.521	0.086
21000.0	0.258	23.842	3.610	944.198	0.200	0.034	4.338	1.129	0.539	0.092
21500.0	0.257	23.452	3.675	943.920	0.206	0.035	4.362	1.161	0.557	0.098
22000.0	0.255	23.065	3.738	943.641	0.213	0.037	4.385	1.193	0.575	0.104
22500.0	0.253	22.682	3.800	943.360	0.219	0.039	4.406	1.225	0.593	0.111
25000.0	0.246	20.816	4.101	941.934	0.253	0.051	4.494	1.381	0.682	0.147
27500.0	0.238	19.037	4.381	940.472	0.288	0.063	4.552	1.531	0.767	0.188
30000.0	0.230	17.343	4.641	938.970	0.324	0.078	4.584	1.675	0.848	0.236
32500.0	0.222	15.735	4.881	937.428	0.361	0.095	4.595	1.813	0.922	0.289
35000.0	0.215	14.212	5.102	935.844	0.398	0.113	4.587	1.944	0.990	0.347
37500.0	0.207	12.776	5.303	934.214	0.434	0.133	4.564	2.067	1.051	0.411
40000.0	0.200	11.426	5.485	932.536	0.471	0.155	4.528	2.182	1.105	0.479
42500.0	0.192	10.163	5.647	930.809	0.507	0.178	4.482	2.288	1.151	0.553
45000.0	0.185	8.988	5.790	929.030	0.542	0.203	4.428	2.386	1.191	0.631
47500.0	0.177	7.900	5.914	927.197	0.577	0.228	4.368	2.475	1.224	0.714
50000.0	0.170	6.899	6.018	925.309	0.610	0.255	4.305	2.554	1.250	0.800
52500.0	0.163	5.986	6.104	923.363	0.641	0.282	4.240	2.625	1.270	0.890
55000.0	0.156	5.158	6.171	921.361	0.671	0.309	4.175	2.686	1.285	0.982
57500.0	0.149	4.415	6.221	919.300	0.700	0.336	4.110	2.739	1.295	1.078
60000.0	0.142	3.753	6.254	917.183	0.726	0.362	4.048	2.783	1.301	1.175
62500.0	0.135	3.168	6.270	915.010	0.750	0.388	3.989	2.820	1.303	1.273
65000.0	0.129	2.657	6.272	912.783	0.772	0.413	3.934	2.849	1.303	1.373
67500.0	0.123	2.215	6.259	910.506	0.792	0.436	3.883	2.872	1.300	1.472
70000.0	0.116	1.836	6.234	908.183	0.809	0.458	3.837	2.889	1.296	1.572

**Table C.15 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.331	43.917	0.000	955.752	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.331	43.797	0.024	955.686	0.000	0.000	0.020	0.000	0.000	0.000
500.0	0.329	43.323	0.121	955.422	0.002	0.000	0.222	0.002	0.000	0.000
1000.0	0.327	42.739	0.239	955.092	0.005	0.000	0.493	0.008	0.000	0.000
1500.0	0.324	42.165	0.355	954.762	0.007	0.000	0.752	0.017	0.001	0.000
2000.0	0.322	41.601	0.469	954.433	0.011	0.000	0.999	0.030	0.003	0.000
2500.0	0.320	41.045	0.581	954.103	0.014	0.000	1.235	0.046	0.007	0.000
3000.0	0.318	40.498	0.691	953.775	0.018	0.001	1.460	0.064	0.011	0.000
3500.0	0.315	39.959	0.799	953.446	0.022	0.001	1.675	0.084	0.017	0.000
4000.0	0.313	39.428	0.905	953.118	0.026	0.001	1.880	0.106	0.024	0.001
4500.0	0.311	38.904	1.009	952.791	0.030	0.001	2.076	0.129	0.032	0.001
5000.0	0.309	38.387	1.111	952.464	0.035	0.002	2.264	0.154	0.041	0.001
5500.0	0.307	37.877	1.212	952.137	0.039	0.002	2.443	0.179	0.052	0.002
6000.0	0.305	37.374	1.311	951.811	0.045	0.003	2.615	0.206	0.064	0.002
6500.0	0.303	36.877	1.408	951.485	0.050	0.003	2.779	0.234	0.076	0.003
7000.0	0.300	36.386	1.504	951.159	0.055	0.004	2.936	0.263	0.090	0.004
7500.0	0.298	35.901	1.598	950.834	0.061	0.005	3.086	0.292	0.105	0.005
8000.0	0.296	35.422	1.691	950.510	0.067	0.005	3.229	0.323	0.121	0.006
8500.0	0.294	34.949	1.782	950.186	0.073	0.006	3.365	0.353	0.137	0.007
9000.0	0.292	34.481	1.872	949.863	0.079	0.007	3.496	0.385	0.154	0.009
9500.0	0.290	34.018	1.961	949.540	0.085	0.008	3.620	0.417	0.172	0.011
10000.0	0.288	33.561	2.048	949.218	0.091	0.009	3.739	0.449	0.190	0.012
10500.0	0.286	33.108	2.134	948.896	0.097	0.010	3.852	0.482	0.209	0.014
11000.0	0.284	32.660	2.218	948.575	0.104	0.011	3.960	0.516	0.228	0.017
11500.0	0.282	32.217	2.302	948.254	0.110	0.012	4.063	0.549	0.248	0.019
12000.0	0.281	31.779	2.384	947.933	0.117	0.013	4.161	0.583	0.268	0.022
12500.0	0.279	31.345	2.465	947.613	0.124	0.015	4.255	0.617	0.288	0.024
13000.0	0.277	30.916	2.545	947.293	0.130	0.016	4.344	0.652	0.309	0.027
13500.0	0.275	30.491	2.623	946.973	0.137	0.018	4.428	0.687	0.330	0.030
14000.0	0.273	30.070	2.701	946.654	0.144	0.019	4.509	0.722	0.351	0.034
14500.0	0.271	29.653	2.777	946.335	0.151	0.021	4.585	0.757	0.372	0.037
15000.0	0.269	29.241	2.853	946.016	0.158	0.023	4.658	0.792	0.393	0.041
15500.0	0.267	28.832	2.927	945.698	0.165	0.024	4.727	0.828	0.415	0.045
16000.0	0.266	28.427	3.000	945.380	0.173	0.026	4.792	0.863	0.436	0.049
16500.0	0.264	28.026	3.072	945.062	0.180	0.028	4.854	0.899	0.457	0.053
17000.0	0.262	27.628	3.143	944.744	0.187	0.030	4.913	0.935	0.479	0.058
17500.0	0.260	27.234	3.214	944.426	0.195	0.032	4.969	0.970	0.500	0.063
18000.0	0.259	26.844	3.283	944.108	0.202	0.034	5.022	1.006	0.522	0.068
18500.0	0.257	26.458	3.351	943.790	0.210	0.036	5.071	1.042	0.543	0.073
19000.0	0.255	26.075	3.419	943.472	0.217	0.039	5.119	1.078	0.564	0.078
19500.0	0.253	25.695	3.485	943.153	0.225	0.041	5.164	1.113	0.585	0.084
20000.0	0.252	25.319	3.550	942.834	0.232	0.043	5.206	1.149	0.607	0.089
20500.0	0.250	24.946	3.615	942.514	0.240	0.046	5.247	1.184	0.628	0.095
21000.0	0.248	24.576	3.679	942.194	0.247	0.048	5.285	1.219	0.649	0.101
21500.0	0.247	24.211	3.742	941.872	0.255	0.051	5.322	1.255	0.670	0.108
22000.0	0.245	23.848	3.804	941.550	0.263	0.054	5.357	1.290	0.691	0.114
22500.0	0.243	23.489	3.865	941.227	0.270	0.057	5.390	1.325	0.711	0.121
23000.0	0.242	23.133	3.925	940.902	0.278	0.060	5.421	1.359	0.732	0.128
23500.0	0.240	22.781	3.985	940.576	0.286	0.063	5.451	1.394	0.753	0.135
24000.0	0.238	22.432	4.044	940.249	0.294	0.066	5.480	1.428	0.773	0.142
24500.0	0.237	22.087	4.102	939.921	0.302	0.069	5.507	1.462	0.794	0.149
25000.0	0.235	21.744	4.159	939.592	0.309	0.072	5.533	1.496	0.814	0.157
27500.0	0.227	20.084	4.431	937.924	0.349	0.090	5.645	1.662	0.915	0.198
30000.0	0.219	18.507	4.684	936.223	0.390	0.110	5.729	1.822	1.011	0.244
32500.0	0.211	17.011	4.916	934.487	0.430	0.132	5.788	1.976	1.102	0.295
35000.0	0.203	15.596	5.129	932.715	0.471	0.156	5.825	2.123	1.187	0.350
37500.0	0.195	14.259	5.322	930.908	0.511	0.182	5.845	2.263	1.266	0.409
40000.0	0.188	13.000	5.497	929.063	0.551	0.210	5.848	2.395	1.338	0.472
42500.0	0.181	11.818	5.653	927.181	0.591	0.240	5.838	2.520	1.404	0.539
45000.0	0.174	10.711	5.790	925.261	0.629	0.272	5.817	2.637	1.463	0.609
47500.0	0.167	9.677	5.911	923.303	0.667	0.304	5.787	2.746	1.515	0.682
50000.0	0.160	8.716	6.014	921.306	0.703	0.338	5.750	2.847	1.562	0.758
52500.0	0.153	7.824	6.101	919.270	0.737	0.373	5.706	2.939	1.602	0.837
55000.0	0.147	7.002	6.172	917.196	0.770	0.409	5.659	3.023	1.637	0.918
57500.0	0.141	6.245	6.227	915.084	0.801	0.444	5.608	3.100	1.666	1.001
60000.0	0.135	5.552	6.268	912.935	0.830	0.480	5.556	3.168	1.690	1.085
62500.0	0.129	4.920	6.296	910.750	0.857	0.516	5.503	3.230	1.710	1.171
65000.0	0.124	4.347	6.310	908.529	0.882	0.550	5.451	3.283	1.726	1.258
67500.0	0.119	3.829	6.312	906.275	0.905	0.584	5.399	3.331	1.739	1.346
70000.0	0.113	3.363	6.303	903.988	0.926	0.617	5.349	3.371	1.748	1.435

**Table C.16 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.321	42.545	0.000	957.134	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.321	42.425	0.022	957.086	0.000	0.000	0.015	0.000	0.000	0.000
500.0	0.319	41.947	0.109	956.895	0.001	0.000	0.164	0.001	0.000	0.000
1000.0	0.318	41.356	0.216	956.655	0.003	0.000	0.364	0.006	0.000	0.000
1500.0	0.316	40.773	0.322	956.414	0.005	0.000	0.556	0.013	0.001	0.000
2000.0	0.314	40.197	0.426	956.174	0.007	0.000	0.738	0.023	0.002	0.000
2500.0	0.313	39.628	0.528	955.933	0.009	0.000	0.912	0.036	0.003	0.000
3000.0	0.311	39.066	0.629	955.693	0.012	0.000	1.078	0.050	0.006	0.000
3500.0	0.310	38.511	0.729	955.452	0.014	0.000	1.236	0.067	0.009	0.000
4000.0	0.308	37.962	0.827	955.212	0.017	0.001	1.386	0.085	0.013	0.000
4500.0	0.306	37.418	0.924	954.972	0.020	0.001	1.529	0.105	0.018	0.001
5000.0	0.305	36.881	1.020	954.732	0.023	0.001	1.665	0.126	0.023	0.001
5500.0	0.303	36.349	1.114	954.492	0.026	0.001	1.795	0.148	0.030	0.001
6000.0	0.302	35.822	1.207	954.252	0.029	0.001	1.918	0.172	0.037	0.001
6500.0	0.300	35.301	1.299	954.012	0.032	0.002	2.036	0.196	0.045	0.002
7000.0	0.298	34.785	1.390	953.772	0.036	0.002	2.147	0.221	0.054	0.003
7500.0	0.297	34.273	1.479	953.533	0.039	0.002	2.252	0.247	0.063	0.003
8000.0	0.295	33.767	1.567	953.294	0.043	0.003	2.353	0.274	0.073	0.004
8500.0	0.294	33.265	1.655	953.055	0.047	0.003	2.447	0.301	0.084	0.005
9000.0	0.292	32.768	1.741	952.817	0.051	0.003	2.537	0.329	0.095	0.006
9500.0	0.291	32.275	1.826	952.578	0.054	0.004	2.621	0.358	0.107	0.007
10000.0	0.289	31.787	1.910	952.341	0.058	0.004	2.701	0.387	0.119	0.009
10500.0	0.288	31.303	1.993	952.103	0.063	0.005	2.776	0.416	0.132	0.010
11000.0	0.286	30.822	2.075	951.866	0.067	0.005	2.847	0.446	0.145	0.012
11500.0	0.285	30.346	2.156	951.630	0.071	0.006	2.914	0.476	0.158	0.014
12000.0	0.283	29.874	2.236	951.393	0.075	0.007	2.976	0.506	0.172	0.016
12500.0	0.282	29.405	2.315	951.157	0.080	0.007	3.035	0.537	0.186	0.018
13000.0	0.280	28.940	2.394	950.921	0.084	0.008	3.090	0.568	0.200	0.020
13500.0	0.279	28.478	2.471	950.686	0.089	0.009	3.141	0.599	0.214	0.022
14000.0	0.277	28.020	2.547	950.451	0.093	0.010	3.189	0.630	0.229	0.025
14500.0	0.276	27.566	2.623	950.216	0.098	0.010	3.233	0.661	0.243	0.028
15000.0	0.274	27.114	2.698	949.981	0.102	0.011	3.275	0.693	0.258	0.031
15500.0	0.273	26.666	2.772	949.745	0.107	0.012	3.314	0.724	0.273	0.034
16000.0	0.271	26.222	2.845	949.509	0.112	0.013	3.350	0.756	0.288	0.038
16500.0	0.270	25.781	2.917	949.273	0.117	0.014	3.384	0.787	0.303	0.041
17000.0	0.268	25.343	2.988	949.036	0.122	0.015	3.416	0.819	0.318	0.045
17500.0	0.267	24.909	3.059	948.798	0.127	0.016	3.445	0.850	0.333	0.049
18000.0	0.265	24.478	3.129	948.559	0.132	0.017	3.473	0.882	0.348	0.053
18500.0	0.264	24.050	3.198	948.318	0.137	0.018	3.499	0.913	0.363	0.058
19000.0	0.263	23.626	3.267	948.077	0.142	0.019	3.523	0.944	0.379	0.062
19500.0	0.261	23.205	3.334	947.834	0.147	0.021	3.545	0.976	0.394	0.067
20000.0	0.260	22.788	3.401	947.590	0.152	0.022	3.566	1.007	0.409	0.072
20500.0	0.258	22.374	3.467	947.345	0.158	0.023	3.585	1.038	0.425	0.078
21000.0	0.257	21.964	3.533	947.098	0.163	0.025	3.603	1.069	0.440	0.083
22500.0	0.252	20.754	3.724	946.348	0.179	0.029	3.649	1.160	0.486	0.101
25000.0	0.245	18.808	4.027	945.065	0.208	0.038	3.701	1.309	0.561	0.136
27500.0	0.238	16.952	4.310	943.737	0.238	0.047	3.726	1.454	0.632	0.177
30000.0	0.230	15.187	4.574	942.363	0.269	0.059	3.729	1.592	0.698	0.225
32500.0	0.223	13.516	4.817	940.937	0.300	0.072	3.713	1.724	0.758	0.279
35000.0	0.215	11.940	5.039	939.456	0.332	0.086	3.681	1.849	0.811	0.340
37500.0	0.207	10.463	5.241	937.915	0.365	0.102	3.637	1.965	0.858	0.407
40000.0	0.200	9.088	5.421	936.309	0.397	0.120	3.585	2.073	0.897	0.481
42500.0	0.192	7.818	5.579	934.633	0.429	0.138	3.525	2.171	0.930	0.561
45000.0	0.184	6.656	5.715	932.884	0.460	0.158	3.462	2.259	0.956	0.648
47500.0	0.176	5.605	5.829	931.056	0.491	0.179	3.398	2.337	0.975	0.740
50000.0	0.168	4.665	5.920	929.148	0.520	0.199	3.334	2.405	0.989	0.837
52500.0	0.160	3.836	5.989	927.156	0.548	0.221	3.272	2.463	0.999	0.939
55000.0	0.152	3.116	6.037	925.082	0.574	0.241	3.214	2.511	1.004	1.045
57500.0	0.145	2.502	6.064	922.926	0.598	0.262	3.161	2.549	1.005	1.155
60000.0	0.137	1.986	6.072	920.693	0.620	0.281	3.114	2.579	1.004	1.266
62500.0	0.129	1.560	6.063	918.389	0.639	0.299	3.072	2.602	1.002	1.379
65000.0	0.122	1.214	6.038	916.022	0.656	0.316	3.037	2.618	0.998	1.491
67500.0	0.115	0.938	6.001	913.599	0.671	0.331	3.006	2.629	0.994	1.604
70000.0	0.108	0.720	5.954	911.129	0.683	0.344	2.980	2.635	0.989	1.715

**Table C.17 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.321	42.545	0.000	957.134	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.321	42.425	0.023	957.079	0.000	0.000	0.017	0.000	0.000	0.000
500.0	0.319	41.949	0.113	956.857	0.002	0.000	0.189	0.001	0.000	0.000
1000.0	0.317	41.361	0.224	956.578	0.004	0.000	0.419	0.007	0.000	0.000
1500.0	0.315	40.783	0.334	956.300	0.006	0.000	0.639	0.015	0.001	0.000
2000.0	0.314	40.212	0.441	956.022	0.008	0.000	0.848	0.027	0.002	0.000
2500.0	0.312	39.650	0.547	955.745	0.011	0.000	1.048	0.041	0.005	0.000
3000.0	0.310	39.096	0.651	955.467	0.014	0.000	1.237	0.058	0.008	0.000
3500.0	0.308	38.549	0.753	955.190	0.017	0.001	1.418	0.076	0.012	0.000
4000.0	0.306	38.008	0.854	954.913	0.020	0.001	1.590	0.096	0.017	0.000
4500.0	0.304	37.475	0.953	954.636	0.024	0.001	1.754	0.118	0.024	0.001
5000.0	0.303	36.948	1.050	954.360	0.027	0.001	1.910	0.142	0.031	0.001
5500.0	0.301	36.427	1.146	954.084	0.031	0.002	2.058	0.166	0.039	0.001
6000.0	0.299	35.912	1.241	953.809	0.035	0.002	2.199	0.191	0.048	0.002
6500.0	0.297	35.403	1.334	953.533	0.039	0.002	2.333	0.218	0.059	0.003
7000.0	0.295	34.900	1.426	953.259	0.043	0.003	2.461	0.245	0.070	0.003
7500.0	0.294	34.402	1.517	952.985	0.048	0.003	2.582	0.273	0.082	0.004
8000.0	0.292	33.910	1.606	952.711	0.052	0.004	2.697	0.302	0.094	0.005
8500.0	0.290	33.423	1.694	952.437	0.057	0.004	2.806	0.331	0.107	0.006
9000.0	0.288	32.940	1.781	952.165	0.061	0.005	2.909	0.361	0.121	0.008
9500.0	0.287	32.463	1.866	951.893	0.066	0.005	3.007	0.392	0.136	0.009
10000.0	0.285	31.990	1.950	951.621	0.071	0.006	3.099	0.423	0.151	0.011
10500.0	0.283	31.521	2.034	951.350	0.076	0.007	3.186	0.454	0.166	0.013
11000.0	0.282	31.058	2.116	951.079	0.081	0.007	3.269	0.486	0.182	0.014
11500.0	0.280	30.598	2.196	950.809	0.086	0.008	3.346	0.518	0.198	0.017
12000.0	0.278	30.143	2.276	950.539	0.091	0.009	3.420	0.550	0.215	0.019
12500.0	0.277	29.692	2.355	950.270	0.097	0.010	3.489	0.582	0.232	0.022
13000.0	0.275	29.244	2.433	950.001	0.102	0.011	3.554	0.615	0.249	0.024
13500.0	0.274	28.801	2.509	949.732	0.107	0.012	3.615	0.648	0.266	0.027
14000.0	0.272	28.361	2.585	949.464	0.113	0.013	3.672	0.681	0.283	0.030
14500.0	0.270	27.926	2.660	949.195	0.118	0.014	3.726	0.714	0.301	0.034
15000.0	0.269	27.493	2.734	948.927	0.124	0.015	3.776	0.747	0.318	0.037
15500.0	0.267	27.065	2.807	948.660	0.130	0.016	3.824	0.780	0.336	0.041
16000.0	0.266	26.639	2.879	948.392	0.135	0.017	3.868	0.814	0.354	0.045
16500.0	0.264	26.218	2.950	948.124	0.141	0.019	3.909	0.847	0.371	0.049
17000.0	0.263	25.800	3.021	947.856	0.147	0.020	3.948	0.880	0.389	0.053
17500.0	0.261	25.385	3.090	947.587	0.153	0.021	3.984	0.913	0.407	0.058
18000.0	0.259	24.973	3.159	947.317	0.158	0.023	4.018	0.946	0.425	0.062
18500.0	0.258	24.566	3.227	947.047	0.164	0.024	4.050	0.979	0.443	0.067
19000.0	0.256	24.162	3.294	946.775	0.170	0.026	4.080	1.012	0.460	0.073
19500.0	0.255	23.761	3.360	946.503	0.176	0.028	4.108	1.045	0.478	0.078
20000.0	0.253	23.363	3.425	946.229	0.182	0.029	4.135	1.078	0.496	0.084
20500.0	0.252	22.970	3.490	945.954	0.189	0.031	4.159	1.110	0.514	0.089
21000.0	0.250	22.580	3.554	945.678	0.195	0.033	4.183	1.142	0.531	0.095
21500.0	0.249	22.193	3.617	945.401	0.201	0.035	4.204	1.175	0.549	0.102
22500.0	0.246	21.430	3.740	944.841	0.214	0.038	4.244	1.238	0.584	0.115
25000.0	0.238	19.584	4.034	943.416	0.247	0.049	4.320	1.394	0.671	0.152
27500.0	0.230	17.827	4.308	941.952	0.281	0.062	4.367	1.543	0.754	0.196
30000.0	0.223	16.158	4.561	940.446	0.316	0.076	4.390	1.687	0.831	0.245
32500.0	0.215	14.577	4.794	938.897	0.352	0.093	4.391	1.823	0.902	0.300
35000.0	0.208	13.085	5.007	937.302	0.388	0.111	4.375	1.952	0.965	0.360
37500.0	0.200	11.682	5.201	935.658	0.423	0.130	4.345	2.073	1.022	0.427
40000.0	0.193	10.370	5.374	933.964	0.459	0.151	4.303	2.186	1.071	0.498
42500.0	0.185	9.148	5.528	932.215	0.494	0.174	4.253	2.289	1.114	0.575
45000.0	0.178	8.017	5.662	930.411	0.528	0.198	4.195	2.383	1.149	0.656
47500.0	0.171	6.977	5.776	928.548	0.561	0.222	4.134	2.468	1.177	0.742
50000.0	0.163	6.029	5.870	926.626	0.593	0.248	4.070	2.543	1.199	0.832
52500.0	0.156	5.171	5.946	924.642	0.623	0.273	4.005	2.608	1.216	0.925
55000.0	0.149	4.402	6.003	922.598	0.651	0.299	3.942	2.665	1.227	1.021
57500.0	0.142	3.719	6.042	920.492	0.678	0.324	3.880	2.712	1.234	1.120
60000.0	0.135	3.118	6.064	918.327	0.703	0.349	3.822	2.752	1.237	1.220
62500.0	0.129	2.595	6.071	916.104	0.725	0.373	3.768	2.783	1.238	1.321
65000.0	0.122	2.146	6.062	913.828	0.745	0.395	3.718	2.808	1.236	1.423
67500.0	0.116	1.762	6.041	911.502	0.763	0.416	3.673	2.827	1.232	1.525
70000.0	0.110	1.440	6.008	909.130	0.778	0.436	3.633	2.840	1.227	1.626

**Table C.18 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.321	42.545	0.000	957.134	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.321	42.426	0.024	957.068	0.000	0.000	0.020	0.000	0.000	0.000
500.0	0.319	41.953	0.120	956.802	0.002	0.000	0.223	0.002	0.000	0.000
1000.0	0.317	41.371	0.237	956.470	0.005	0.000	0.495	0.008	0.000	0.000
1500.0	0.314	40.799	0.352	956.138	0.008	0.000	0.754	0.018	0.002	0.000
2000.0	0.312	40.238	0.464	955.807	0.011	0.000	1.001	0.031	0.004	0.000
2500.0	0.310	39.685	0.575	955.477	0.014	0.000	1.236	0.047	0.007	0.000
3000.0	0.308	39.142	0.683	955.146	0.018	0.001	1.459	0.066	0.011	0.000
3500.0	0.306	38.606	0.789	954.817	0.022	0.001	1.673	0.087	0.017	0.000
4000.0	0.303	38.079	0.894	954.488	0.026	0.001	1.876	0.109	0.024	0.001
4500.0	0.301	37.559	0.996	954.159	0.030	0.001	2.070	0.133	0.033	0.001
5000.0	0.299	37.046	1.097	953.831	0.035	0.002	2.255	0.158	0.043	0.001
5500.0	0.297	36.540	1.196	953.503	0.040	0.002	2.432	0.185	0.054	0.002
6000.0	0.295	36.041	1.294	953.176	0.045	0.003	2.600	0.213	0.066	0.003
6500.0	0.293	35.549	1.390	952.850	0.050	0.003	2.761	0.241	0.079	0.003
7000.0	0.291	35.063	1.484	952.524	0.055	0.004	2.914	0.271	0.093	0.004
7500.0	0.289	34.583	1.576	952.199	0.061	0.005	3.060	0.301	0.108	0.005
8000.0	0.287	34.108	1.667	951.875	0.067	0.005	3.199	0.332	0.124	0.007
8500.0	0.285	33.639	1.757	951.551	0.072	0.006	3.332	0.363	0.140	0.008
9000.0	0.283	33.176	1.845	951.228	0.078	0.007	3.458	0.396	0.158	0.010
9500.0	0.281	32.719	1.932	950.906	0.085	0.008	3.578	0.428	0.176	0.011
10000.0	0.279	32.266	2.017	950.584	0.091	0.009	3.692	0.461	0.194	0.013
10500.0	0.277	31.818	2.102	950.263	0.097	0.010	3.801	0.495	0.213	0.015
11000.0	0.275	31.375	2.184	949.942	0.103	0.011	3.904	0.529	0.232	0.018
11500.0	0.273	30.937	2.266	949.622	0.110	0.012	4.002	0.563	0.252	0.020
12000.0	0.272	30.504	2.347	949.303	0.116	0.014	4.096	0.598	0.272	0.023
12500.0	0.270	30.075	2.426	948.984	0.123	0.015	4.184	0.632	0.292	0.026
13000.0	0.268	29.650	2.504	948.665	0.130	0.016	4.269	0.668	0.313	0.029
13500.0	0.266	29.230	2.581	948.346	0.136	0.018	4.349	0.703	0.334	0.032
14000.0	0.264	28.814	2.657	948.028	0.143	0.019	4.425	0.738	0.355	0.036
14500.0	0.262	28.402	2.732	947.710	0.150	0.021	4.497	0.774	0.376	0.039
15000.0	0.261	27.994	2.805	947.392	0.157	0.023	4.565	0.810	0.397	0.043
15500.0	0.259	27.590	2.878	947.075	0.164	0.024	4.630	0.845	0.418	0.047
16000.0	0.257	27.190	2.949	946.757	0.171	0.026	4.691	0.881	0.439	0.052
16500.0	0.255	26.793	3.020	946.440	0.178	0.028	4.749	0.917	0.461	0.056
17000.0	0.254	26.401	3.090	946.122	0.185	0.030	4.804	0.953	0.482	0.061
17500.0	0.252	26.012	3.158	945.805	0.193	0.032	4.856	0.989	0.503	0.066
18000.0	0.250	25.626	3.226	945.487	0.200	0.034	4.905	1.025	0.524	0.071
18500.0	0.249	25.245	3.293	945.170	0.207	0.036	4.951	1.061	0.545	0.076
19000.0	0.247	24.866	3.358	944.851	0.215	0.038	4.995	1.097	0.566	0.082
19500.0	0.245	24.492	3.423	944.533	0.222	0.041	5.037	1.133	0.587	0.088
20000.0	0.244	24.120	3.487	944.213	0.229	0.043	5.076	1.168	0.608	0.094
20500.0	0.242	23.753	3.550	943.893	0.237	0.046	5.113	1.204	0.629	0.100
21000.0	0.240	23.388	3.613	943.572	0.244	0.048	5.149	1.239	0.650	0.106
21500.0	0.239	23.028	3.674	943.250	0.252	0.051	5.183	1.274	0.671	0.113
22000.0	0.237	22.671	3.735	942.926	0.259	0.054	5.215	1.309	0.691	0.119
22500.0	0.235	22.317	3.794	942.602	0.267	0.056	5.245	1.344	0.712	0.126
23000.0	0.234	21.967	3.853	942.276	0.275	0.059	5.274	1.379	0.733	0.134
23500.0	0.232	21.620	3.911	941.949	0.282	0.062	5.302	1.413	0.753	0.141
24000.0	0.230	21.277	3.968	941.621	0.290	0.065	5.328	1.447	0.773	0.149
25000.0	0.227	20.601	4.080	940.960	0.306	0.072	5.377	1.515	0.813	0.164
27500.0	0.219	18.970	4.344	939.284	0.345	0.089	5.477	1.680	0.912	0.207
30000.0	0.211	17.424	4.589	937.572	0.385	0.109	5.550	1.838	1.006	0.255
32500.0	0.204	15.962	4.813	935.824	0.425	0.131	5.599	1.990	1.095	0.308
35000.0	0.196	14.581	5.017	934.040	0.465	0.155	5.627	2.135	1.177	0.365
37500.0	0.189	13.280	5.202	932.218	0.504	0.180	5.638	2.272	1.252	0.426
40000.0	0.181	12.058	5.368	930.358	0.543	0.208	5.634	2.402	1.321	0.492
42500.0	0.174	10.914	5.516	928.458	0.582	0.238	5.618	2.523	1.382	0.561
45000.0	0.167	9.847	5.645	926.520	0.619	0.269	5.591	2.636	1.438	0.633
47500.0	0.160	8.854	5.757	924.541	0.656	0.301	5.556	2.741	1.486	0.709
50000.0	0.154	7.934	5.852	922.522	0.690	0.334	5.515	2.837	1.528	0.788
52500.0	0.147	7.085	5.930	920.464	0.724	0.368	5.469	2.925	1.565	0.868
55000.0	0.141	6.304	5.993	918.365	0.755	0.402	5.420	3.004	1.595	0.952
57500.0	0.135	5.591	6.041	916.228	0.785	0.436	5.368	3.075	1.621	1.037
60000.0	0.129	4.941	6.074	914.053	0.813	0.471	5.316	3.139	1.642	1.123
62500.0	0.124	4.352	6.094	911.841	0.839	0.504	5.264	3.194	1.659	1.211
65000.0	0.118	3.820	6.101	909.593	0.862	0.537	5.212	3.243	1.672	1.300
67500.0	0.113	3.343	6.097	907.311	0.884	0.569	5.162	3.285	1.681	1.390
70000.0	0.108	2.917	6.081	904.998	0.903	0.600	5.114	3.321	1.688	1.480

**Table C.19 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.321	42.598	0.000	957.080	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.321	42.478	0.022	957.035	0.000	0.000	0.014	0.000	0.000	0.000
500.0	0.320	42.000	0.108	956.849	0.001	0.000	0.159	0.001	0.000	0.000
1000.0	0.318	41.408	0.215	956.617	0.003	0.000	0.352	0.005	0.000	0.000
1500.0	0.316	40.824	0.320	956.385	0.005	0.000	0.537	0.013	0.001	0.000
2000.0	0.315	40.247	0.423	956.153	0.007	0.000	0.713	0.023	0.002	0.000
2500.0	0.313	39.677	0.525	955.921	0.009	0.000	0.881	0.035	0.003	0.000
3000.0	0.312	39.114	0.626	955.689	0.011	0.000	1.041	0.049	0.005	0.000
3500.0	0.310	38.556	0.725	955.457	0.013	0.000	1.193	0.065	0.008	0.000
4000.0	0.308	38.005	0.823	955.226	0.016	0.001	1.338	0.083	0.012	0.000
4500.0	0.307	37.459	0.920	954.994	0.019	0.001	1.476	0.102	0.016	0.000
5000.0	0.305	36.919	1.015	954.763	0.021	0.001	1.607	0.123	0.022	0.001
5500.0	0.304	36.384	1.109	954.532	0.024	0.001	1.732	0.145	0.028	0.001
6000.0	0.302	35.855	1.202	954.301	0.027	0.001	1.851	0.167	0.034	0.001
6500.0	0.301	35.330	1.293	954.070	0.031	0.002	1.963	0.191	0.042	0.002
7000.0	0.299	34.811	1.384	953.840	0.034	0.002	2.070	0.216	0.050	0.002
7500.0	0.298	34.296	1.473	953.610	0.037	0.002	2.171	0.241	0.059	0.003
8000.0	0.296	33.785	1.562	953.381	0.041	0.002	2.267	0.267	0.068	0.004
8500.0	0.295	33.279	1.649	953.152	0.044	0.003	2.357	0.294	0.078	0.005
9000.0	0.293	32.778	1.735	952.924	0.048	0.003	2.443	0.321	0.089	0.006
9500.0	0.292	32.280	1.821	952.696	0.051	0.004	2.524	0.349	0.100	0.007
10000.0	0.290	31.786	1.905	952.469	0.055	0.004	2.600	0.377	0.111	0.008
10500.0	0.289	31.296	1.988	952.242	0.059	0.004	2.671	0.406	0.123	0.009
11000.0	0.287	30.810	2.070	952.016	0.063	0.005	2.739	0.435	0.135	0.011
11500.0	0.286	30.328	2.152	951.790	0.067	0.006	2.802	0.464	0.147	0.012
12000.0	0.284	29.849	2.232	951.564	0.071	0.006	2.862	0.494	0.160	0.014
12500.0	0.283	29.374	2.312	951.338	0.075	0.007	2.919	0.524	0.173	0.016
13000.0	0.281	28.903	2.390	951.111	0.079	0.007	2.973	0.554	0.186	0.018
13500.0	0.280	28.435	2.468	950.883	0.084	0.008	3.024	0.584	0.200	0.021
14000.0	0.278	27.972	2.545	950.654	0.088	0.009	3.072	0.614	0.214	0.023
14500.0	0.277	27.511	2.621	950.424	0.093	0.009	3.118	0.644	0.228	0.026
15000.0	0.276	27.055	2.697	950.192	0.097	0.010	3.162	0.675	0.242	0.029
15500.0	0.274	26.602	2.771	949.960	0.102	0.011	3.203	0.705	0.257	0.032
16000.0	0.273	26.153	2.845	949.726	0.107	0.012	3.242	0.736	0.272	0.035
17500.0	0.268	24.828	3.061	949.017	0.121	0.015	3.348	0.828	0.317	0.046
20000.0	0.261	22.692	3.405	947.807	0.147	0.021	3.487	0.982	0.395	0.068
22500.0	0.254	20.647	3.729	946.559	0.175	0.028	3.586	1.133	0.472	0.096
25000.0	0.246	18.694	4.033	945.270	0.204	0.036	3.650	1.282	0.548	0.131
27500.0	0.239	16.832	4.317	943.937	0.234	0.046	3.685	1.428	0.619	0.171
30000.0	0.231	15.064	4.580	942.557	0.265	0.057	3.695	1.567	0.685	0.218
32500.0	0.223	13.391	4.823	941.125	0.297	0.070	3.685	1.701	0.746	0.272
35000.0	0.216	11.816	5.045	939.637	0.329	0.085	3.658	1.828	0.800	0.333
37500.0	0.208	10.341	5.246	938.088	0.362	0.101	3.618	1.946	0.847	0.400
40000.0	0.200	8.970	5.425	936.474	0.395	0.118	3.568	2.056	0.888	0.474
42500.0	0.192	7.705	5.582	934.789	0.427	0.137	3.511	2.156	0.921	0.554
45000.0	0.184	6.550	5.717	933.030	0.459	0.157	3.449	2.246	0.948	0.640
47500.0	0.176	5.506	5.828	931.192	0.490	0.177	3.386	2.326	0.968	0.733
50000.0	0.168	4.575	5.918	929.273	0.519	0.198	3.323	2.396	0.983	0.830
52500.0	0.160	3.756	5.985	927.271	0.547	0.220	3.263	2.455	0.993	0.933
55000.0	0.152	3.046	6.030	925.185	0.573	0.241	3.206	2.504	0.998	1.039
57500.0	0.145	2.441	6.055	923.018	0.598	0.261	3.154	2.543	1.001	1.149
60000.0	0.137	1.935	6.062	920.775	0.619	0.280	3.108	2.574	1.000	1.260
62500.0	0.129	1.518	6.051	918.462	0.639	0.299	3.068	2.598	0.998	1.373
65000.0	0.122	1.180	6.025	916.085	0.656	0.315	3.033	2.614	0.995	1.486
67500.0	0.115	0.911	5.987	913.654	0.670	0.331	3.003	2.626	0.991	1.599
70000.0	0.108	0.699	5.938	911.178	0.683	0.344	2.978	2.633	0.987	1.710

**Table C.20 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.321	42.598	0.000	957.080	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.321	42.478	0.023	957.027	0.000	0.000	0.016	0.000	0.000	0.000
500.0	0.319	42.001	0.112	956.814	0.002	0.000	0.182	0.001	0.000	0.000
1000.0	0.318	41.413	0.223	956.546	0.004	0.000	0.404	0.006	0.000	0.000
1500.0	0.316	40.834	0.331	956.279	0.006	0.000	0.615	0.015	0.001	0.000
2000.0	0.314	40.262	0.438	956.012	0.008	0.000	0.816	0.026	0.002	0.000
2500.0	0.312	39.698	0.543	955.745	0.011	0.000	1.007	0.040	0.004	0.000
3000.0	0.310	39.142	0.646	955.478	0.013	0.000	1.189	0.056	0.007	0.000
3500.0	0.309	38.592	0.748	955.211	0.016	0.001	1.363	0.074	0.011	0.000
4000.0	0.307	38.050	0.848	954.945	0.019	0.001	1.528	0.094	0.016	0.000
4500.0	0.305	37.514	0.947	954.680	0.023	0.001	1.685	0.115	0.022	0.001
5000.0	0.303	36.984	1.044	954.414	0.026	0.001	1.834	0.138	0.029	0.001
5500.0	0.301	36.460	1.140	954.149	0.030	0.001	1.977	0.162	0.037	0.001
6000.0	0.300	35.942	1.234	953.884	0.033	0.002	2.112	0.187	0.045	0.002
6500.0	0.298	35.429	1.327	953.620	0.037	0.002	2.240	0.212	0.055	0.002
7000.0	0.296	34.922	1.419	953.356	0.041	0.002	2.362	0.239	0.065	0.003
7500.0	0.295	34.420	1.509	953.093	0.045	0.003	2.478	0.267	0.076	0.004
8000.0	0.293	33.923	1.598	952.830	0.049	0.003	2.588	0.295	0.088	0.005
8500.0	0.291	33.431	1.686	952.568	0.054	0.004	2.692	0.324	0.100	0.006
9000.0	0.290	32.944	1.773	952.307	0.058	0.004	2.790	0.353	0.113	0.007
9500.0	0.288	32.462	1.858	952.046	0.062	0.005	2.883	0.383	0.127	0.008
10000.0	0.286	31.983	1.943	951.786	0.067	0.005	2.971	0.413	0.141	0.010
10500.0	0.285	31.509	2.026	951.527	0.072	0.006	3.054	0.444	0.155	0.012
11000.0	0.283	31.039	2.108	951.268	0.076	0.007	3.133	0.474	0.170	0.013
11500.0	0.282	30.573	2.189	951.010	0.081	0.007	3.207	0.506	0.185	0.015
12000.0	0.280	30.112	2.269	950.752	0.086	0.008	3.277	0.537	0.201	0.018
12500.0	0.278	29.654	2.349	950.494	0.091	0.009	3.343	0.569	0.216	0.020
13000.0	0.277	29.200	2.427	950.236	0.097	0.010	3.406	0.601	0.232	0.022
13500.0	0.275	28.749	2.504	949.977	0.102	0.011	3.465	0.632	0.249	0.025
14000.0	0.274	28.303	2.580	949.717	0.107	0.012	3.522	0.664	0.265	0.028
14500.0	0.272	27.861	2.656	949.456	0.112	0.013	3.576	0.697	0.282	0.031
15000.0	0.270	27.422	2.730	949.195	0.118	0.014	3.628	0.729	0.299	0.034
15500.0	0.269	26.988	2.804	948.932	0.123	0.015	3.677	0.761	0.316	0.038
16000.0	0.267	26.557	2.876	948.668	0.129	0.016	3.723	0.793	0.334	0.042
16500.0	0.266	26.130	2.948	948.403	0.135	0.017	3.768	0.826	0.351	0.046
17000.0	0.264	25.707	3.019	948.137	0.140	0.019	3.810	0.858	0.369	0.050
17500.0	0.263	25.287	3.089	947.869	0.146	0.020	3.850	0.890	0.386	0.054
20000.0	0.255	23.247	3.427	946.510	0.176	0.027	4.022	1.050	0.477	0.079
22500.0	0.247	21.299	3.744	945.116	0.208	0.037	4.151	1.208	0.567	0.110
25000.0	0.239	19.444	4.039	943.684	0.242	0.047	4.243	1.363	0.654	0.146
27500.0	0.232	17.680	4.313	942.213	0.276	0.060	4.303	1.513	0.737	0.189
30000.0	0.224	16.006	4.567	940.701	0.312	0.074	4.336	1.657	0.814	0.238
32500.0	0.216	14.422	4.800	939.145	0.348	0.090	4.345	1.795	0.885	0.292
35000.0	0.209	12.930	5.013	937.542	0.384	0.108	4.336	1.926	0.950	0.353
37500.0	0.201	11.528	5.205	935.890	0.420	0.128	4.311	2.049	1.007	0.419
40000.0	0.193	10.219	5.378	934.187	0.456	0.149	4.273	2.164	1.057	0.490
42500.0	0.186	9.001	5.530	932.429	0.491	0.172	4.226	2.269	1.100	0.567
45000.0	0.178	7.876	5.662	930.614	0.526	0.196	4.172	2.365	1.136	0.648
47500.0	0.171	6.844	5.774	928.741	0.559	0.220	4.112	2.452	1.165	0.734
50000.0	0.164	5.904	5.867	926.807	0.591	0.246	4.050	2.529	1.188	0.824
52500.0	0.156	5.055	5.940	924.813	0.622	0.272	3.988	2.596	1.205	0.917
55000.0	0.149	4.296	5.995	922.756	0.650	0.298	3.926	2.654	1.218	1.014
57500.0	0.142	3.623	6.032	920.639	0.677	0.323	3.866	2.703	1.225	1.113
60000.0	0.136	3.032	6.052	918.462	0.701	0.348	3.809	2.743	1.229	1.213
62500.0	0.129	2.520	6.057	916.228	0.724	0.372	3.757	2.776	1.230	1.315
65000.0	0.122	2.080	6.047	913.940	0.744	0.394	3.708	2.801	1.229	1.417
67500.0	0.116	1.706	6.023	911.604	0.762	0.415	3.664	2.821	1.226	1.519
70000.0	0.110	1.392	5.989	909.222	0.777	0.435	3.625	2.835	1.222	1.621

**Table C.21 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.321	42.598	0.000	957.080	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.321	42.479	0.024	957.017	0.000	0.000	0.019	0.000	0.000	0.000
500.0	0.319	42.006	0.118	956.763	0.002	0.000	0.214	0.002	0.000	0.000
1000.0	0.317	41.423	0.234	956.445	0.004	0.000	0.474	0.008	0.000	0.000
1500.0	0.315	40.850	0.348	956.127	0.007	0.000	0.722	0.017	0.001	0.000
2000.0	0.313	40.287	0.460	955.810	0.010	0.000	0.957	0.030	0.003	0.000
2500.0	0.310	39.732	0.569	955.493	0.013	0.000	1.182	0.046	0.006	0.000
3000.0	0.308	39.187	0.677	955.177	0.017	0.001	1.396	0.064	0.011	0.000
3500.0	0.306	38.649	0.782	954.861	0.021	0.001	1.600	0.084	0.016	0.000
4000.0	0.304	38.118	0.886	954.545	0.025	0.001	1.794	0.106	0.023	0.001
4500.0	0.302	37.596	0.988	954.230	0.029	0.001	1.979	0.130	0.031	0.001
5000.0	0.300	37.080	1.088	953.915	0.033	0.002	2.156	0.155	0.040	0.001
5500.0	0.298	36.571	1.187	953.601	0.038	0.002	2.324	0.181	0.050	0.002
6000.0	0.296	36.068	1.284	953.287	0.042	0.003	2.485	0.208	0.061	0.002
6500.0	0.294	35.572	1.379	952.973	0.047	0.003	2.639	0.236	0.074	0.003
7000.0	0.292	35.081	1.473	952.661	0.052	0.004	2.785	0.265	0.087	0.004
7500.0	0.290	34.597	1.566	952.348	0.058	0.004	2.924	0.294	0.101	0.005
8000.0	0.288	34.118	1.656	952.036	0.063	0.005	3.057	0.325	0.116	0.006
8500.0	0.286	33.645	1.746	951.725	0.069	0.006	3.183	0.356	0.132	0.007
9000.0	0.284	33.177	1.834	951.415	0.075	0.006	3.304	0.387	0.148	0.009
9500.0	0.282	32.714	1.921	951.105	0.080	0.007	3.418	0.419	0.165	0.011
10000.0	0.281	32.256	2.006	950.796	0.086	0.008	3.527	0.452	0.183	0.012
10500.0	0.279	31.802	2.091	950.487	0.092	0.009	3.630	0.485	0.200	0.014
11000.0	0.277	31.354	2.174	950.180	0.098	0.010	3.729	0.518	0.219	0.017
11500.0	0.275	30.910	2.255	949.872	0.104	0.011	3.822	0.552	0.237	0.019
12000.0	0.273	30.470	2.336	949.565	0.111	0.012	3.911	0.586	0.256	0.021
12500.0	0.271	30.035	2.416	949.258	0.117	0.014	3.996	0.620	0.275	0.024
13000.0	0.270	29.604	2.494	948.952	0.123	0.015	4.077	0.654	0.295	0.027
13500.0	0.268	29.177	2.571	948.645	0.130	0.016	4.154	0.689	0.314	0.030
14000.0	0.266	28.753	2.648	948.338	0.136	0.018	4.227	0.723	0.334	0.034
14500.0	0.264	28.335	2.723	948.030	0.143	0.019	4.297	0.758	0.354	0.037
15000.0	0.263	27.920	2.797	947.722	0.150	0.021	4.364	0.793	0.374	0.041
15500.0	0.261	27.509	2.870	947.414	0.157	0.022	4.428	0.828	0.395	0.045
16000.0	0.259	27.102	2.942	947.104	0.163	0.024	4.490	0.862	0.415	0.049
16500.0	0.257	26.699	3.014	946.794	0.170	0.026	4.549	0.897	0.436	0.053
17000.0	0.256	26.300	3.084	946.482	0.177	0.028	4.605	0.932	0.457	0.058
17500.0	0.254	25.905	3.153	946.169	0.185	0.030	4.660	0.967	0.478	0.062
18000.0	0.252	25.514	3.221	945.855	0.192	0.032	4.712	1.002	0.498	0.067
18500.0	0.251	25.127	3.289	945.540	0.199	0.034	4.761	1.037	0.519	0.072
19000.0	0.249	24.744	3.355	945.223	0.207	0.036	4.809	1.072	0.540	0.078
20000.0	0.245	23.988	3.485	944.586	0.221	0.040	4.899	1.141	0.582	0.089
22500.0	0.237	22.166	3.795	942.971	0.260	0.053	5.092	1.312	0.688	0.121
25000.0	0.229	20.436	4.082	941.322	0.299	0.069	5.245	1.480	0.791	0.158
27500.0	0.221	18.796	4.348	939.638	0.339	0.086	5.362	1.644	0.890	0.201
30000.0	0.213	17.243	4.592	937.919	0.379	0.105	5.450	1.802	0.984	0.248
32500.0	0.205	15.775	4.817	936.163	0.420	0.127	5.511	1.955	1.073	0.301
35000.0	0.197	14.392	5.021	934.371	0.460	0.151	5.549	2.101	1.155	0.358
37500.0	0.190	13.090	5.205	932.540	0.500	0.177	5.568	2.240	1.231	0.419
40000.0	0.182	11.870	5.370	930.670	0.540	0.205	5.571	2.371	1.300	0.484
42500.0	0.175	10.729	5.517	928.762	0.578	0.234	5.561	2.494	1.362	0.553
45000.0	0.168	9.665	5.644	926.813	0.616	0.265	5.539	2.609	1.418	0.625
47500.0	0.161	8.678	5.755	924.823	0.653	0.298	5.508	2.715	1.467	0.701
50000.0	0.154	7.764	5.848	922.794	0.688	0.331	5.471	2.813	1.510	0.780
52500.0	0.148	6.923	5.924	920.724	0.721	0.365	5.428	2.903	1.547	0.861
55000.0	0.142	6.151	5.985	918.614	0.753	0.399	5.381	2.984	1.578	0.944
57500.0	0.136	5.446	6.030	916.465	0.783	0.434	5.333	3.056	1.605	1.029
60000.0	0.130	4.805	6.061	914.278	0.811	0.468	5.283	3.121	1.626	1.116
62500.0	0.124	4.226	6.079	912.054	0.836	0.502	5.233	3.178	1.644	1.204
65000.0	0.119	3.704	6.084	909.795	0.860	0.535	5.183	3.228	1.657	1.293
67500.0	0.113	3.237	6.077	907.502	0.881	0.567	5.136	3.272	1.668	1.383
70000.0	0.108	2.820	6.059	905.177	0.901	0.598	5.089	3.309	1.675	1.474

**Table C.22 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.322	42.668	0.000	957.009	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.322	42.549	0.023	956.954	0.000	0.000	0.020	0.000	0.000	0.000
500.0	0.320	42.072	0.113	956.729	0.002	0.000	0.201	0.002	0.000	0.000
1000.0	0.318	41.485	0.224	956.448	0.004	0.000	0.434	0.007	0.000	0.000
1500.0	0.316	40.906	0.333	956.167	0.006	0.000	0.656	0.016	0.001	0.000
2000.0	0.315	40.337	0.441	955.886	0.008	0.000	0.868	0.028	0.003	0.000
2500.0	0.313	39.775	0.546	955.605	0.011	0.000	1.069	0.043	0.005	0.000
3000.0	0.311	39.222	0.650	955.325	0.014	0.000	1.261	0.060	0.008	0.000
3500.0	0.309	38.675	0.752	955.044	0.017	0.001	1.443	0.079	0.013	0.000
4000.0	0.307	38.136	0.852	954.764	0.020	0.001	1.617	0.100	0.018	0.000
4500.0	0.305	37.604	0.951	954.484	0.024	0.001	1.782	0.122	0.024	0.001
5000.0	0.303	37.078	1.048	954.205	0.027	0.001	1.940	0.146	0.032	0.001
5500.0	0.302	36.558	1.144	953.925	0.031	0.002	2.090	0.171	0.040	0.002
6000.0	0.300	36.045	1.239	953.646	0.035	0.002	2.233	0.197	0.050	0.002
6500.0	0.298	35.538	1.332	953.367	0.039	0.002	2.369	0.224	0.060	0.003
7000.0	0.296	35.036	1.423	953.089	0.043	0.003	2.498	0.251	0.071	0.003
7500.0	0.295	34.540	1.514	952.811	0.047	0.003	2.621	0.280	0.083	0.004
8000.0	0.293	34.049	1.603	952.533	0.052	0.004	2.737	0.309	0.096	0.005
8500.0	0.291	33.563	1.691	952.256	0.056	0.004	2.848	0.339	0.110	0.007
9000.0	0.289	33.083	1.777	951.979	0.061	0.005	2.953	0.369	0.124	0.008
9500.0	0.288	32.607	1.863	951.703	0.066	0.005	3.052	0.400	0.139	0.010
10000.0	0.286	32.136	1.947	951.427	0.070	0.006	3.146	0.431	0.154	0.011
10500.0	0.284	31.669	2.030	951.152	0.075	0.007	3.235	0.463	0.170	0.013
11000.0	0.283	31.207	2.112	950.878	0.080	0.007	3.320	0.495	0.186	0.015
11500.0	0.281	30.749	2.192	950.603	0.086	0.008	3.399	0.527	0.202	0.017
12000.0	0.279	30.296	2.272	950.330	0.091	0.009	3.474	0.559	0.219	0.020
12500.0	0.278	29.846	2.351	950.056	0.096	0.010	3.545	0.592	0.236	0.022
13000.0	0.276	29.401	2.428	949.783	0.101	0.011	3.612	0.625	0.253	0.025
13500.0	0.274	28.960	2.505	949.510	0.107	0.012	3.675	0.658	0.271	0.028
14000.0	0.273	28.522	2.580	949.237	0.112	0.013	3.734	0.691	0.288	0.031
14500.0	0.271	28.088	2.655	948.965	0.118	0.014	3.790	0.724	0.306	0.035
15000.0	0.270	27.658	2.729	948.692	0.124	0.015	3.843	0.757	0.324	0.038
15500.0	0.268	27.232	2.801	948.420	0.129	0.016	3.892	0.790	0.342	0.042
16000.0	0.267	26.809	2.873	948.147	0.135	0.018	3.939	0.824	0.360	0.046
16500.0	0.265	26.389	2.944	947.873	0.141	0.019	3.983	0.857	0.378	0.051
17000.0	0.263	25.973	3.014	947.599	0.147	0.020	4.024	0.890	0.396	0.055
17500.0	0.262	25.561	3.084	947.325	0.153	0.022	4.063	0.923	0.414	0.060
18000.0	0.260	25.153	3.152	947.049	0.159	0.023	4.100	0.956	0.433	0.065
18500.0	0.259	24.748	3.219	946.772	0.165	0.025	4.135	0.989	0.451	0.070
19000.0	0.257	24.346	3.286	946.495	0.171	0.026	4.168	1.022	0.469	0.075
19500.0	0.256	23.949	3.352	946.216	0.177	0.028	4.200	1.054	0.487	0.080
20000.0	0.254	23.554	3.417	945.935	0.183	0.030	4.229	1.087	0.506	0.086
20500.0	0.252	23.164	3.481	945.654	0.190	0.031	4.257	1.119	0.524	0.092
22500.0	0.246	21.638	3.730	944.513	0.215	0.039	4.353	1.247	0.597	0.119
25000.0	0.239	19.811	4.021	943.053	0.249	0.051	4.443	1.402	0.686	0.157
27500.0	0.231	18.072	4.293	941.555	0.284	0.064	4.503	1.551	0.771	0.201
30000.0	0.223	16.422	4.544	940.017	0.319	0.079	4.536	1.694	0.851	0.251
32500.0	0.216	14.860	4.775	938.436	0.356	0.096	4.548	1.830	0.924	0.306
35000.0	0.208	13.386	4.986	936.810	0.392	0.115	4.541	1.959	0.991	0.368
37500.0	0.201	12.000	5.178	935.138	0.429	0.135	4.519	2.080	1.050	0.434
40000.0	0.193	10.702	5.349	933.417	0.465	0.158	4.485	2.193	1.102	0.506
42500.0	0.186	9.492	5.501	931.646	0.501	0.181	4.441	2.297	1.147	0.583
45000.0	0.179	8.370	5.634	929.821	0.536	0.206	4.389	2.392	1.185	0.664
47500.0	0.172	7.336	5.747	927.942	0.571	0.233	4.332	2.478	1.217	0.749
50000.0	0.164	6.389	5.842	926.007	0.604	0.259	4.272	2.554	1.242	0.838
52500.0	0.158	5.529	5.918	924.016	0.635	0.287	4.211	2.622	1.261	0.930
55000.0	0.151	4.753	5.977	921.968	0.665	0.314	4.149	2.681	1.275	1.024
57500.0	0.144	4.058	6.018	919.863	0.693	0.341	4.089	2.731	1.285	1.121
60000.0	0.138	3.443	6.043	917.703	0.719	0.368	4.031	2.773	1.291	1.220
62500.0	0.131	2.902	6.053	915.490	0.743	0.393	3.976	2.808	1.293	1.319
65000.0	0.125	2.431	6.049	913.226	0.764	0.417	3.925	2.836	1.293	1.419
67500.0	0.119	2.025	6.031	910.915	0.784	0.440	3.878	2.858	1.291	1.519
70000.0	0.113	1.678	6.002	908.560	0.800	0.462	3.836	2.874	1.287	1.618

**Table C.23 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.322	42.668	0.000	957.009	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.322	42.549	0.024	956.946	0.000	0.000	0.022	0.000	0.000	0.000
500.0	0.320	42.074	0.118	956.690	0.002	0.000	0.227	0.002	0.000	0.000
1000.0	0.318	41.491	0.233	956.370	0.004	0.000	0.491	0.008	0.000	0.000
1500.0	0.316	40.917	0.346	956.051	0.007	0.000	0.742	0.018	0.001	0.000
2000.0	0.314	40.353	0.457	955.731	0.010	0.000	0.980	0.032	0.003	0.000
2500.0	0.311	39.799	0.565	955.413	0.013	0.000	1.207	0.048	0.007	0.000
3000.0	0.309	39.253	0.672	955.094	0.016	0.001	1.423	0.067	0.011	0.000
3500.0	0.307	38.715	0.777	954.776	0.020	0.001	1.629	0.087	0.016	0.000
4000.0	0.305	38.185	0.880	954.459	0.024	0.001	1.825	0.110	0.023	0.001
4500.0	0.303	37.662	0.981	954.142	0.028	0.001	2.012	0.134	0.031	0.001
5000.0	0.301	37.147	1.080	953.825	0.032	0.002	2.191	0.160	0.040	0.001
5500.0	0.299	36.639	1.178	953.508	0.037	0.002	2.360	0.186	0.051	0.002
6000.0	0.297	36.137	1.274	953.192	0.041	0.002	2.522	0.214	0.062	0.003
6500.0	0.295	35.642	1.369	952.877	0.046	0.003	2.677	0.243	0.075	0.003
7000.0	0.293	35.153	1.462	952.562	0.051	0.003	2.824	0.272	0.088	0.004
7500.0	0.291	34.670	1.553	952.247	0.056	0.004	2.964	0.303	0.103	0.005
8000.0	0.289	34.192	1.644	951.934	0.061	0.005	3.097	0.334	0.118	0.007
8500.0	0.288	33.721	1.732	951.620	0.067	0.005	3.225	0.365	0.134	0.008
9000.0	0.286	33.254	1.820	951.307	0.072	0.006	3.345	0.397	0.151	0.010
9500.0	0.284	32.793	1.906	950.995	0.078	0.007	3.460	0.430	0.168	0.011
10000.0	0.282	32.337	1.990	950.684	0.084	0.008	3.569	0.463	0.186	0.013
10500.0	0.280	31.886	2.074	950.373	0.090	0.009	3.673	0.496	0.205	0.015
11000.0	0.278	31.440	2.156	950.063	0.096	0.010	3.771	0.530	0.224	0.018
11500.0	0.276	30.998	2.236	949.753	0.102	0.011	3.865	0.563	0.243	0.020
12000.0	0.275	30.561	2.316	949.444	0.108	0.012	3.953	0.598	0.262	0.023
12500.0	0.273	30.128	2.395	949.135	0.114	0.013	4.038	0.632	0.282	0.026
13000.0	0.271	29.699	2.472	948.827	0.120	0.014	4.117	0.667	0.302	0.029
13500.0	0.269	29.275	2.549	948.519	0.127	0.016	4.193	0.701	0.322	0.033
14000.0	0.268	28.855	2.624	948.211	0.133	0.017	4.265	0.736	0.342	0.036
14500.0	0.266	28.439	2.698	947.903	0.140	0.018	4.333	0.771	0.363	0.040
15000.0	0.264	28.026	2.771	947.596	0.146	0.020	4.397	0.806	0.383	0.044
15500.0	0.262	27.618	2.844	947.289	0.153	0.021	4.458	0.841	0.404	0.048
16000.0	0.261	27.213	2.915	946.981	0.159	0.023	4.516	0.876	0.425	0.052
16500.0	0.259	26.812	2.985	946.673	0.166	0.025	4.571	0.911	0.445	0.057
17000.0	0.257	26.415	3.055	946.365	0.173	0.026	4.623	0.946	0.466	0.062
17500.0	0.256	26.021	3.123	946.057	0.180	0.028	4.672	0.980	0.487	0.067
18000.0	0.254	25.632	3.191	945.747	0.187	0.030	4.720	1.015	0.508	0.072
18500.0	0.252	25.245	3.257	945.437	0.194	0.032	4.764	1.050	0.528	0.078
19000.0	0.251	24.863	3.323	945.127	0.201	0.034	4.807	1.084	0.549	0.083
19500.0	0.249	24.484	3.388	944.815	0.208	0.036	4.848	1.119	0.570	0.089
20000.0	0.247	24.109	3.452	944.502	0.215	0.039	4.886	1.153	0.591	0.095
20500.0	0.246	23.737	3.515	944.188	0.222	0.041	4.923	1.187	0.611	0.102
21000.0	0.244	23.369	3.577	943.873	0.229	0.043	4.958	1.221	0.632	0.108
21500.0	0.242	23.004	3.638	943.556	0.237	0.046	4.992	1.255	0.653	0.115
22000.0	0.241	22.644	3.699	943.238	0.244	0.048	5.023	1.289	0.673	0.122
22500.0	0.239	22.286	3.758	942.919	0.251	0.051	5.054	1.322	0.694	0.129
25000.0	0.231	20.553	4.043	941.303	0.289	0.065	5.185	1.485	0.795	0.168
27500.0	0.223	18.908	4.307	939.651	0.328	0.082	5.283	1.643	0.892	0.213
30000.0	0.215	17.348	4.550	937.963	0.368	0.100	5.354	1.794	0.984	0.263
32500.0	0.208	15.873	4.773	936.238	0.408	0.121	5.401	1.939	1.071	0.318
35000.0	0.200	14.481	4.977	934.476	0.448	0.144	5.428	2.077	1.150	0.377
37500.0	0.193	13.171	5.161	932.674	0.488	0.169	5.437	2.207	1.223	0.441
40000.0	0.186	11.940	5.327	930.832	0.527	0.196	5.431	2.330	1.288	0.510
42500.0	0.178	10.789	5.474	928.950	0.566	0.225	5.413	2.444	1.347	0.582
45000.0	0.172	9.715	5.603	927.027	0.603	0.255	5.385	2.550	1.399	0.657
47500.0	0.165	8.717	5.715	925.062	0.640	0.286	5.349	2.648	1.445	0.736
50000.0	0.158	7.793	5.810	923.056	0.674	0.318	5.307	2.738	1.484	0.817
52500.0	0.152	6.941	5.889	921.007	0.708	0.351	5.261	2.819	1.517	0.900
55000.0	0.146	6.160	5.952	918.917	0.740	0.385	5.211	2.892	1.545	0.986
57500.0	0.140	5.446	5.999	916.786	0.770	0.418	5.160	2.958	1.568	1.073
60000.0	0.134	4.797	6.033	914.615	0.798	0.451	5.108	3.016	1.586	1.162
62500.0	0.128	4.211	6.053	912.405	0.824	0.484	5.056	3.067	1.600	1.251
65000.0	0.123	3.684	6.060	910.158	0.848	0.516	5.006	3.111	1.611	1.341
67500.0	0.118	3.211	6.055	907.875	0.870	0.547	4.957	3.148	1.618	1.431
70000.0	0.113	2.791	6.039	905.559	0.890	0.576	4.910	3.180	1.623	1.521

**Table C.24 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.322	42.668	0.000	957.009	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.322	42.550	0.025	956.936	0.000	0.000	0.025	0.000	0.000	0.000
500.0	0.320	42.079	0.123	956.641	0.002	0.000	0.259	0.002	0.000	0.000
1000.0	0.317	41.501	0.244	956.271	0.005	0.000	0.560	0.009	0.001	0.000
1500.0	0.315	40.934	0.362	955.903	0.008	0.000	0.847	0.020	0.002	0.000
2000.0	0.312	40.379	0.478	955.535	0.012	0.000	1.119	0.035	0.005	0.000
2500.0	0.310	39.833	0.591	955.168	0.016	0.000	1.379	0.053	0.009	0.000
3000.0	0.307	39.297	0.701	954.801	0.020	0.001	1.627	0.073	0.014	0.000
3500.0	0.305	38.769	0.810	954.435	0.024	0.001	1.864	0.095	0.021	0.000
4000.0	0.303	38.251	0.917	954.069	0.029	0.001	2.090	0.119	0.030	0.001
4500.0	0.300	37.740	1.021	953.704	0.034	0.002	2.306	0.145	0.040	0.001
5000.0	0.298	37.237	1.124	953.339	0.039	0.002	2.512	0.172	0.051	0.002
5500.0	0.296	36.742	1.224	952.975	0.045	0.003	2.710	0.200	0.063	0.002
6000.0	0.294	36.254	1.323	952.612	0.050	0.003	2.899	0.229	0.077	0.003
6500.0	0.291	35.772	1.420	952.249	0.056	0.004	3.080	0.259	0.092	0.004
7000.0	0.289	35.298	1.516	951.886	0.062	0.005	3.253	0.290	0.108	0.005
7500.0	0.287	34.829	1.609	951.525	0.069	0.006	3.418	0.322	0.125	0.006
8000.0	0.285	34.367	1.702	951.163	0.075	0.007	3.577	0.355	0.143	0.008
8500.0	0.283	33.911	1.792	950.803	0.082	0.008	3.729	0.388	0.162	0.009
9000.0	0.281	33.460	1.881	950.443	0.088	0.009	3.874	0.421	0.181	0.011
9500.0	0.279	33.016	1.969	950.083	0.095	0.010	4.012	0.456	0.201	0.013
10000.0	0.276	32.576	2.055	949.725	0.102	0.011	4.145	0.490	0.221	0.015
10500.0	0.274	32.142	2.139	949.367	0.109	0.012	4.272	0.526	0.242	0.017
11000.0	0.272	31.713	2.223	949.010	0.116	0.014	4.393	0.561	0.264	0.020
11500.0	0.270	31.289	2.305	948.653	0.123	0.015	4.509	0.597	0.285	0.023
12000.0	0.268	30.870	2.386	948.297	0.131	0.017	4.620	0.633	0.307	0.026
12500.0	0.266	30.455	2.465	947.941	0.138	0.018	4.727	0.670	0.330	0.029
13000.0	0.264	30.045	2.543	947.585	0.146	0.020	4.828	0.706	0.352	0.032
13500.0	0.262	29.640	2.620	947.230	0.153	0.022	4.925	0.743	0.375	0.036
14000.0	0.261	29.238	2.696	946.875	0.161	0.024	5.018	0.780	0.398	0.039
14500.0	0.259	28.841	2.771	946.521	0.169	0.026	5.107	0.817	0.421	0.043
15000.0	0.257	28.449	2.844	946.167	0.176	0.028	5.192	0.855	0.444	0.048
15500.0	0.255	28.060	2.917	945.813	0.184	0.030	5.273	0.892	0.467	0.052
16000.0	0.253	27.675	2.988	945.458	0.192	0.032	5.351	0.930	0.490	0.056
16500.0	0.251	27.295	3.058	945.104	0.200	0.034	5.425	0.967	0.514	0.061
17000.0	0.249	26.918	3.127	944.750	0.208	0.037	5.497	1.005	0.537	0.066
17500.0	0.247	26.545	3.196	944.395	0.216	0.039	5.565	1.043	0.560	0.071
18000.0	0.246	26.176	3.263	944.040	0.224	0.042	5.631	1.080	0.584	0.076
18500.0	0.244	25.810	3.329	943.684	0.232	0.045	5.694	1.118	0.607	0.082
19000.0	0.242	25.449	3.394	943.328	0.240	0.047	5.754	1.155	0.630	0.088
19500.0	0.240	25.091	3.459	942.971	0.249	0.050	5.813	1.193	0.653	0.094
20000.0	0.239	24.736	3.522	942.614	0.257	0.053	5.868	1.230	0.676	0.100
20500.0	0.237	24.386	3.584	942.255	0.265	0.056	5.922	1.267	0.699	0.106
21000.0	0.235	24.038	3.646	941.896	0.274	0.059	5.974	1.304	0.722	0.112
21500.0	0.233	23.695	3.707	941.536	0.282	0.063	6.024	1.341	0.745	0.119
22000.0	0.232	23.355	3.766	941.175	0.290	0.066	6.072	1.378	0.768	0.126
22500.0	0.230	23.018	3.825	940.813	0.299	0.070	6.118	1.415	0.791	0.133
23000.0	0.228	22.685	3.883	940.449	0.307	0.073	6.163	1.451	0.814	0.140
23500.0	0.226	22.356	3.940	940.085	0.316	0.077	6.205	1.488	0.837	0.148
24000.0	0.225	22.030	3.996	939.719	0.324	0.081	6.247	1.524	0.859	0.155
24500.0	0.223	21.707	4.051	939.352	0.333	0.085	6.287	1.560	0.882	0.163
25000.0	0.221	21.388	4.106	938.984	0.341	0.088	6.325	1.596	0.904	0.171
27500.0	0.213	19.844	4.365	937.124	0.384	0.110	6.498	1.771	1.014	0.213
30000.0	0.205	18.382	4.604	935.232	0.427	0.134	6.641	1.941	1.121	0.259
32500.0	0.197	17.001	4.822	933.308	0.470	0.161	6.757	2.106	1.222	0.310
35000.0	0.190	15.698	5.021	931.351	0.513	0.190	6.850	2.264	1.319	0.364
37500.0	0.182	14.471	5.202	929.363	0.555	0.221	6.923	2.416	1.409	0.422
40000.0	0.175	13.317	5.363	927.342	0.597	0.254	6.979	2.561	1.494	0.482
42500.0	0.168	12.235	5.507	925.289	0.637	0.290	7.019	2.698	1.572	0.546
45000.0	0.162	11.221	5.634	923.205	0.677	0.327	7.046	2.829	1.645	0.612
47500.0	0.155	10.273	5.745	921.089	0.715	0.366	7.062	2.953	1.712	0.681
50000.0	0.149	9.390	5.840	918.943	0.752	0.406	7.068	3.069	1.774	0.751
52500.0	0.143	8.568	5.920	916.767	0.787	0.447	7.066	3.178	1.830	0.824
55000.0	0.138	7.805	5.985	914.562	0.821	0.489	7.058	3.280	1.881	0.898
57500.0	0.132	7.099	6.037	912.329	0.853	0.531	7.044	3.375	1.927	0.974
60000.0	0.127	6.447	6.076	910.069	0.882	0.574	7.026	3.463	1.969	1.052
62500.0	0.122	5.845	6.104	907.783	0.910	0.617	7.005	3.545	2.006	1.130
65000.0	0.118	5.292	6.119	905.472	0.936	0.659	6.981	3.620	2.040	1.210
67500.0	0.113	4.785	6.125	903.138	0.960	0.701	6.956	3.689	2.069	1.291
70000.0	0.109	4.321	6.120	900.781	0.982	0.742	6.929	3.752	2.095	1.372

**Table C.25 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.327	43.333	0.000	956.340	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.326	43.213	0.023	956.286	0.000	0.000	0.019	0.000	0.000	0.000
500.0	0.325	42.736	0.113	956.069	0.002	0.000	0.194	0.001	0.000	0.000
1000.0	0.323	42.147	0.223	955.796	0.003	0.000	0.421	0.007	0.000	0.000
1500.0	0.321	41.568	0.332	955.524	0.006	0.000	0.636	0.015	0.001	0.000
2000.0	0.319	40.996	0.439	955.251	0.008	0.000	0.842	0.027	0.002	0.000
2500.0	0.317	40.433	0.545	954.978	0.011	0.000	1.038	0.041	0.005	0.000
3000.0	0.316	39.877	0.649	954.705	0.013	0.000	1.226	0.057	0.008	0.000
3500.0	0.314	39.328	0.751	954.432	0.016	0.001	1.404	0.076	0.012	0.000
4000.0	0.312	38.786	0.851	954.159	0.020	0.001	1.575	0.096	0.017	0.000
4500.0	0.310	38.250	0.950	953.886	0.023	0.001	1.737	0.117	0.023	0.001
5000.0	0.308	37.721	1.048	953.613	0.026	0.001	1.892	0.140	0.030	0.001
5500.0	0.307	37.199	1.144	953.340	0.030	0.001	2.041	0.165	0.038	0.001
6000.0	0.305	36.682	1.239	953.067	0.034	0.002	2.182	0.190	0.047	0.002
6500.0	0.303	36.171	1.333	952.793	0.038	0.002	2.317	0.216	0.057	0.002
7000.0	0.301	35.665	1.425	952.520	0.042	0.002	2.445	0.243	0.067	0.003
7500.0	0.300	35.165	1.516	952.247	0.046	0.003	2.567	0.271	0.079	0.004
8000.0	0.298	34.671	1.605	951.974	0.050	0.003	2.684	0.299	0.091	0.005
8500.0	0.296	34.181	1.694	951.700	0.055	0.004	2.795	0.328	0.104	0.006
9000.0	0.294	33.696	1.781	951.427	0.059	0.004	2.901	0.358	0.118	0.007
9500.0	0.293	33.217	1.867	951.154	0.064	0.005	3.001	0.388	0.132	0.009
10000.0	0.291	32.742	1.952	950.882	0.069	0.006	3.097	0.419	0.147	0.011
10500.0	0.289	32.272	2.035	950.609	0.074	0.006	3.187	0.450	0.163	0.012
11000.0	0.288	31.806	2.118	950.337	0.079	0.007	3.273	0.481	0.178	0.014
11500.0	0.286	31.344	2.200	950.064	0.084	0.008	3.355	0.512	0.195	0.016
12000.0	0.284	30.887	2.280	949.792	0.089	0.009	3.432	0.544	0.211	0.019
12500.0	0.283	30.435	2.359	949.520	0.095	0.010	3.505	0.576	0.228	0.021
13000.0	0.281	29.986	2.438	949.248	0.100	0.010	3.574	0.609	0.245	0.024
13500.0	0.279	29.541	2.515	948.976	0.105	0.011	3.640	0.641	0.262	0.027
14000.0	0.278	29.100	2.591	948.704	0.111	0.012	3.701	0.674	0.280	0.030
14500.0	0.276	28.663	2.667	948.432	0.117	0.014	3.759	0.707	0.298	0.033
15000.0	0.274	28.229	2.741	948.160	0.122	0.015	3.814	0.740	0.315	0.037
15500.0	0.273	27.800	2.815	947.888	0.128	0.016	3.866	0.772	0.333	0.040
16000.0	0.271	27.374	2.887	947.617	0.134	0.017	3.915	0.805	0.351	0.044
16500.0	0.270	26.951	2.959	947.344	0.140	0.018	3.961	0.838	0.369	0.048
17000.0	0.268	26.532	3.030	947.072	0.145	0.020	4.004	0.871	0.387	0.053
17500.0	0.266	26.116	3.100	946.798	0.151	0.021	4.045	0.904	0.405	0.057
18000.0	0.265	25.705	3.169	946.524	0.157	0.023	4.083	0.937	0.423	0.062
18500.0	0.263	25.296	3.237	946.249	0.164	0.024	4.120	0.969	0.441	0.067
19000.0	0.262	24.891	3.305	945.973	0.170	0.026	4.154	1.002	0.460	0.072
19500.0	0.260	24.490	3.371	945.695	0.176	0.027	4.187	1.034	0.478	0.077
20000.0	0.259	24.093	3.437	945.417	0.182	0.029	4.218	1.067	0.496	0.083
20500.0	0.257	23.698	3.502	945.137	0.189	0.031	4.247	1.099	0.514	0.089
21000.0	0.255	23.308	3.566	944.856	0.195	0.033	4.275	1.131	0.532	0.095
22500.0	0.251	22.158	3.753	944.004	0.214	0.038	4.348	1.226	0.587	0.114
25000.0	0.243	20.313	4.049	942.555	0.248	0.050	4.444	1.381	0.676	0.152
27500.0	0.235	18.556	4.325	941.067	0.283	0.063	4.508	1.530	0.762	0.195
30000.0	0.228	16.886	4.580	939.540	0.319	0.078	4.546	1.673	0.842	0.243
32500.0	0.220	15.304	4.815	937.972	0.355	0.095	4.562	1.810	0.916	0.298
35000.0	0.212	13.809	5.030	936.359	0.392	0.113	4.559	1.940	0.983	0.358
37500.0	0.205	12.401	5.226	934.701	0.429	0.134	4.539	2.061	1.044	0.423
40000.0	0.197	11.081	5.402	932.995	0.466	0.156	4.507	2.175	1.097	0.494
42500.0	0.190	9.848	5.558	931.239	0.502	0.180	4.465	2.280	1.143	0.569
45000.0	0.183	8.703	5.695	929.431	0.538	0.205	4.415	2.376	1.182	0.649
47500.0	0.175	7.645	5.813	927.569	0.572	0.231	4.358	2.464	1.215	0.733
50000.0	0.168	6.674	5.912	925.652	0.606	0.258	4.299	2.542	1.241	0.821
52500.0	0.161	5.789	5.993	923.679	0.638	0.286	4.237	2.611	1.262	0.912
55000.0	0.154	4.989	6.056	921.649	0.668	0.313	4.175	2.672	1.277	1.006
57500.0	0.147	4.271	6.101	919.564	0.696	0.340	4.114	2.724	1.287	1.102
60000.0	0.141	3.632	6.130	917.422	0.723	0.367	4.055	2.768	1.294	1.200
62500.0	0.134	3.069	6.144	915.227	0.747	0.393	3.999	2.804	1.297	1.299
65000.0	0.128	2.577	6.143	912.981	0.769	0.418	3.946	2.833	1.297	1.398
67500.0	0.122	2.151	6.128	910.686	0.789	0.442	3.898	2.856	1.295	1.498
70000.0	0.116	1.786	6.102	908.347	0.807	0.463	3.854	2.873	1.292	1.597

**Table C.26 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.327	43.333	0.000	956.340	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.326	43.213	0.024	956.279	0.000	0.000	0.022	0.000	0.000	0.000
500.0	0.325	42.738	0.117	956.031	0.002	0.000	0.220	0.002	0.000	0.000
1000.0	0.323	42.153	0.232	955.721	0.004	0.000	0.475	0.008	0.000	0.000
1500.0	0.320	41.578	0.345	955.411	0.007	0.000	0.719	0.017	0.001	0.000
2000.0	0.318	41.013	0.455	955.101	0.009	0.000	0.951	0.030	0.003	0.000
2500.0	0.316	40.456	0.564	954.792	0.013	0.000	1.172	0.046	0.006	0.000
3000.0	0.314	39.907	0.670	954.482	0.016	0.000	1.383	0.064	0.010	0.000
3500.0	0.312	39.366	0.775	954.172	0.019	0.001	1.585	0.084	0.015	0.000
4000.0	0.310	38.833	0.878	953.862	0.023	0.001	1.777	0.106	0.021	0.001
4500.0	0.308	38.307	0.980	953.553	0.027	0.001	1.961	0.129	0.029	0.001
5000.0	0.306	37.789	1.080	953.243	0.031	0.002	2.136	0.154	0.038	0.001
5500.0	0.304	37.277	1.178	952.934	0.036	0.002	2.304	0.180	0.048	0.002
6000.0	0.302	36.771	1.274	952.624	0.040	0.002	2.464	0.207	0.059	0.002
6500.0	0.300	36.272	1.370	952.315	0.045	0.003	2.617	0.235	0.071	0.003
7000.0	0.298	35.779	1.463	952.006	0.050	0.003	2.763	0.264	0.084	0.004
7500.0	0.296	35.292	1.555	951.697	0.055	0.004	2.902	0.293	0.098	0.005
8000.0	0.294	34.810	1.646	951.388	0.060	0.004	3.036	0.324	0.112	0.006
8500.0	0.292	34.334	1.735	951.079	0.065	0.005	3.163	0.354	0.128	0.007
9000.0	0.291	33.863	1.823	950.771	0.071	0.006	3.284	0.386	0.144	0.009
9500.0	0.289	33.398	1.910	950.463	0.076	0.007	3.400	0.418	0.161	0.011
10000.0	0.287	32.938	1.996	950.155	0.082	0.007	3.510	0.450	0.178	0.012
10500.0	0.285	32.483	2.080	949.847	0.088	0.008	3.615	0.482	0.196	0.015
11000.0	0.283	32.032	2.163	949.539	0.094	0.009	3.715	0.515	0.215	0.017
11500.0	0.281	31.586	2.244	949.232	0.100	0.010	3.810	0.549	0.234	0.019
12000.0	0.280	31.145	2.325	948.925	0.106	0.011	3.901	0.582	0.253	0.022
12500.0	0.278	30.709	2.404	948.618	0.112	0.013	3.988	0.616	0.272	0.025
13000.0	0.276	30.276	2.482	948.311	0.119	0.014	4.070	0.650	0.292	0.028
13500.0	0.274	29.848	2.560	948.004	0.125	0.015	4.148	0.684	0.312	0.031
14000.0	0.272	29.424	2.636	947.697	0.131	0.016	4.222	0.718	0.332	0.034
14500.0	0.271	29.004	2.711	947.391	0.138	0.018	4.292	0.753	0.353	0.038
15000.0	0.269	28.589	2.785	947.084	0.145	0.019	4.359	0.787	0.373	0.042
15500.0	0.267	28.177	2.858	946.778	0.151	0.021	4.423	0.822	0.393	0.046
16000.0	0.265	27.768	2.930	946.471	0.158	0.022	4.483	0.857	0.414	0.050
16500.0	0.264	27.364	3.001	946.165	0.165	0.024	4.540	0.891	0.435	0.055
17000.0	0.262	26.963	3.071	945.858	0.171	0.026	4.594	0.926	0.455	0.059
17500.0	0.260	26.566	3.141	945.550	0.178	0.028	4.646	0.960	0.476	0.064
18000.0	0.259	26.173	3.209	945.242	0.185	0.029	4.695	0.995	0.497	0.069
18500.0	0.257	25.783	3.276	944.934	0.192	0.031	4.742	1.029	0.517	0.075
19000.0	0.255	25.397	3.343	944.624	0.199	0.033	4.786	1.064	0.538	0.080
19500.0	0.254	25.014	3.409	944.314	0.206	0.036	4.828	1.098	0.559	0.086
20000.0	0.252	24.636	3.473	944.003	0.214	0.038	4.869	1.132	0.579	0.092
20500.0	0.250	24.260	3.537	943.690	0.221	0.040	4.907	1.166	0.600	0.098
21000.0	0.249	23.889	3.600	943.377	0.228	0.042	4.944	1.200	0.621	0.104
21500.0	0.247	23.521	3.662	943.062	0.235	0.045	4.978	1.233	0.641	0.111
22000.0	0.245	23.156	3.724	942.746	0.243	0.047	5.012	1.267	0.662	0.118
22500.0	0.244	22.795	3.784	942.429	0.250	0.050	5.043	1.300	0.682	0.125
25000.0	0.236	21.044	4.073	940.822	0.288	0.064	5.181	1.463	0.783	0.163
27500.0	0.228	19.379	4.341	939.180	0.328	0.080	5.285	1.621	0.881	0.207
30000.0	0.220	17.801	4.588	937.503	0.368	0.099	5.361	1.772	0.973	0.256
32500.0	0.212	16.306	4.815	935.789	0.408	0.120	5.412	1.918	1.060	0.310
35000.0	0.204	14.895	5.023	934.038	0.448	0.143	5.443	2.056	1.141	0.368
37500.0	0.197	13.564	5.211	932.248	0.488	0.168	5.455	2.187	1.214	0.431
40000.0	0.189	12.313	5.381	930.419	0.528	0.194	5.452	2.310	1.281	0.498
42500.0	0.182	11.142	5.532	928.550	0.567	0.223	5.436	2.426	1.341	0.569
45000.0	0.175	10.047	5.666	926.640	0.604	0.253	5.410	2.533	1.394	0.644
47500.0	0.168	9.028	5.782	924.689	0.641	0.284	5.376	2.633	1.441	0.721
50000.0	0.162	8.083	5.881	922.696	0.677	0.317	5.335	2.724	1.481	0.802
52500.0	0.155	7.211	5.963	920.662	0.711	0.350	5.289	2.807	1.516	0.885
55000.0	0.149	6.409	6.030	918.586	0.743	0.384	5.240	2.882	1.545	0.969
57500.0	0.143	5.676	6.081	916.469	0.773	0.417	5.188	2.949	1.568	1.056
60000.0	0.137	5.008	6.118	914.313	0.802	0.451	5.136	3.008	1.587	1.144
62500.0	0.131	4.402	6.141	912.117	0.829	0.484	5.084	3.060	1.602	1.233
65000.0	0.126	3.857	6.151	909.883	0.853	0.516	5.033	3.106	1.614	1.322
67500.0	0.120	3.367	6.149	907.614	0.876	0.547	4.983	3.145	1.622	1.412
70000.0	0.115	2.930	6.136	905.310	0.896	0.578	4.935	3.178	1.627	1.502

**Table C.27 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.327	43.333	0.000	956.340	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.326	43.214	0.025	956.269	0.000	0.000	0.025	0.000	0.000	0.000
500.0	0.324	42.743	0.123	955.983	0.002	0.000	0.251	0.002	0.000	0.000
1000.0	0.322	42.164	0.243	955.625	0.005	0.000	0.543	0.009	0.001	0.000
1500.0	0.319	41.595	0.360	955.267	0.008	0.000	0.821	0.019	0.002	0.000
2000.0	0.317	41.038	0.476	954.910	0.012	0.000	1.086	0.034	0.004	0.000
2500.0	0.315	40.490	0.589	954.552	0.015	0.000	1.339	0.051	0.008	0.000
3000.0	0.312	39.951	0.699	954.195	0.019	0.001	1.581	0.070	0.013	0.000
3500.0	0.310	39.420	0.808	953.838	0.024	0.001	1.813	0.092	0.020	0.000
4000.0	0.308	38.898	0.915	953.481	0.028	0.001	2.034	0.115	0.028	0.001
4500.0	0.305	38.384	1.019	953.125	0.033	0.002	2.246	0.140	0.037	0.001
5000.0	0.303	37.878	1.122	952.768	0.038	0.002	2.449	0.166	0.048	0.002
5500.0	0.301	37.379	1.223	952.412	0.044	0.003	2.644	0.194	0.060	0.002
6000.0	0.299	36.886	1.323	952.056	0.049	0.003	2.830	0.222	0.073	0.003
6500.0	0.296	36.401	1.420	951.700	0.055	0.004	3.009	0.252	0.087	0.004
7000.0	0.294	35.922	1.516	951.344	0.061	0.005	3.181	0.282	0.103	0.005
7500.0	0.292	35.450	1.610	950.988	0.067	0.005	3.345	0.313	0.119	0.006
8000.0	0.290	34.983	1.703	950.633	0.073	0.006	3.503	0.345	0.136	0.007
8500.0	0.288	34.522	1.794	950.278	0.080	0.007	3.654	0.377	0.154	0.009
9000.0	0.286	34.068	1.884	949.923	0.086	0.008	3.799	0.410	0.173	0.010
9500.0	0.283	33.618	1.972	949.569	0.093	0.009	3.938	0.444	0.192	0.012
10000.0	0.281	33.174	2.059	949.214	0.100	0.011	4.072	0.478	0.212	0.014
10500.0	0.279	32.736	2.145	948.861	0.107	0.012	4.200	0.512	0.233	0.017
11000.0	0.277	32.302	2.229	948.507	0.114	0.013	4.322	0.547	0.254	0.019
11500.0	0.275	31.874	2.312	948.153	0.121	0.015	4.440	0.582	0.275	0.022
12000.0	0.273	31.450	2.394	947.800	0.129	0.016	4.552	0.618	0.297	0.024
12500.0	0.271	31.031	2.474	947.447	0.136	0.018	4.660	0.653	0.319	0.027
13000.0	0.269	30.617	2.553	947.094	0.144	0.019	4.764	0.689	0.341	0.031
13500.0	0.267	30.207	2.631	946.740	0.151	0.021	4.863	0.726	0.363	0.034
14000.0	0.265	29.802	2.708	946.388	0.159	0.023	4.959	0.762	0.386	0.038
14500.0	0.263	29.401	2.783	946.035	0.166	0.025	5.050	0.799	0.409	0.041
15000.0	0.261	29.004	2.858	945.682	0.174	0.027	5.137	0.836	0.432	0.045
15500.0	0.260	28.611	2.931	945.329	0.182	0.029	5.221	0.873	0.455	0.050
16000.0	0.258	28.223	3.004	944.976	0.190	0.031	5.301	0.910	0.478	0.054
16500.0	0.256	27.838	3.075	944.623	0.198	0.033	5.378	0.947	0.501	0.059
17000.0	0.254	27.458	3.145	944.270	0.206	0.036	5.452	0.984	0.524	0.063
17500.0	0.252	27.081	3.214	943.917	0.214	0.038	5.523	1.021	0.547	0.068
18000.0	0.250	26.708	3.282	943.563	0.222	0.041	5.591	1.059	0.571	0.074
18500.0	0.248	26.339	3.349	943.209	0.230	0.044	5.656	1.096	0.594	0.079
19000.0	0.247	25.973	3.415	942.854	0.239	0.046	5.718	1.133	0.617	0.084
19500.0	0.245	25.611	3.481	942.498	0.247	0.049	5.778	1.170	0.640	0.090
20000.0	0.243	25.253	3.545	942.142	0.255	0.052	5.836	1.207	0.663	0.096
20500.0	0.241	24.899	3.608	941.786	0.264	0.055	5.892	1.244	0.686	0.102
21000.0	0.239	24.548	3.670	941.428	0.272	0.058	5.945	1.281	0.709	0.109
21500.0	0.238	24.200	3.732	941.070	0.280	0.062	5.997	1.318	0.732	0.115
22000.0	0.236	23.856	3.793	940.710	0.289	0.065	6.047	1.354	0.755	0.122
22500.0	0.234	23.516	3.852	940.350	0.297	0.068	6.094	1.391	0.777	0.129
23000.0	0.232	23.179	3.911	939.988	0.306	0.072	6.141	1.427	0.800	0.136
23500.0	0.231	22.846	3.969	939.625	0.314	0.075	6.185	1.464	0.823	0.143
24000.0	0.229	22.516	4.026	939.262	0.323	0.079	6.228	1.500	0.845	0.150
24500.0	0.227	22.190	4.082	938.896	0.331	0.083	6.269	1.536	0.868	0.158
25000.0	0.226	21.867	4.137	938.530	0.340	0.087	6.309	1.571	0.890	0.166
25500.0	0.224	21.547	4.192	938.163	0.348	0.091	6.348	1.607	0.912	0.174
27500.0	0.217	20.303	4.401	936.680	0.383	0.108	6.488	1.747	1.000	0.207
30000.0	0.209	18.823	4.644	934.798	0.426	0.132	6.637	1.917	1.107	0.253
32500.0	0.201	17.423	4.867	932.884	0.470	0.159	6.758	2.082	1.209	0.302
35000.0	0.194	16.101	5.070	930.938	0.513	0.188	6.856	2.240	1.306	0.356
37500.0	0.186	14.854	5.254	928.960	0.556	0.219	6.933	2.393	1.397	0.412
40000.0	0.179	13.682	5.420	926.950	0.598	0.252	6.992	2.538	1.482	0.472
42500.0	0.172	12.580	5.568	924.908	0.639	0.288	7.035	2.677	1.562	0.535
45000.0	0.165	11.548	5.698	922.834	0.679	0.325	7.065	2.809	1.636	0.600
47500.0	0.159	10.582	5.813	920.730	0.717	0.364	7.083	2.934	1.704	0.668
50000.0	0.152	9.681	5.911	918.595	0.755	0.404	7.091	3.051	1.766	0.738
52500.0	0.146	8.841	5.994	916.430	0.791	0.445	7.091	3.162	1.823	0.810
55000.0	0.141	8.061	6.063	914.236	0.825	0.487	7.084	3.265	1.876	0.884
57500.0	0.135	7.338	6.118	912.013	0.857	0.530	7.071	3.362	1.923	0.959
60000.0	0.130	6.669	6.160	909.764	0.887	0.573	7.054	3.451	1.965	1.036
62500.0	0.125	6.052	6.190	907.488	0.916	0.616	7.033	3.534	2.003	1.114
65000.0	0.120	5.484	6.209	905.187	0.942	0.659	7.010	3.611	2.038	1.194
67500.0	0.116	4.962	6.217	902.862	0.967	0.701	6.984	3.681	2.068	1.274
70000.0	0.111	4.484	6.214	900.515	0.989	0.742	6.957	3.745	2.095	1.355

**Table C.28 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.332	43.981	0.000	955.687	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.332	43.861	0.022	955.636	0.000	0.000	0.016	0.000	0.000	0.000
500.0	0.330	43.383	0.111	955.433	0.002	0.000	0.177	0.001	0.000	0.000
1000.0	0.328	42.793	0.221	955.178	0.003	0.000	0.390	0.006	0.000	0.000
1500.0	0.327	42.210	0.329	954.923	0.005	0.000	0.593	0.014	0.001	0.000
2000.0	0.325	41.635	0.435	954.668	0.007	0.000	0.786	0.024	0.002	0.000
2500.0	0.323	41.067	0.540	954.413	0.010	0.000	0.971	0.037	0.004	0.000
3000.0	0.321	40.506	0.643	954.158	0.012	0.000	1.148	0.052	0.007	0.000
3500.0	0.319	39.952	0.745	953.903	0.015	0.000	1.316	0.069	0.010	0.000
4000.0	0.318	39.404	0.845	953.648	0.018	0.001	1.476	0.088	0.014	0.000
4500.0	0.316	38.863	0.944	953.393	0.021	0.001	1.629	0.108	0.020	0.001
5000.0	0.314	38.327	1.041	953.138	0.024	0.001	1.775	0.130	0.026	0.001
5500.0	0.312	37.797	1.137	952.884	0.028	0.001	1.915	0.153	0.033	0.001
6000.0	0.311	37.273	1.232	952.629	0.031	0.002	2.047	0.176	0.041	0.002
6500.0	0.309	36.754	1.326	952.375	0.035	0.002	2.174	0.201	0.049	0.002
7000.0	0.307	36.240	1.418	952.121	0.039	0.002	2.294	0.227	0.059	0.003
7500.0	0.306	35.731	1.509	951.867	0.043	0.003	2.409	0.253	0.069	0.003
8000.0	0.304	35.228	1.599	951.613	0.047	0.003	2.518	0.280	0.080	0.004
8500.0	0.302	34.729	1.687	951.360	0.051	0.003	2.621	0.308	0.092	0.005
9000.0	0.301	34.235	1.775	951.107	0.055	0.004	2.719	0.336	0.104	0.006
9500.0	0.299	33.745	1.862	950.854	0.059	0.004	2.812	0.365	0.117	0.008
10000.0	0.297	33.260	1.947	950.602	0.064	0.005	2.900	0.394	0.130	0.009
10500.0	0.296	32.779	2.031	950.350	0.068	0.006	2.984	0.424	0.144	0.011
11000.0	0.294	32.302	2.114	950.098	0.073	0.006	3.063	0.454	0.158	0.012
11500.0	0.293	31.830	2.197	949.846	0.077	0.007	3.138	0.484	0.173	0.014
12000.0	0.291	31.361	2.278	949.595	0.082	0.008	3.208	0.515	0.187	0.016
12500.0	0.289	30.896	2.358	949.344	0.087	0.008	3.275	0.546	0.203	0.018
13000.0	0.288	30.436	2.437	949.093	0.092	0.009	3.338	0.577	0.218	0.021
13500.0	0.286	29.978	2.515	948.843	0.097	0.010	3.396	0.608	0.234	0.023
14000.0	0.285	29.524	2.593	948.593	0.102	0.011	3.452	0.639	0.249	0.026
14500.0	0.283	29.074	2.669	948.343	0.107	0.012	3.504	0.671	0.265	0.029
15000.0	0.282	28.628	2.745	948.093	0.112	0.013	3.553	0.703	0.281	0.032
15500.0	0.280	28.184	2.820	947.843	0.117	0.014	3.599	0.734	0.297	0.035
16000.0	0.278	27.744	2.893	947.593	0.123	0.015	3.642	0.766	0.314	0.039
16500.0	0.277	27.308	2.966	947.342	0.128	0.016	3.683	0.798	0.330	0.043
17000.0	0.275	26.875	3.039	947.091	0.133	0.017	3.721	0.830	0.346	0.046
17500.0	0.274	26.445	3.110	946.839	0.139	0.018	3.757	0.861	0.363	0.051
18000.0	0.272	26.019	3.181	946.585	0.144	0.019	3.791	0.893	0.380	0.055
18500.0	0.271	25.596	3.250	946.331	0.150	0.021	3.823	0.925	0.396	0.059
19000.0	0.269	25.177	3.319	946.076	0.156	0.022	3.854	0.956	0.413	0.064
19500.0	0.268	24.761	3.387	945.819	0.161	0.023	3.882	0.988	0.430	0.069
20000.0	0.266	24.349	3.455	945.561	0.167	0.025	3.909	1.019	0.447	0.074
20500.0	0.265	23.940	3.521	945.302	0.173	0.026	3.935	1.050	0.463	0.079
22500.0	0.259	22.340	3.780	944.250	0.197	0.033	4.021	1.174	0.530	0.103
25000.0	0.251	20.417	4.085	942.902	0.229	0.043	4.100	1.324	0.613	0.138
27500.0	0.243	18.583	4.370	941.515	0.261	0.054	4.149	1.470	0.692	0.178
30000.0	0.236	16.835	4.635	940.087	0.295	0.067	4.172	1.611	0.766	0.225
32500.0	0.228	15.176	4.881	938.614	0.329	0.082	4.174	1.745	0.834	0.277
35000.0	0.220	13.606	5.106	937.095	0.364	0.098	4.158	1.872	0.896	0.336
37500.0	0.213	12.126	5.312	935.525	0.399	0.116	4.127	1.992	0.950	0.400
40000.0	0.205	10.738	5.497	933.902	0.434	0.136	4.085	2.104	0.998	0.470
42500.0	0.197	9.444	5.662	932.222	0.469	0.157	4.033	2.207	1.039	0.546
45000.0	0.190	8.244	5.807	930.482	0.503	0.179	3.974	2.301	1.072	0.626
47500.0	0.182	7.140	5.931	928.680	0.536	0.203	3.911	2.386	1.099	0.712
50000.0	0.174	6.133	6.035	926.813	0.568	0.227	3.846	2.461	1.120	0.802
52500.0	0.167	5.223	6.119	924.878	0.599	0.251	3.780	2.527	1.136	0.896
55000.0	0.159	4.408	6.183	922.876	0.628	0.276	3.716	2.584	1.146	0.994
57500.0	0.152	3.687	6.227	920.806	0.656	0.300	3.654	2.631	1.152	1.095
60000.0	0.145	3.057	6.254	918.669	0.681	0.324	3.595	2.670	1.154	1.198
62500.0	0.138	2.513	6.263	916.467	0.704	0.346	3.541	2.701	1.154	1.302
65000.0	0.131	2.048	6.257	914.205	0.725	0.368	3.492	2.725	1.151	1.407
67500.0	0.124	1.657	6.236	911.886	0.743	0.388	3.448	2.742	1.147	1.513
70000.0	0.117	1.332	6.203	909.516	0.759	0.406	3.409	2.755	1.141	1.618

**Table C.29 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.332	43.981	0.000	955.687	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.332	43.862	0.023	955.629	0.000	0.000	0.019	0.000	0.000	0.000
500.0	0.330	43.385	0.116	955.396	0.002	0.000	0.202	0.001	0.000	0.000
1000.0	0.328	42.798	0.230	955.104	0.004	0.000	0.443	0.007	0.000	0.000
1500.0	0.326	42.219	0.341	954.813	0.006	0.000	0.673	0.016	0.001	0.000
2000.0	0.324	41.649	0.451	954.521	0.009	0.000	0.893	0.028	0.003	0.000
2500.0	0.322	41.088	0.559	954.230	0.012	0.000	1.102	0.042	0.005	0.000
3000.0	0.320	40.534	0.665	953.939	0.015	0.000	1.302	0.059	0.009	0.000
3500.0	0.318	39.988	0.770	953.649	0.018	0.001	1.493	0.078	0.013	0.000
4000.0	0.316	39.448	0.872	953.358	0.022	0.001	1.675	0.098	0.019	0.000
4500.0	0.314	38.916	0.974	953.068	0.025	0.001	1.848	0.120	0.025	0.001
5000.0	0.312	38.390	1.073	952.778	0.029	0.001	2.014	0.144	0.033	0.001
5500.0	0.310	37.870	1.171	952.488	0.033	0.002	2.172	0.168	0.042	0.001
6000.0	0.308	37.357	1.268	952.199	0.037	0.002	2.323	0.194	0.052	0.002
6500.0	0.306	36.850	1.363	951.910	0.042	0.002	2.466	0.221	0.063	0.003
7000.0	0.304	36.348	1.457	951.621	0.046	0.003	2.603	0.248	0.074	0.003
7500.0	0.303	35.852	1.549	951.333	0.051	0.003	2.734	0.276	0.087	0.004
8000.0	0.301	35.361	1.640	951.045	0.056	0.004	2.858	0.305	0.100	0.005
8500.0	0.299	34.876	1.730	950.757	0.061	0.005	2.977	0.335	0.114	0.006
9000.0	0.297	34.395	1.818	950.470	0.066	0.005	3.089	0.365	0.129	0.008
9500.0	0.295	33.920	1.905	950.183	0.071	0.006	3.196	0.395	0.145	0.009
10000.0	0.293	33.449	1.991	949.897	0.076	0.007	3.298	0.427	0.160	0.011
10500.0	0.292	32.983	2.076	949.611	0.081	0.007	3.395	0.458	0.177	0.013
11000.0	0.290	32.522	2.159	949.326	0.087	0.008	3.487	0.490	0.194	0.015
11500.0	0.288	32.065	2.241	949.041	0.093	0.009	3.574	0.522	0.211	0.017
12000.0	0.286	31.612	2.323	948.756	0.098	0.010	3.656	0.554	0.229	0.019
12500.0	0.285	31.163	2.403	948.472	0.104	0.011	3.734	0.587	0.246	0.022
13000.0	0.283	30.719	2.482	948.188	0.110	0.012	3.808	0.620	0.265	0.025
13500.0	0.281	30.279	2.560	947.904	0.116	0.013	3.879	0.653	0.283	0.027
14000.0	0.279	29.842	2.637	947.621	0.122	0.014	3.945	0.686	0.301	0.031
14500.0	0.278	29.409	2.713	947.338	0.128	0.016	4.007	0.719	0.320	0.034
15000.0	0.276	28.980	2.788	947.055	0.134	0.017	4.066	0.753	0.339	0.037
15500.0	0.274	28.555	2.862	946.772	0.140	0.018	4.122	0.786	0.358	0.041
16000.0	0.273	28.133	2.935	946.490	0.146	0.020	4.175	0.819	0.376	0.045
16500.0	0.271	27.715	3.008	946.207	0.152	0.021	4.225	0.853	0.395	0.049
17000.0	0.269	27.300	3.079	945.923	0.159	0.022	4.272	0.886	0.414	0.053
17500.0	0.268	26.889	3.150	945.639	0.165	0.024	4.317	0.920	0.433	0.058
18000.0	0.266	26.481	3.219	945.355	0.171	0.026	4.359	0.953	0.453	0.063
18500.0	0.265	26.077	3.288	945.069	0.178	0.027	4.399	0.987	0.472	0.068
19000.0	0.263	25.677	3.356	944.783	0.184	0.029	4.437	1.020	0.491	0.073
19500.0	0.261	25.280	3.423	944.495	0.191	0.031	4.474	1.053	0.510	0.078
20000.0	0.260	24.886	3.489	944.207	0.198	0.033	4.508	1.086	0.529	0.084
20500.0	0.258	24.496	3.555	943.917	0.204	0.035	4.540	1.119	0.548	0.089
21000.0	0.256	24.109	3.619	943.626	0.211	0.037	4.571	1.151	0.567	0.095
21500.0	0.255	23.727	3.683	943.334	0.218	0.039	4.601	1.184	0.587	0.102
22500.0	0.252	22.971	3.808	942.746	0.232	0.043	4.655	1.249	0.625	0.115
25000.0	0.244	21.144	4.105	941.250	0.268	0.056	4.766	1.407	0.719	0.151
27500.0	0.236	19.403	4.382	939.719	0.304	0.070	4.846	1.560	0.809	0.193
30000.0	0.228	17.748	4.639	938.150	0.342	0.086	4.898	1.707	0.895	0.240
32500.0	0.220	16.178	4.876	936.543	0.381	0.104	4.927	1.849	0.975	0.293
35000.0	0.212	14.693	5.093	934.896	0.419	0.124	4.935	1.983	1.048	0.351
37500.0	0.205	13.291	5.290	933.207	0.457	0.146	4.927	2.110	1.114	0.414
40000.0	0.197	11.973	5.469	931.474	0.495	0.170	4.904	2.229	1.174	0.482
42500.0	0.190	10.738	5.628	929.696	0.533	0.196	4.870	2.341	1.226	0.553
45000.0	0.182	9.586	5.769	927.872	0.569	0.222	4.826	2.443	1.272	0.629
47500.0	0.175	8.516	5.891	926.000	0.605	0.250	4.776	2.537	1.310	0.709
50000.0	0.168	7.527	5.996	924.079	0.639	0.279	4.720	2.623	1.343	0.793
52500.0	0.161	6.619	6.082	922.108	0.672	0.309	4.661	2.699	1.369	0.879
55000.0	0.154	5.790	6.151	920.087	0.703	0.339	4.600	2.767	1.390	0.968
57500.0	0.148	5.037	6.204	918.017	0.733	0.368	4.538	2.827	1.405	1.059
60000.0	0.141	4.359	6.240	915.897	0.760	0.398	4.477	2.879	1.417	1.152
62500.0	0.135	3.752	6.261	913.729	0.786	0.427	4.419	2.923	1.424	1.246
65000.0	0.129	3.214	6.268	911.515	0.809	0.455	4.362	2.959	1.428	1.341
67500.0	0.123	2.738	6.262	909.256	0.830	0.481	4.309	2.989	1.429	1.436
70000.0	0.117	2.323	6.244	906.955	0.849	0.507	4.259	3.013	1.428	1.531

**Table C.30 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.332	43.981	0.000	955.687	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.331	43.862	0.024	955.619	0.000	0.000	0.022	0.000	0.000	0.000
500.0	0.330	43.389	0.122	955.347	0.002	0.000	0.233	0.002	0.000	0.000
1000.0	0.327	42.807	0.241	955.007	0.005	0.000	0.511	0.008	0.000	0.000
1500.0	0.325	42.235	0.358	954.667	0.008	0.000	0.777	0.018	0.002	0.000
2000.0	0.322	41.673	0.473	954.328	0.011	0.000	1.030	0.031	0.004	0.000
2500.0	0.320	41.119	0.585	953.989	0.015	0.000	1.272	0.047	0.007	0.000
3000.0	0.318	40.575	0.696	953.650	0.018	0.001	1.503	0.066	0.012	0.000
3500.0	0.316	40.039	0.804	953.312	0.022	0.001	1.723	0.086	0.018	0.000
4000.0	0.313	39.511	0.911	952.974	0.027	0.001	1.934	0.109	0.025	0.001
4500.0	0.311	38.990	1.015	952.637	0.031	0.002	2.136	0.132	0.033	0.001
5000.0	0.309	38.476	1.118	952.300	0.036	0.002	2.329	0.157	0.043	0.001
5500.0	0.307	37.970	1.219	951.963	0.041	0.002	2.514	0.184	0.054	0.002
6000.0	0.304	37.470	1.319	951.627	0.046	0.003	2.690	0.211	0.067	0.002
6500.0	0.302	36.976	1.417	951.291	0.052	0.004	2.859	0.239	0.080	0.003
7000.0	0.300	36.489	1.513	950.956	0.057	0.004	3.021	0.268	0.094	0.004
7500.0	0.298	36.008	1.607	950.621	0.063	0.005	3.176	0.298	0.110	0.005
8000.0	0.296	35.533	1.700	950.286	0.069	0.006	3.324	0.329	0.126	0.006
8500.0	0.294	35.063	1.792	949.952	0.075	0.006	3.465	0.360	0.142	0.008
9000.0	0.292	34.599	1.882	949.619	0.082	0.007	3.600	0.392	0.160	0.009
9500.0	0.290	34.140	1.971	949.286	0.088	0.008	3.729	0.425	0.178	0.011
10000.0	0.288	33.686	2.058	948.954	0.094	0.009	3.853	0.458	0.197	0.013
10500.0	0.286	33.238	2.144	948.622	0.101	0.011	3.971	0.491	0.216	0.015
11000.0	0.284	32.794	2.229	948.291	0.108	0.012	4.084	0.525	0.236	0.017
11500.0	0.282	32.355	2.313	947.960	0.114	0.013	4.191	0.559	0.256	0.020
12000.0	0.280	31.921	2.395	947.629	0.121	0.014	4.294	0.593	0.276	0.022
12500.0	0.278	31.491	2.476	947.299	0.128	0.016	4.393	0.628	0.297	0.025
13000.0	0.276	31.066	2.556	946.969	0.135	0.017	4.486	0.663	0.318	0.028
13500.0	0.274	30.645	2.634	946.639	0.142	0.019	4.576	0.698	0.339	0.031
14000.0	0.272	30.228	2.712	946.310	0.149	0.021	4.661	0.734	0.361	0.035
14500.0	0.270	29.816	2.788	945.980	0.157	0.022	4.743	0.769	0.382	0.038
15000.0	0.268	29.407	2.864	945.651	0.164	0.024	4.820	0.805	0.404	0.042
15500.0	0.267	29.002	2.938	945.322	0.171	0.026	4.894	0.841	0.425	0.046
16000.0	0.265	28.602	3.011	944.994	0.179	0.028	4.965	0.877	0.447	0.050
16500.0	0.263	28.205	3.084	944.665	0.186	0.030	5.032	0.913	0.469	0.054
17000.0	0.261	27.812	3.155	944.336	0.194	0.032	5.096	0.949	0.491	0.059
17500.0	0.259	27.422	3.225	944.007	0.202	0.034	5.157	0.985	0.513	0.064
18000.0	0.257	27.036	3.294	943.678	0.209	0.036	5.216	1.021	0.535	0.069
18500.0	0.256	26.654	3.362	943.348	0.217	0.039	5.272	1.058	0.556	0.074
19000.0	0.254	26.276	3.430	943.017	0.225	0.041	5.325	1.094	0.578	0.079
19500.0	0.252	25.901	3.496	942.686	0.233	0.044	5.377	1.130	0.600	0.084
20000.0	0.250	25.529	3.562	942.354	0.240	0.046	5.426	1.166	0.622	0.090
20500.0	0.249	25.161	3.626	942.022	0.248	0.049	5.473	1.201	0.644	0.096
21000.0	0.247	24.797	3.690	941.688	0.256	0.052	5.518	1.237	0.665	0.102
21500.0	0.245	24.436	3.753	941.353	0.264	0.055	5.561	1.273	0.687	0.108
22000.0	0.243	24.079	3.815	941.018	0.272	0.058	5.602	1.308	0.709	0.115
22500.0	0.242	23.725	3.876	940.681	0.280	0.061	5.642	1.344	0.730	0.122
23000.0	0.240	23.375	3.936	940.343	0.288	0.064	5.680	1.379	0.752	0.128
23500.0	0.238	23.028	3.995	940.004	0.296	0.067	5.716	1.414	0.773	0.135
24000.0	0.237	22.685	4.054	939.663	0.305	0.070	5.751	1.449	0.794	0.143
25000.0	0.233	22.008	4.168	938.978	0.321	0.077	5.817	1.518	0.837	0.158
27500.0	0.225	20.377	4.439	937.243	0.362	0.096	5.959	1.688	0.941	0.198
30000.0	0.217	18.829	4.690	935.475	0.404	0.118	6.071	1.852	1.042	0.244
32500.0	0.209	17.362	4.921	933.674	0.446	0.142	6.157	2.010	1.137	0.293
35000.0	0.201	15.975	5.131	931.838	0.488	0.168	6.220	2.163	1.227	0.347
37500.0	0.193	14.665	5.323	929.969	0.529	0.196	6.262	2.309	1.311	0.405
40000.0	0.186	13.432	5.496	928.064	0.570	0.226	6.288	2.448	1.389	0.466
42500.0	0.179	12.273	5.650	926.125	0.610	0.258	6.299	2.579	1.460	0.530
45000.0	0.172	11.187	5.787	924.151	0.650	0.292	6.297	2.703	1.526	0.598
47500.0	0.165	10.172	5.906	922.141	0.688	0.327	6.285	2.820	1.585	0.668
50000.0	0.158	9.226	6.009	920.096	0.725	0.364	6.264	2.929	1.638	0.741
52500.0	0.152	8.347	6.096	918.016	0.760	0.401	6.236	3.030	1.686	0.817
55000.0	0.146	7.533	6.167	915.902	0.794	0.440	6.203	3.123	1.728	0.894
57500.0	0.140	6.781	6.224	913.755	0.825	0.478	6.165	3.209	1.764	0.974
60000.0	0.134	6.089	6.267	911.574	0.855	0.517	6.124	3.287	1.797	1.055
62500.0	0.129	5.455	6.297	909.361	0.883	0.555	6.081	3.359	1.824	1.137
65000.0	0.124	4.875	6.314	907.118	0.909	0.594	6.037	3.423	1.848	1.221
67500.0	0.119	4.347	6.319	904.846	0.933	0.631	5.993	3.480	1.867	1.306
70000.0	0.114	3.867	6.314	902.545	0.954	0.668	5.949	3.531	1.884	1.391

**Table C.31 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.332	43.981	0.000	955.687	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.332	43.861	0.022	955.637	0.000	0.000	0.016	0.000	0.000	0.000
500.0	0.330	43.383	0.111	955.436	0.002	0.000	0.175	0.001	0.000	0.000
1000.0	0.328	42.793	0.220	955.185	0.003	0.000	0.384	0.006	0.000	0.000
1500.0	0.327	42.210	0.328	954.934	0.005	0.000	0.584	0.014	0.001	0.000
2000.0	0.325	41.634	0.434	954.683	0.007	0.000	0.775	0.024	0.002	0.000
2500.0	0.323	41.066	0.538	954.431	0.010	0.000	0.957	0.037	0.004	0.000
3000.0	0.321	40.505	0.641	954.180	0.012	0.000	1.131	0.052	0.006	0.000
3500.0	0.320	39.950	0.742	953.928	0.015	0.000	1.297	0.069	0.010	0.000
4000.0	0.318	39.402	0.842	953.676	0.018	0.001	1.455	0.087	0.014	0.000
4500.0	0.316	38.860	0.941	953.425	0.021	0.001	1.606	0.107	0.019	0.001
5000.0	0.314	38.323	1.038	953.173	0.024	0.001	1.750	0.128	0.025	0.001
5500.0	0.313	37.793	1.134	952.922	0.028	0.001	1.887	0.151	0.032	0.001
6000.0	0.311	37.268	1.228	952.671	0.031	0.001	2.018	0.174	0.040	0.002
6500.0	0.309	36.748	1.322	952.419	0.035	0.002	2.143	0.199	0.048	0.002
7000.0	0.308	36.233	1.414	952.168	0.038	0.002	2.262	0.224	0.057	0.003
7500.0	0.306	35.724	1.505	951.917	0.042	0.002	2.375	0.251	0.067	0.003
8000.0	0.304	35.220	1.594	951.666	0.046	0.003	2.483	0.277	0.078	0.004
8500.0	0.303	34.720	1.683	951.415	0.050	0.003	2.585	0.305	0.090	0.005
9000.0	0.301	34.225	1.770	951.165	0.054	0.004	2.682	0.333	0.102	0.006
9500.0	0.299	33.734	1.857	950.915	0.058	0.004	2.774	0.362	0.114	0.008
10000.0	0.298	33.248	1.942	950.665	0.063	0.005	2.861	0.391	0.127	0.009
10500.0	0.296	32.766	2.026	950.415	0.067	0.005	2.944	0.420	0.141	0.010
11000.0	0.294	32.289	2.109	950.165	0.072	0.006	3.022	0.450	0.155	0.012
11500.0	0.293	31.815	2.192	949.916	0.076	0.007	3.096	0.480	0.169	0.014
12000.0	0.291	31.346	2.273	949.667	0.081	0.007	3.166	0.510	0.184	0.016
12500.0	0.290	30.880	2.353	949.417	0.086	0.008	3.232	0.541	0.199	0.018
13000.0	0.288	30.419	2.432	949.168	0.091	0.009	3.294	0.572	0.214	0.021
13500.0	0.287	29.961	2.510	948.919	0.096	0.010	3.353	0.603	0.229	0.023
14000.0	0.285	29.506	2.588	948.670	0.101	0.011	3.408	0.634	0.245	0.026
14500.0	0.283	29.056	2.664	948.422	0.106	0.012	3.460	0.666	0.261	0.029
15000.0	0.282	28.608	2.740	948.173	0.111	0.012	3.508	0.697	0.277	0.032
15500.0	0.280	28.165	2.814	947.924	0.116	0.013	3.554	0.729	0.292	0.035
16000.0	0.279	27.724	2.888	947.675	0.121	0.014	3.596	0.761	0.309	0.039
16500.0	0.277	27.287	2.961	947.426	0.127	0.016	3.636	0.792	0.325	0.042
17000.0	0.276	26.853	3.033	947.177	0.132	0.017	3.674	0.824	0.341	0.046
17500.0	0.274	26.423	3.105	946.927	0.137	0.018	3.709	0.856	0.357	0.050
18000.0	0.273	25.996	3.175	946.677	0.143	0.019	3.742	0.888	0.373	0.055
18500.0	0.271	25.572	3.245	946.425	0.148	0.020	3.772	0.919	0.389	0.059
19000.0	0.270	25.152	3.314	946.173	0.154	0.022	3.801	0.951	0.406	0.064
19500.0	0.268	24.735	3.382	945.920	0.160	0.023	3.828	0.982	0.422	0.069
20000.0	0.267	24.321	3.450	945.665	0.165	0.024	3.854	1.013	0.438	0.074
20500.0	0.265	23.911	3.516	945.410	0.171	0.026	3.877	1.045	0.455	0.079
21000.0	0.264	23.504	3.582	945.153	0.177	0.028	3.900	1.076	0.471	0.085
21500.0	0.262	23.101	3.647	944.894	0.183	0.029	3.920	1.107	0.487	0.091
22500.0	0.259	22.304	3.775	944.373	0.195	0.032	3.958	1.168	0.520	0.103
25000.0	0.251	20.373	4.081	943.044	0.225	0.042	4.029	1.319	0.600	0.137
27500.0	0.244	18.529	4.367	941.674	0.257	0.053	4.072	1.464	0.677	0.178
30000.0	0.236	16.772	4.633	940.263	0.290	0.066	4.091	1.604	0.749	0.224
32500.0	0.229	15.103	4.880	938.806	0.324	0.080	4.089	1.737	0.815	0.277
35000.0	0.221	13.524	5.107	937.301	0.358	0.096	4.070	1.864	0.875	0.335
37500.0	0.213	12.036	5.313	935.745	0.393	0.114	4.036	1.983	0.928	0.399
40000.0	0.206	10.640	5.500	934.135	0.427	0.133	3.991	2.094	0.975	0.470
42500.0	0.198	9.339	5.666	932.466	0.461	0.153	3.938	2.196	1.014	0.545
45000.0	0.190	8.134	5.811	930.736	0.495	0.175	3.878	2.289	1.046	0.626
47500.0	0.182	7.026	5.936	928.941	0.528	0.198	3.814	2.373	1.072	0.712
50000.0	0.175	6.016	6.041	927.080	0.560	0.221	3.748	2.447	1.092	0.803
52500.0	0.167	5.106	6.125	925.149	0.590	0.245	3.682	2.512	1.106	0.898
55000.0	0.160	4.293	6.188	923.148	0.619	0.269	3.617	2.567	1.115	0.997
57500.0	0.152	3.575	6.233	921.077	0.645	0.292	3.556	2.614	1.121	1.098
60000.0	0.145	2.950	6.259	918.938	0.670	0.315	3.498	2.651	1.122	1.202
62500.0	0.138	2.412	6.268	916.732	0.693	0.337	3.445	2.681	1.121	1.308
65000.0	0.131	1.955	6.260	914.463	0.713	0.357	3.397	2.704	1.118	1.414
67500.0	0.124	1.573	6.239	912.137	0.731	0.376	3.354	2.721	1.114	1.520
70000.0	0.117	1.257	6.204	909.759	0.746	0.394	3.317	2.732	1.108	1.626

**Table C.32 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.332	43.981	0.000	955.687	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.331	43.862	0.023	955.630	0.000	0.000	0.018	0.000	0.000	0.000
500.0	0.330	43.385	0.115	955.399	0.002	0.000	0.199	0.001	0.000	0.000
1000.0	0.328	42.798	0.229	955.111	0.004	0.000	0.438	0.007	0.000	0.000
1500.0	0.326	42.219	0.340	954.822	0.006	0.000	0.666	0.016	0.001	0.000
2000.0	0.324	41.649	0.450	954.534	0.009	0.000	0.883	0.027	0.003	0.000
2500.0	0.322	41.088	0.557	954.246	0.012	0.000	1.090	0.042	0.005	0.000
3000.0	0.320	40.533	0.663	953.958	0.015	0.000	1.287	0.058	0.008	0.000
3500.0	0.318	39.987	0.767	953.670	0.018	0.001	1.476	0.077	0.013	0.000
4000.0	0.316	39.447	0.870	953.383	0.022	0.001	1.656	0.097	0.018	0.000
4500.0	0.314	38.914	0.971	953.095	0.025	0.001	1.828	0.119	0.025	0.001
5000.0	0.312	38.388	1.070	952.808	0.029	0.001	1.991	0.143	0.033	0.001
5500.0	0.310	37.868	1.168	952.521	0.033	0.002	2.148	0.167	0.041	0.001
6000.0	0.308	37.354	1.264	952.234	0.037	0.002	2.297	0.192	0.051	0.002
6500.0	0.306	36.846	1.359	951.948	0.041	0.002	2.439	0.219	0.062	0.003
7000.0	0.305	36.343	1.453	951.662	0.046	0.003	2.575	0.246	0.073	0.003
7500.0	0.303	35.847	1.545	951.376	0.050	0.003	2.704	0.274	0.085	0.004
8000.0	0.301	35.355	1.636	951.090	0.055	0.004	2.827	0.303	0.099	0.005
8500.0	0.299	34.869	1.725	950.805	0.060	0.004	2.945	0.332	0.113	0.006
9000.0	0.297	34.388	1.814	950.520	0.065	0.005	3.056	0.362	0.127	0.008
9500.0	0.295	33.912	1.901	950.236	0.070	0.006	3.162	0.393	0.142	0.009
10000.0	0.294	33.441	1.986	949.952	0.075	0.006	3.263	0.423	0.158	0.011
10500.0	0.292	32.974	2.071	949.668	0.081	0.007	3.359	0.455	0.174	0.013
11000.0	0.290	32.512	2.154	949.384	0.086	0.008	3.450	0.486	0.191	0.015
11500.0	0.288	32.054	2.236	949.101	0.092	0.009	3.536	0.518	0.208	0.017
12000.0	0.287	31.601	2.318	948.818	0.097	0.010	3.618	0.550	0.225	0.019
12500.0	0.285	31.152	2.398	948.535	0.103	0.011	3.696	0.583	0.243	0.022
13000.0	0.283	30.707	2.477	948.253	0.109	0.012	3.769	0.615	0.261	0.024
13500.0	0.281	30.266	2.555	947.971	0.115	0.013	3.839	0.648	0.279	0.027
14000.0	0.280	29.829	2.632	947.688	0.121	0.014	3.905	0.681	0.297	0.031
14500.0	0.278	29.396	2.708	947.406	0.127	0.015	3.967	0.715	0.316	0.034
15000.0	0.276	28.966	2.783	947.124	0.133	0.017	4.026	0.748	0.335	0.037
15500.0	0.275	28.541	2.857	946.842	0.139	0.018	4.082	0.781	0.353	0.041
16000.0	0.273	28.119	2.930	946.560	0.145	0.019	4.134	0.814	0.372	0.045
16500.0	0.271	27.700	3.002	946.278	0.151	0.021	4.183	0.848	0.391	0.049
17000.0	0.270	27.285	3.074	945.996	0.158	0.022	4.230	0.881	0.410	0.053
17500.0	0.268	26.874	3.144	945.714	0.164	0.024	4.273	0.915	0.429	0.058
18000.0	0.266	26.466	3.214	945.431	0.170	0.025	4.315	0.948	0.447	0.063
18500.0	0.265	26.061	3.283	945.148	0.177	0.027	4.354	0.981	0.466	0.068
19000.0	0.263	25.660	3.350	944.864	0.183	0.029	4.390	1.015	0.485	0.073
19500.0	0.262	25.262	3.417	944.580	0.190	0.031	4.425	1.048	0.504	0.078
20000.0	0.260	24.868	3.484	944.295	0.196	0.032	4.457	1.081	0.523	0.084
20500.0	0.258	24.477	3.549	944.008	0.203	0.034	4.488	1.114	0.541	0.090
21000.0	0.257	24.090	3.614	943.721	0.209	0.036	4.517	1.146	0.560	0.095
21500.0	0.255	23.705	3.677	943.432	0.216	0.038	4.545	1.179	0.579	0.102
22000.0	0.254	23.325	3.740	943.142	0.223	0.040	4.570	1.211	0.597	0.108
22500.0	0.252	22.948	3.802	942.851	0.230	0.043	4.595	1.244	0.616	0.115
23000.0	0.250	22.574	3.863	942.558	0.237	0.045	4.618	1.276	0.634	0.122
25000.0	0.244	21.114	4.100	941.374	0.265	0.055	4.697	1.402	0.707	0.151
27500.0	0.236	19.366	4.378	939.861	0.301	0.069	4.769	1.554	0.796	0.193
30000.0	0.228	17.703	4.635	938.310	0.339	0.085	4.814	1.701	0.880	0.241
32500.0	0.221	16.125	4.873	936.720	0.376	0.102	4.837	1.841	0.958	0.293
35000.0	0.213	14.632	5.091	935.089	0.414	0.122	4.840	1.974	1.029	0.351
37500.0	0.205	13.222	5.289	933.415	0.452	0.144	4.827	2.100	1.094	0.414
40000.0	0.198	11.897	5.469	931.697	0.490	0.167	4.800	2.218	1.151	0.482
42500.0	0.190	10.655	5.629	929.933	0.526	0.192	4.762	2.328	1.202	0.554
45000.0	0.183	9.496	5.771	928.121	0.563	0.218	4.716	2.429	1.246	0.631
47500.0	0.176	8.421	5.894	926.261	0.598	0.245	4.662	2.522	1.283	0.711
50000.0	0.169	7.428	5.999	924.350	0.632	0.274	4.604	2.605	1.313	0.795
52500.0	0.162	6.517	6.086	922.388	0.664	0.302	4.543	2.680	1.338	0.882
55000.0	0.155	5.685	6.155	920.375	0.695	0.331	4.480	2.747	1.357	0.971
57500.0	0.148	4.932	6.208	918.310	0.724	0.360	4.418	2.805	1.371	1.063
60000.0	0.142	4.255	6.244	916.195	0.751	0.389	4.356	2.855	1.381	1.157
62500.0	0.135	3.650	6.265	914.029	0.776	0.417	4.297	2.897	1.387	1.252
65000.0	0.129	3.114	6.272	911.816	0.799	0.444	4.240	2.932	1.390	1.347
67500.0	0.123	2.643	6.265	909.557	0.820	0.470	4.187	2.960	1.390	1.444
70000.0	0.117	2.232	6.246	907.256	0.838	0.494	4.137	2.983	1.388	1.540

**Table C.33 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.332	43.981	0.000	955.687	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.331	43.862	0.024	955.620	0.000	0.000	0.021	0.000	0.000	0.000
500.0	0.329	43.389	0.121	955.349	0.002	0.000	0.232	0.002	0.000	0.000
1000.0	0.327	42.807	0.241	955.010	0.005	0.000	0.509	0.008	0.000	0.000
1500.0	0.325	42.235	0.357	954.672	0.008	0.000	0.773	0.018	0.002	0.000
2000.0	0.322	41.673	0.472	954.334	0.011	0.000	1.025	0.031	0.004	0.000
2500.0	0.320	41.120	0.584	953.996	0.015	0.000	1.265	0.047	0.007	0.000
3000.0	0.318	40.576	0.694	953.659	0.018	0.001	1.495	0.066	0.012	0.000
3500.0	0.316	40.040	0.803	953.322	0.022	0.001	1.715	0.086	0.017	0.000
4000.0	0.313	39.512	0.909	952.985	0.027	0.001	1.925	0.108	0.025	0.001
4500.0	0.311	38.991	1.013	952.649	0.031	0.002	2.126	0.132	0.033	0.001
5000.0	0.309	38.477	1.116	952.313	0.036	0.002	2.318	0.157	0.043	0.001
5500.0	0.307	37.971	1.217	951.977	0.041	0.002	2.502	0.183	0.054	0.002
6000.0	0.305	37.471	1.316	951.642	0.046	0.003	2.678	0.210	0.066	0.002
6500.0	0.302	36.977	1.414	951.307	0.052	0.003	2.846	0.238	0.079	0.003
7000.0	0.300	36.490	1.510	950.973	0.057	0.004	3.007	0.267	0.094	0.004
7500.0	0.298	36.009	1.605	950.639	0.063	0.005	3.161	0.297	0.109	0.005
8000.0	0.296	35.533	1.697	950.305	0.069	0.006	3.309	0.328	0.125	0.006
8500.0	0.294	35.064	1.789	949.972	0.075	0.006	3.450	0.359	0.142	0.008
9000.0	0.292	34.600	1.879	949.639	0.082	0.007	3.585	0.391	0.159	0.009
9500.0	0.290	34.141	1.968	949.307	0.088	0.008	3.714	0.423	0.177	0.011
10000.0	0.288	33.687	2.055	948.976	0.094	0.009	3.837	0.456	0.196	0.013
10500.0	0.286	33.238	2.141	948.644	0.101	0.011	3.954	0.489	0.215	0.015
11000.0	0.284	32.795	2.226	948.313	0.108	0.012	4.067	0.523	0.234	0.017
11500.0	0.282	32.356	2.309	947.983	0.114	0.013	4.175	0.557	0.255	0.020
12000.0	0.280	31.922	2.391	947.652	0.121	0.014	4.277	0.591	0.275	0.022
12500.0	0.278	31.492	2.472	947.322	0.128	0.016	4.376	0.626	0.296	0.025
13000.0	0.276	31.067	2.552	946.992	0.135	0.017	4.469	0.660	0.317	0.028
13500.0	0.274	30.646	2.631	946.662	0.142	0.019	4.559	0.695	0.338	0.031
14000.0	0.272	30.230	2.708	946.333	0.150	0.020	4.644	0.731	0.359	0.035
14500.0	0.270	29.817	2.785	946.003	0.157	0.022	4.726	0.766	0.381	0.038
15000.0	0.268	29.409	2.860	945.674	0.164	0.024	4.804	0.802	0.402	0.042
15500.0	0.267	29.005	2.934	945.345	0.172	0.026	4.878	0.838	0.424	0.046
16000.0	0.265	28.604	3.007	945.016	0.179	0.028	4.948	0.874	0.446	0.050
16500.0	0.263	28.208	3.080	944.687	0.187	0.030	5.016	0.910	0.468	0.055
17000.0	0.261	27.815	3.151	944.357	0.194	0.032	5.080	0.946	0.490	0.059
17500.0	0.259	27.426	3.221	944.028	0.202	0.034	5.141	0.982	0.512	0.064
18000.0	0.258	27.041	3.290	943.698	0.210	0.036	5.199	1.018	0.533	0.069
18500.0	0.256	26.659	3.358	943.369	0.217	0.039	5.255	1.054	0.555	0.074
19000.0	0.254	26.281	3.425	943.039	0.225	0.041	5.307	1.090	0.577	0.079
19500.0	0.252	25.907	3.492	942.708	0.233	0.044	5.358	1.126	0.599	0.085
20000.0	0.250	25.536	3.557	942.377	0.241	0.046	5.406	1.162	0.621	0.091
20500.0	0.249	25.168	3.622	942.046	0.249	0.049	5.451	1.198	0.642	0.097
21000.0	0.247	24.804	3.685	941.714	0.256	0.052	5.495	1.234	0.664	0.103
21500.0	0.245	24.443	3.748	941.381	0.264	0.055	5.537	1.269	0.685	0.109
22000.0	0.244	24.086	3.810	941.047	0.272	0.058	5.576	1.305	0.707	0.115
22500.0	0.242	23.733	3.871	940.712	0.280	0.061	5.614	1.340	0.728	0.122
23000.0	0.240	23.382	3.931	940.376	0.288	0.064	5.651	1.376	0.749	0.129
23500.0	0.238	23.035	3.990	940.039	0.296	0.067	5.685	1.411	0.770	0.136
24000.0	0.237	22.692	4.048	939.701	0.304	0.070	5.718	1.446	0.791	0.143
24500.0	0.235	22.351	4.106	939.362	0.313	0.074	5.750	1.480	0.812	0.151
25000.0	0.233	22.015	4.163	939.022	0.321	0.077	5.780	1.515	0.833	0.158
25500.0	0.232	21.681	4.219	938.680	0.329	0.081	5.809	1.549	0.854	0.166
27500.0	0.225	20.381	4.434	937.300	0.362	0.096	5.913	1.685	0.936	0.199
30000.0	0.217	18.830	4.685	935.545	0.403	0.117	6.017	1.848	1.035	0.245
32500.0	0.209	17.360	4.915	933.757	0.445	0.141	6.096	2.006	1.129	0.295
35000.0	0.201	15.969	5.127	931.934	0.486	0.166	6.152	2.157	1.218	0.348
37500.0	0.194	14.655	5.319	930.077	0.527	0.194	6.189	2.302	1.300	0.406
40000.0	0.186	13.418	5.492	928.185	0.568	0.224	6.209	2.439	1.377	0.468
42500.0	0.179	12.255	5.647	926.257	0.608	0.256	6.215	2.570	1.447	0.532
45000.0	0.172	11.165	5.784	924.294	0.647	0.289	6.209	2.692	1.511	0.600
47500.0	0.165	10.146	5.904	922.295	0.685	0.324	6.193	2.807	1.569	0.671
50000.0	0.159	9.197	6.008	920.261	0.721	0.360	6.168	2.914	1.620	0.745
52500.0	0.152	8.314	6.095	918.192	0.757	0.397	6.136	3.014	1.667	0.820
55000.0	0.146	7.497	6.167	916.087	0.790	0.435	6.100	3.105	1.707	0.898
57500.0	0.140	6.742	6.224	913.948	0.822	0.473	6.059	3.189	1.743	0.978
60000.0	0.135	6.048	6.268	911.776	0.851	0.511	6.015	3.266	1.773	1.059
62500.0	0.129	5.412	6.298	909.571	0.879	0.549	5.970	3.335	1.799	1.142
65000.0	0.124	4.830	6.315	907.335	0.905	0.587	5.924	3.397	1.821	1.226
67500.0	0.119	4.301	6.321	905.069	0.928	0.623	5.877	3.453	1.840	1.311
70000.0	0.114	3.821	6.315	902.775	0.950	0.659	5.832	3.502	1.855	1.397

**Table C.34 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.330	43.715	0.000	955.955	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.330	43.594	0.022	955.907	0.000	0.000	0.015	0.000	0.000	0.000
500.0	0.328	43.116	0.110	955.712	0.001	0.000	0.167	0.001	0.000	0.000
1000.0	0.327	42.524	0.218	955.468	0.003	0.000	0.371	0.006	0.000	0.000
1500.0	0.325	41.940	0.325	955.224	0.005	0.000	0.566	0.013	0.001	0.000
2000.0	0.323	41.364	0.430	954.979	0.007	0.000	0.752	0.023	0.002	0.000
2500.0	0.321	40.795	0.534	954.735	0.009	0.000	0.929	0.036	0.004	0.000
3000.0	0.320	40.232	0.636	954.491	0.012	0.000	1.098	0.050	0.006	0.000
3500.0	0.318	39.675	0.737	954.246	0.014	0.000	1.260	0.067	0.009	0.000
4000.0	0.316	39.125	0.836	954.002	0.017	0.001	1.414	0.085	0.013	0.000
4500.0	0.315	38.581	0.934	953.758	0.020	0.001	1.561	0.105	0.018	0.001
5000.0	0.313	38.042	1.031	953.514	0.023	0.001	1.701	0.126	0.024	0.001
5500.0	0.311	37.510	1.126	953.270	0.026	0.001	1.834	0.148	0.030	0.001
6000.0	0.310	36.982	1.220	953.026	0.030	0.001	1.961	0.171	0.038	0.001
6500.0	0.308	36.460	1.313	952.782	0.033	0.002	2.082	0.195	0.046	0.002
7000.0	0.306	35.943	1.405	952.539	0.037	0.002	2.197	0.220	0.055	0.003
7500.0	0.305	35.431	1.496	952.295	0.040	0.002	2.306	0.246	0.064	0.003
8000.0	0.303	34.924	1.585	952.052	0.044	0.003	2.410	0.273	0.074	0.004
8500.0	0.302	34.421	1.673	951.809	0.048	0.003	2.509	0.300	0.085	0.005
9000.0	0.300	33.923	1.760	951.567	0.052	0.004	2.602	0.328	0.097	0.006
9500.0	0.298	33.430	1.847	951.324	0.056	0.004	2.691	0.356	0.109	0.007
10000.0	0.297	32.940	1.932	951.082	0.060	0.005	2.774	0.385	0.121	0.009
10500.0	0.295	32.455	2.016	950.841	0.064	0.005	2.853	0.414	0.134	0.010
11000.0	0.294	31.974	2.099	950.599	0.069	0.006	2.928	0.443	0.148	0.012
11500.0	0.292	31.497	2.181	950.358	0.073	0.006	2.998	0.473	0.162	0.013
12000.0	0.291	31.024	2.262	950.117	0.077	0.007	3.065	0.503	0.176	0.015
12500.0	0.289	30.555	2.342	949.876	0.082	0.008	3.127	0.534	0.190	0.018
13000.0	0.288	30.090	2.421	949.636	0.087	0.008	3.186	0.564	0.205	0.020
13500.0	0.286	29.628	2.499	949.396	0.091	0.009	3.241	0.595	0.219	0.022
14000.0	0.285	29.169	2.576	949.156	0.096	0.010	3.293	0.626	0.234	0.025
14500.0	0.283	28.714	2.653	948.916	0.101	0.011	3.341	0.657	0.250	0.028
15000.0	0.281	28.263	2.728	948.677	0.106	0.012	3.386	0.689	0.265	0.031
15500.0	0.280	27.814	2.803	948.438	0.111	0.012	3.428	0.720	0.280	0.034
16000.0	0.279	27.369	2.877	948.198	0.116	0.013	3.467	0.751	0.295	0.037
16500.0	0.277	26.927	2.950	947.959	0.121	0.014	3.504	0.783	0.311	0.041
17000.0	0.276	26.489	3.022	947.719	0.126	0.015	3.538	0.814	0.326	0.045
17500.0	0.274	26.053	3.094	947.478	0.131	0.017	3.570	0.846	0.342	0.049
18000.0	0.273	25.622	3.165	947.236	0.136	0.018	3.600	0.877	0.357	0.053
18500.0	0.271	25.193	3.235	946.994	0.141	0.019	3.628	0.908	0.373	0.057
19000.0	0.270	24.768	3.304	946.750	0.146	0.020	3.654	0.939	0.389	0.062
19500.0	0.268	24.346	3.372	946.506	0.152	0.021	3.678	0.970	0.404	0.066
20000.0	0.267	23.927	3.440	946.260	0.157	0.023	3.701	1.002	0.420	0.071
20500.0	0.265	23.512	3.507	946.013	0.163	0.024	3.722	1.032	0.436	0.077
21000.0	0.264	23.100	3.573	945.764	0.168	0.025	3.742	1.063	0.452	0.082
21500.0	0.262	22.692	3.638	945.514	0.174	0.027	3.760	1.094	0.467	0.088
22500.0	0.259	21.885	3.767	945.010	0.185	0.030	3.793	1.155	0.499	0.100
25000.0	0.252	19.929	4.074	943.722	0.215	0.039	3.854	1.304	0.576	0.134
27500.0	0.244	18.059	4.362	942.393	0.245	0.049	3.887	1.447	0.650	0.174
30000.0	0.237	16.278	4.630	941.020	0.277	0.061	3.897	1.586	0.719	0.220
32500.0	0.229	14.586	4.879	939.600	0.309	0.074	3.887	1.718	0.782	0.272
35000.0	0.221	12.985	5.107	938.128	0.342	0.089	3.861	1.843	0.839	0.331
37500.0	0.214	11.479	5.315	936.602	0.376	0.105	3.822	1.960	0.889	0.396
40000.0	0.206	10.069	5.503	935.016	0.409	0.123	3.772	2.069	0.932	0.467
42500.0	0.198	8.758	5.669	933.367	0.442	0.142	3.715	2.169	0.968	0.545
45000.0	0.190	7.549	5.814	931.651	0.475	0.163	3.652	2.260	0.997	0.628
47500.0	0.182	6.444	5.938	929.863	0.507	0.184	3.587	2.341	1.020	0.716
50000.0	0.175	5.445	6.039	928.001	0.538	0.206	3.521	2.412	1.036	0.810
52500.0	0.167	4.551	6.119	926.062	0.567	0.228	3.456	2.473	1.048	0.908
55000.0	0.159	3.763	6.178	924.045	0.595	0.251	3.394	2.525	1.055	1.010
57500.0	0.151	3.077	6.217	921.951	0.621	0.272	3.335	2.567	1.058	1.115
60000.0	0.144	2.489	6.236	919.781	0.644	0.294	3.282	2.601	1.058	1.223
62500.0	0.136	1.993	6.238	917.539	0.666	0.314	3.234	2.627	1.056	1.332
65000.0	0.129	1.581	6.223	915.231	0.685	0.332	3.191	2.646	1.052	1.442
67500.0	0.122	1.244	6.194	912.864	0.701	0.349	3.154	2.660	1.047	1.552
70000.0	0.115	0.972	6.153	910.446	0.715	0.365	3.122	2.668	1.041	1.661

**Table C.35 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.330	43.715	0.000	955.955	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.330	43.595	0.023	955.899	0.000	0.000	0.017	0.000	0.000	0.000
500.0	0.328	43.118	0.114	955.675	0.002	0.000	0.191	0.001	0.000	0.000
1000.0	0.326	42.529	0.227	955.393	0.004	0.000	0.424	0.007	0.000	0.000
1500.0	0.324	41.949	0.338	955.112	0.006	0.000	0.647	0.015	0.001	0.000
2000.0	0.322	41.378	0.446	954.831	0.008	0.000	0.860	0.027	0.003	0.000
2500.0	0.320	40.814	0.553	954.551	0.011	0.000	1.062	0.041	0.005	0.000
3000.0	0.318	40.259	0.658	954.270	0.014	0.000	1.255	0.057	0.008	0.000
3500.0	0.316	39.710	0.762	953.990	0.017	0.001	1.439	0.076	0.012	0.000
4000.0	0.315	39.168	0.864	953.710	0.021	0.001	1.615	0.096	0.017	0.000
4500.0	0.313	38.633	0.964	953.430	0.024	0.001	1.782	0.117	0.024	0.001
5000.0	0.311	38.105	1.063	953.151	0.028	0.001	1.941	0.140	0.031	0.001
5500.0	0.309	37.583	1.160	952.872	0.032	0.002	2.093	0.164	0.039	0.001
6000.0	0.307	37.066	1.256	952.593	0.036	0.002	2.238	0.190	0.049	0.002
6500.0	0.305	36.556	1.350	952.314	0.040	0.002	2.376	0.216	0.059	0.002
7000.0	0.304	36.051	1.443	952.036	0.044	0.003	2.508	0.243	0.070	0.003
7500.0	0.302	35.552	1.535	951.758	0.048	0.003	2.633	0.271	0.082	0.004
8000.0	0.300	35.058	1.626	951.481	0.053	0.004	2.752	0.299	0.095	0.005
8500.0	0.298	34.569	1.715	951.204	0.057	0.004	2.865	0.328	0.108	0.006
9000.0	0.296	34.085	1.803	950.927	0.062	0.005	2.972	0.358	0.122	0.007
9500.0	0.295	33.606	1.889	950.651	0.067	0.005	3.074	0.388	0.137	0.009
10000.0	0.293	33.131	1.975	950.376	0.072	0.006	3.171	0.419	0.152	0.010
10500.0	0.291	32.661	2.059	950.101	0.077	0.007	3.262	0.450	0.168	0.012
11000.0	0.289	32.196	2.142	949.826	0.083	0.008	3.349	0.481	0.184	0.014
11500.0	0.288	31.735	2.224	949.552	0.088	0.008	3.431	0.513	0.201	0.016
12000.0	0.286	31.278	2.305	949.278	0.093	0.009	3.509	0.545	0.218	0.019
12500.0	0.284	30.826	2.385	949.004	0.099	0.010	3.582	0.577	0.235	0.021
13000.0	0.283	30.377	2.464	948.731	0.104	0.011	3.652	0.609	0.252	0.024
13500.0	0.281	29.932	2.542	948.458	0.110	0.012	3.717	0.642	0.270	0.027
14000.0	0.279	29.491	2.618	948.185	0.116	0.013	3.778	0.675	0.288	0.030
14500.0	0.278	29.054	2.694	947.913	0.121	0.014	3.836	0.708	0.306	0.033
15000.0	0.276	28.621	2.769	947.641	0.127	0.015	3.890	0.741	0.324	0.036
15500.0	0.274	28.191	2.843	947.369	0.133	0.017	3.941	0.774	0.342	0.040
16000.0	0.273	27.764	2.916	947.098	0.139	0.018	3.989	0.807	0.360	0.044
16500.0	0.271	27.341	2.989	946.826	0.145	0.019	4.034	0.840	0.378	0.048
17000.0	0.270	26.922	3.060	946.554	0.151	0.021	4.076	0.873	0.396	0.052
17500.0	0.268	26.506	3.130	946.283	0.156	0.022	4.115	0.906	0.414	0.057
18000.0	0.266	26.093	3.200	946.010	0.163	0.024	4.153	0.939	0.432	0.061
18500.0	0.265	25.683	3.269	945.737	0.169	0.025	4.187	0.972	0.451	0.066
19000.0	0.263	25.277	3.337	945.464	0.175	0.027	4.220	1.005	0.469	0.071
19500.0	0.262	24.875	3.404	945.189	0.181	0.028	4.251	1.038	0.487	0.076
20000.0	0.260	24.476	3.471	944.914	0.187	0.030	4.280	1.071	0.505	0.082
20500.0	0.259	24.080	3.536	944.637	0.194	0.032	4.307	1.103	0.523	0.088
21000.0	0.257	23.687	3.601	944.359	0.200	0.034	4.332	1.135	0.541	0.094
21500.0	0.255	23.299	3.665	944.080	0.206	0.036	4.356	1.168	0.559	0.100
22000.0	0.254	22.913	3.728	943.800	0.213	0.038	4.379	1.200	0.577	0.106
22500.0	0.252	22.531	3.790	943.518	0.219	0.040	4.400	1.231	0.595	0.113
25000.0	0.245	20.672	4.089	942.088	0.253	0.051	4.487	1.387	0.684	0.149
27500.0	0.237	18.899	4.368	940.620	0.288	0.064	4.544	1.537	0.770	0.191
30000.0	0.229	17.213	4.627	939.114	0.324	0.078	4.576	1.681	0.850	0.239
32500.0	0.221	15.611	4.866	937.566	0.361	0.095	4.587	1.819	0.924	0.292
35000.0	0.214	14.096	5.085	935.976	0.397	0.113	4.578	1.949	0.992	0.351
37500.0	0.206	12.667	5.285	934.340	0.434	0.133	4.555	2.072	1.052	0.415
40000.0	0.199	11.325	5.465	932.657	0.471	0.155	4.519	2.187	1.106	0.484
42500.0	0.191	10.070	5.626	930.924	0.506	0.178	4.473	2.293	1.152	0.558
45000.0	0.184	8.902	5.768	929.139	0.542	0.203	4.419	2.390	1.191	0.636
47500.0	0.176	7.821	5.890	927.300	0.576	0.229	4.360	2.478	1.223	0.719
50000.0	0.169	6.828	5.993	925.406	0.609	0.255	4.297	2.557	1.249	0.806
52500.0	0.162	5.922	6.078	923.455	0.640	0.282	4.232	2.627	1.269	0.896
55000.0	0.155	5.102	6.144	921.446	0.670	0.309	4.167	2.688	1.284	0.989
57500.0	0.148	4.365	6.193	919.380	0.698	0.336	4.103	2.740	1.294	1.084
60000.0	0.141	3.709	6.225	917.257	0.724	0.362	4.042	2.784	1.300	1.181
62500.0	0.134	3.131	6.240	915.078	0.748	0.388	3.983	2.821	1.302	1.280
65000.0	0.128	2.625	6.241	912.847	0.770	0.412	3.929	2.850	1.302	1.379
67500.0	0.122	2.188	6.228	910.566	0.790	0.436	3.878	2.872	1.299	1.479
70000.0	0.116	1.813	6.203	908.238	0.807	0.457	3.832	2.889	1.295	1.579

**Table C.36 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.330	43.715	0.000	955.955	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.330	43.595	0.024	955.889	0.000	0.000	0.020	0.000	0.000	0.000
500.0	0.328	43.121	0.121	955.624	0.002	0.000	0.223	0.002	0.000	0.000
1000.0	0.325	42.538	0.239	955.292	0.005	0.000	0.496	0.008	0.000	0.000
1500.0	0.323	41.964	0.355	954.960	0.007	0.000	0.756	0.017	0.002	0.000
2000.0	0.321	41.400	0.469	954.629	0.011	0.000	1.004	0.031	0.004	0.000
2500.0	0.319	40.846	0.581	954.298	0.014	0.000	1.240	0.046	0.007	0.000
3000.0	0.316	40.300	0.690	953.968	0.018	0.001	1.466	0.065	0.011	0.000
3500.0	0.314	39.762	0.798	953.638	0.022	0.001	1.681	0.085	0.017	0.000
4000.0	0.312	39.231	0.904	953.308	0.026	0.001	1.887	0.107	0.024	0.001
4500.0	0.310	38.709	1.008	952.979	0.030	0.001	2.083	0.131	0.032	0.001
5000.0	0.308	38.193	1.110	952.651	0.035	0.002	2.271	0.156	0.042	0.001
5500.0	0.305	37.684	1.210	952.323	0.040	0.002	2.450	0.182	0.053	0.002
6000.0	0.303	37.182	1.309	951.995	0.045	0.003	2.622	0.209	0.065	0.002
6500.0	0.301	36.687	1.406	951.668	0.050	0.003	2.785	0.237	0.078	0.003
7000.0	0.299	36.197	1.502	951.342	0.055	0.004	2.942	0.266	0.092	0.004
7500.0	0.297	35.714	1.596	951.016	0.061	0.005	3.091	0.296	0.106	0.005
8000.0	0.295	35.236	1.688	950.690	0.067	0.005	3.234	0.326	0.122	0.006
8500.0	0.293	34.764	1.779	950.365	0.073	0.006	3.370	0.357	0.139	0.008
9000.0	0.291	34.297	1.869	950.041	0.079	0.007	3.500	0.389	0.156	0.009
9500.0	0.289	33.836	1.957	949.717	0.085	0.008	3.624	0.421	0.174	0.011
10000.0	0.287	33.380	2.044	949.394	0.091	0.009	3.742	0.454	0.192	0.013
10500.0	0.285	32.929	2.129	949.072	0.097	0.010	3.854	0.487	0.211	0.015
11000.0	0.283	32.483	2.214	948.750	0.104	0.011	3.962	0.520	0.230	0.017
11500.0	0.281	32.041	2.297	948.428	0.110	0.012	4.064	0.554	0.250	0.019
12000.0	0.279	31.604	2.379	948.107	0.117	0.014	4.161	0.588	0.270	0.022
12500.0	0.277	31.172	2.459	947.786	0.124	0.015	4.254	0.623	0.291	0.025
13000.0	0.275	30.744	2.539	947.465	0.130	0.016	4.343	0.657	0.311	0.028
13500.0	0.274	30.320	2.617	947.145	0.137	0.018	4.427	0.692	0.332	0.031
14000.0	0.272	29.901	2.694	946.825	0.144	0.019	4.507	0.728	0.353	0.034
14500.0	0.270	29.485	2.770	946.505	0.151	0.021	4.583	0.763	0.375	0.038
15000.0	0.268	29.074	2.845	946.186	0.158	0.023	4.655	0.798	0.396	0.042
15500.0	0.266	28.666	2.919	945.867	0.165	0.024	4.723	0.834	0.417	0.046
16000.0	0.264	28.263	2.992	945.548	0.173	0.026	4.788	0.870	0.439	0.050
16500.0	0.263	27.863	3.064	945.229	0.180	0.028	4.849	0.905	0.460	0.054
17000.0	0.261	27.467	3.135	944.911	0.187	0.030	4.908	0.941	0.482	0.059
17500.0	0.259	27.074	3.205	944.592	0.195	0.032	4.963	0.977	0.503	0.064
18000.0	0.257	26.685	3.274	944.274	0.202	0.034	5.015	1.013	0.524	0.069
18500.0	0.256	26.300	3.342	943.955	0.209	0.036	5.065	1.048	0.546	0.074
19000.0	0.254	25.918	3.409	943.636	0.217	0.039	5.112	1.084	0.567	0.079
19500.0	0.252	25.540	3.475	943.316	0.224	0.041	5.157	1.120	0.588	0.085
20000.0	0.251	25.165	3.540	942.996	0.232	0.044	5.199	1.155	0.609	0.091
20500.0	0.249	24.793	3.605	942.675	0.240	0.046	5.239	1.191	0.631	0.097
21000.0	0.247	24.425	3.668	942.354	0.247	0.049	5.278	1.226	0.652	0.103
21500.0	0.245	24.060	3.731	942.032	0.255	0.051	5.314	1.261	0.673	0.109
22000.0	0.244	23.699	3.793	941.709	0.263	0.054	5.349	1.296	0.693	0.116
22500.0	0.242	23.341	3.854	941.384	0.270	0.057	5.381	1.331	0.714	0.122
23000.0	0.240	22.987	3.914	941.059	0.278	0.060	5.413	1.366	0.735	0.129
23500.0	0.239	22.636	3.973	940.732	0.286	0.063	5.443	1.400	0.756	0.137
24000.0	0.237	22.288	4.031	940.405	0.294	0.066	5.471	1.435	0.776	0.144
24500.0	0.235	21.944	4.089	940.075	0.301	0.069	5.498	1.469	0.797	0.151
25000.0	0.234	21.603	4.146	939.745	0.309	0.072	5.524	1.503	0.817	0.159
27500.0	0.226	19.950	4.417	938.073	0.349	0.090	5.635	1.668	0.917	0.201
30000.0	0.218	18.379	4.668	936.367	0.389	0.110	5.718	1.828	1.013	0.247
32500.0	0.210	16.890	4.899	934.626	0.430	0.132	5.776	1.982	1.104	0.298
35000.0	0.202	15.482	5.111	932.850	0.470	0.156	5.814	2.128	1.189	0.353
37500.0	0.194	14.152	5.303	931.037	0.511	0.182	5.833	2.268	1.267	0.413
40000.0	0.187	12.900	5.476	929.188	0.551	0.210	5.836	2.400	1.339	0.476
42500.0	0.180	11.724	5.631	927.301	0.590	0.240	5.826	2.525	1.404	0.543
45000.0	0.173	10.624	5.768	925.376	0.628	0.272	5.805	2.641	1.463	0.614
47500.0	0.166	9.597	5.887	923.412	0.665	0.305	5.775	2.750	1.515	0.687
50000.0	0.159	8.642	5.989	921.411	0.701	0.338	5.737	2.850	1.561	0.764
52500.0	0.153	7.757	6.074	919.370	0.736	0.373	5.694	2.942	1.601	0.842
55000.0	0.146	6.940	6.144	917.291	0.768	0.409	5.647	3.026	1.636	0.923
57500.0	0.140	6.189	6.199	915.175	0.799	0.444	5.597	3.102	1.665	1.006
60000.0	0.134	5.502	6.239	913.021	0.828	0.480	5.546	3.170	1.689	1.091
62500.0	0.129	4.875	6.266	910.831	0.855	0.515	5.493	3.231	1.709	1.177
65000.0	0.123	4.307	6.279	908.607	0.880	0.550	5.441	3.284	1.725	1.264
67500.0	0.118	3.793	6.281	906.348	0.903	0.584	5.390	3.331	1.737	1.353
70000.0	0.113	3.331	6.271	904.058	0.924	0.616	5.340	3.371	1.746	1.442

**Table C.37 [] Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.312	41.261	0.000	958.427	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.311	41.141	0.022	958.378	0.000	0.000	0.015	0.000	0.000	0.000
500.0	0.310	40.664	0.108	958.182	0.001	0.000	0.168	0.001	0.000	0.000
1000.0	0.308	40.075	0.215	957.936	0.003	0.000	0.373	0.006	0.000	0.000
1500.0	0.307	39.493	0.320	957.690	0.005	0.000	0.568	0.014	0.001	0.000
2000.0	0.305	38.920	0.424	957.444	0.007	0.000	0.754	0.025	0.002	0.000
2500.0	0.303	38.354	0.526	957.198	0.009	0.000	0.930	0.038	0.004	0.000
3000.0	0.302	37.795	0.626	956.953	0.012	0.000	1.098	0.054	0.006	0.000
3500.0	0.300	37.243	0.725	956.707	0.014	0.000	1.257	0.071	0.010	0.000
4000.0	0.299	36.697	0.822	956.462	0.017	0.001	1.409	0.090	0.014	0.000
4500.0	0.297	36.158	0.918	956.216	0.020	0.001	1.553	0.111	0.019	0.001
5000.0	0.295	35.625	1.012	955.971	0.023	0.001	1.689	0.133	0.025	0.001
5500.0	0.294	35.097	1.106	955.726	0.026	0.001	1.819	0.156	0.032	0.001
6000.0	0.292	34.575	1.198	955.481	0.029	0.001	1.942	0.181	0.039	0.002
6500.0	0.291	34.058	1.289	955.237	0.033	0.002	2.059	0.206	0.048	0.002
7000.0	0.289	33.547	1.378	954.993	0.036	0.002	2.169	0.232	0.057	0.003
7500.0	0.288	33.041	1.466	954.749	0.040	0.002	2.274	0.259	0.067	0.004
8000.0	0.286	32.540	1.554	954.506	0.043	0.003	2.373	0.287	0.077	0.005
8500.0	0.285	32.043	1.640	954.262	0.047	0.003	2.466	0.316	0.088	0.006
9000.0	0.283	31.552	1.725	954.020	0.051	0.004	2.554	0.345	0.100	0.007
9500.0	0.281	31.064	1.809	953.778	0.055	0.004	2.637	0.374	0.112	0.008
10000.0	0.280	30.582	1.891	953.536	0.059	0.005	2.715	0.404	0.125	0.010
10500.0	0.278	30.103	1.973	953.295	0.063	0.005	2.789	0.434	0.138	0.011
11000.0	0.277	29.628	2.054	953.053	0.067	0.006	2.858	0.465	0.151	0.013
11500.0	0.276	29.158	2.134	952.813	0.071	0.006	2.922	0.496	0.165	0.015
12000.0	0.274	28.691	2.212	952.572	0.076	0.007	2.983	0.527	0.179	0.017
12500.0	0.273	28.228	2.290	952.332	0.080	0.008	3.040	0.559	0.193	0.019
13000.0	0.271	27.769	2.367	952.093	0.084	0.008	3.093	0.590	0.208	0.022
13500.0	0.270	27.313	2.443	951.853	0.089	0.009	3.142	0.622	0.222	0.025
14000.0	0.268	26.861	2.518	951.614	0.093	0.010	3.188	0.654	0.237	0.027
14500.0	0.267	26.413	2.593	951.375	0.098	0.011	3.231	0.686	0.252	0.031
15000.0	0.265	25.968	2.666	951.135	0.103	0.011	3.271	0.718	0.267	0.034
15500.0	0.264	25.526	2.739	950.896	0.107	0.012	3.308	0.750	0.282	0.037
16000.0	0.262	25.087	2.811	950.656	0.112	0.013	3.343	0.782	0.297	0.041
16500.0	0.261	24.652	2.882	950.415	0.117	0.014	3.375	0.814	0.312	0.045
17000.0	0.260	24.221	2.952	950.173	0.122	0.015	3.406	0.846	0.328	0.049
17500.0	0.258	23.793	3.021	949.930	0.127	0.016	3.434	0.878	0.343	0.053
18000.0	0.257	23.368	3.090	949.686	0.132	0.017	3.460	0.910	0.358	0.058
18500.0	0.255	22.948	3.158	949.441	0.137	0.019	3.485	0.942	0.374	0.062
19000.0	0.254	22.530	3.225	949.195	0.142	0.020	3.507	0.974	0.389	0.067
19500.0	0.252	22.116	3.291	948.947	0.147	0.021	3.528	1.006	0.405	0.073
20000.0	0.251	21.706	3.357	948.698	0.152	0.022	3.548	1.037	0.420	0.078
20500.0	0.250	21.299	3.421	948.447	0.158	0.024	3.566	1.069	0.435	0.084
22500.0	0.244	19.709	3.672	947.428	0.180	0.030	3.625	1.192	0.497	0.109
25000.0	0.237	17.802	3.967	946.114	0.208	0.038	3.672	1.343	0.572	0.146
27500.0	0.229	15.989	4.242	944.755	0.238	0.048	3.692	1.488	0.642	0.189
30000.0	0.222	14.269	4.497	943.347	0.268	0.060	3.691	1.627	0.708	0.239
32500.0	0.214	12.645	4.732	941.884	0.300	0.073	3.671	1.758	0.766	0.296
35000.0	0.207	11.120	4.945	940.363	0.332	0.088	3.637	1.882	0.818	0.360
37500.0	0.199	9.697	5.136	938.780	0.364	0.104	3.592	1.997	0.863	0.430
40000.0	0.192	8.378	5.306	937.129	0.396	0.122	3.538	2.103	0.901	0.507
42500.0	0.184	7.167	5.454	935.407	0.427	0.140	3.479	2.199	0.931	0.591
45000.0	0.176	6.065	5.580	933.607	0.458	0.160	3.416	2.284	0.956	0.680
47500.0	0.168	5.075	5.683	931.729	0.488	0.180	3.354	2.359	0.974	0.776
50000.0	0.161	4.197	5.763	929.768	0.516	0.201	3.292	2.424	0.986	0.876
52500.0	0.153	3.430	5.822	927.725	0.543	0.222	3.233	2.478	0.994	0.980
55000.0	0.145	2.769	5.860	925.600	0.568	0.242	3.179	2.523	0.999	1.089
57500.0	0.137	2.210	5.878	923.396	0.591	0.262	3.130	2.558	1.000	1.199
60000.0	0.130	1.745	5.879	921.118	0.612	0.280	3.086	2.586	0.999	1.312
62500.0	0.123	1.364	5.863	918.774	0.630	0.298	3.048	2.606	0.996	1.425
65000.0	0.116	1.058	5.834	916.370	0.646	0.313	3.016	2.620	0.993	1.538
67500.0	0.109	0.814	5.793	913.917	0.659	0.328	2.988	2.629	0.989	1.650
70000.0	0.103	0.624	5.742	911.421	0.671	0.340	2.965	2.635	0.984	1.761

**Table C.38 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.312	41.261	0.000	958.427	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.311	41.142	0.023	958.371	0.000	0.000	0.017	0.000	0.000	0.000
500.0	0.310	40.666	0.113	958.143	0.002	0.000	0.193	0.001	0.000	0.000
1000.0	0.308	40.080	0.223	957.859	0.004	0.000	0.429	0.007	0.000	0.000
1500.0	0.306	39.504	0.332	957.574	0.006	0.000	0.652	0.016	0.001	0.000
2000.0	0.304	38.936	0.439	957.291	0.009	0.000	0.865	0.029	0.003	0.000
2500.0	0.302	38.377	0.544	957.007	0.011	0.000	1.067	0.044	0.005	0.000
3000.0	0.300	37.826	0.647	956.724	0.014	0.000	1.259	0.061	0.009	0.000
3500.0	0.299	37.283	0.748	956.441	0.017	0.001	1.441	0.081	0.013	0.000
4000.0	0.297	36.747	0.848	956.159	0.021	0.001	1.614	0.102	0.019	0.000
4500.0	0.295	36.218	0.946	955.877	0.024	0.001	1.778	0.125	0.025	0.001
5000.0	0.293	35.695	1.042	955.595	0.028	0.001	1.934	0.149	0.033	0.001
5500.0	0.291	35.179	1.137	955.314	0.032	0.002	2.083	0.174	0.042	0.002
6000.0	0.290	34.670	1.230	955.034	0.035	0.002	2.223	0.201	0.052	0.002
6500.0	0.288	34.166	1.322	954.754	0.040	0.002	2.357	0.228	0.062	0.003
7000.0	0.286	33.668	1.413	954.474	0.044	0.003	2.483	0.257	0.074	0.004
7500.0	0.285	33.176	1.502	954.195	0.048	0.003	2.603	0.286	0.086	0.005
8000.0	0.283	32.689	1.590	953.917	0.052	0.004	2.716	0.316	0.099	0.006
8500.0	0.281	32.208	1.677	953.640	0.057	0.004	2.824	0.346	0.113	0.007
9000.0	0.279	31.731	1.762	953.363	0.062	0.005	2.925	0.377	0.127	0.008
9500.0	0.278	31.259	1.846	953.086	0.066	0.005	3.021	0.409	0.142	0.010
10000.0	0.276	30.793	1.929	952.811	0.071	0.006	3.111	0.440	0.158	0.012
10500.0	0.274	30.330	2.011	952.536	0.076	0.007	3.196	0.473	0.174	0.014
11000.0	0.273	29.873	2.091	952.261	0.081	0.008	3.277	0.505	0.190	0.016
11500.0	0.271	29.419	2.171	951.987	0.086	0.008	3.352	0.538	0.207	0.018
12000.0	0.270	28.970	2.249	951.713	0.092	0.009	3.424	0.571	0.223	0.021
12500.0	0.268	28.525	2.326	951.439	0.097	0.010	3.491	0.604	0.241	0.024
13000.0	0.266	28.084	2.403	951.166	0.102	0.011	3.553	0.638	0.258	0.026
13500.0	0.265	27.647	2.478	950.893	0.108	0.012	3.612	0.671	0.275	0.030
14000.0	0.263	27.214	2.552	950.621	0.113	0.013	3.668	0.705	0.293	0.033
14500.0	0.262	26.785	2.626	950.349	0.119	0.014	3.720	0.739	0.311	0.036
15000.0	0.260	26.359	2.698	950.077	0.124	0.015	3.768	0.773	0.329	0.040
15500.0	0.259	25.937	2.770	949.805	0.130	0.017	3.813	0.807	0.346	0.044
16000.0	0.257	25.518	2.841	949.533	0.135	0.018	3.855	0.840	0.364	0.048
16500.0	0.256	25.103	2.910	949.261	0.141	0.019	3.895	0.874	0.382	0.053
17000.0	0.254	24.691	2.979	948.988	0.147	0.020	3.932	0.908	0.400	0.057
17500.0	0.252	24.283	3.047	948.715	0.153	0.022	3.967	0.942	0.418	0.062
18000.0	0.251	23.878	3.115	948.441	0.158	0.023	3.999	0.975	0.436	0.067
18500.0	0.249	23.477	3.181	948.165	0.164	0.025	4.030	1.009	0.454	0.072
19000.0	0.248	23.080	3.247	947.889	0.170	0.026	4.058	1.042	0.472	0.078
19500.0	0.246	22.686	3.311	947.612	0.176	0.028	4.085	1.075	0.490	0.084
20000.0	0.245	22.296	3.375	947.333	0.182	0.030	4.110	1.108	0.508	0.090
20500.0	0.243	21.910	3.438	947.053	0.189	0.032	4.134	1.141	0.525	0.096
21000.0	0.242	21.527	3.501	946.772	0.195	0.033	4.156	1.173	0.543	0.102
22500.0	0.237	20.399	3.682	945.918	0.214	0.039	4.213	1.270	0.596	0.123
25000.0	0.230	18.593	3.968	944.465	0.247	0.050	4.284	1.426	0.683	0.162
27500.0	0.222	16.877	4.234	942.970	0.281	0.063	4.326	1.576	0.765	0.208
30000.0	0.215	15.251	4.478	941.433	0.315	0.078	4.344	1.720	0.841	0.259
32500.0	0.207	13.716	4.703	939.851	0.351	0.094	4.342	1.856	0.910	0.317
35000.0	0.200	12.271	4.907	938.221	0.386	0.112	4.323	1.984	0.972	0.380
37500.0	0.192	10.917	5.091	936.541	0.421	0.132	4.290	2.103	1.027	0.449
40000.0	0.185	9.654	5.256	934.808	0.456	0.153	4.247	2.214	1.075	0.523
42500.0	0.178	8.483	5.400	933.019	0.491	0.176	4.195	2.315	1.115	0.603
45000.0	0.171	7.405	5.524	931.174	0.524	0.199	4.138	2.406	1.148	0.687
47500.0	0.163	6.418	5.629	929.269	0.556	0.224	4.078	2.488	1.174	0.775
50000.0	0.156	5.522	5.715	927.304	0.587	0.249	4.015	2.560	1.195	0.867
52500.0	0.149	4.716	5.781	925.278	0.616	0.274	3.953	2.623	1.210	0.962
55000.0	0.142	3.998	5.830	923.191	0.643	0.299	3.892	2.676	1.220	1.059
57500.0	0.136	3.363	5.861	921.044	0.669	0.324	3.834	2.721	1.226	1.159
60000.0	0.129	2.809	5.877	918.839	0.692	0.348	3.779	2.758	1.229	1.261
62500.0	0.123	2.329	5.877	916.579	0.713	0.371	3.728	2.787	1.229	1.363
65000.0	0.117	1.919	5.863	914.268	0.732	0.392	3.682	2.809	1.227	1.465
67500.0	0.111	1.572	5.837	911.909	0.749	0.412	3.640	2.826	1.223	1.567
70000.0	0.105	1.280	5.800	909.508	0.763	0.431	3.603	2.838	1.218	1.668

**Table C.39 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.312	41.261	0.000	958.427	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.311	41.142	0.024	958.360	0.000	0.000	0.020	0.000	0.000	0.000
500.0	0.309	40.670	0.119	958.088	0.002	0.000	0.228	0.002	0.000	0.000
1000.0	0.307	40.090	0.236	957.749	0.005	0.000	0.505	0.008	0.000	0.000
1500.0	0.305	39.521	0.350	957.411	0.008	0.000	0.769	0.019	0.002	0.000
2000.0	0.303	38.963	0.461	957.073	0.011	0.000	1.019	0.033	0.004	0.000
2500.0	0.301	38.414	0.571	956.735	0.014	0.000	1.257	0.050	0.007	0.000
3000.0	0.298	37.874	0.678	956.399	0.018	0.001	1.483	0.070	0.012	0.000
3500.0	0.296	37.343	0.784	956.063	0.022	0.001	1.697	0.091	0.019	0.000
4000.0	0.294	36.820	0.887	955.728	0.026	0.001	1.902	0.115	0.026	0.001
4500.0	0.292	36.305	0.988	955.394	0.031	0.002	2.096	0.140	0.035	0.001
5000.0	0.290	35.797	1.088	955.061	0.035	0.002	2.282	0.166	0.045	0.002
5500.0	0.288	35.297	1.186	954.728	0.040	0.002	2.458	0.194	0.057	0.002
6000.0	0.286	34.804	1.282	954.395	0.045	0.003	2.626	0.223	0.070	0.003
6500.0	0.284	34.317	1.376	954.064	0.050	0.003	2.785	0.252	0.083	0.004
7000.0	0.282	33.837	1.469	953.733	0.056	0.004	2.937	0.283	0.098	0.005
7500.0	0.280	33.362	1.560	953.403	0.061	0.005	3.082	0.314	0.114	0.006
8000.0	0.278	32.894	1.649	953.074	0.067	0.006	3.219	0.346	0.130	0.007
8500.0	0.276	32.432	1.737	952.746	0.073	0.006	3.350	0.379	0.147	0.009
9000.0	0.274	31.975	1.824	952.419	0.079	0.007	3.474	0.412	0.165	0.010
9500.0	0.272	31.524	1.909	952.092	0.085	0.008	3.592	0.446	0.183	0.012
10000.0	0.270	31.077	1.993	951.766	0.091	0.009	3.704	0.480	0.202	0.015
10500.0	0.268	30.636	2.076	951.441	0.097	0.010	3.810	0.514	0.222	0.017
11000.0	0.267	30.200	2.157	951.116	0.104	0.011	3.911	0.549	0.242	0.019
11500.0	0.265	29.769	2.237	950.792	0.110	0.013	4.007	0.584	0.262	0.022
12000.0	0.263	29.342	2.316	950.468	0.116	0.014	4.098	0.620	0.282	0.025
12500.0	0.261	28.920	2.393	950.145	0.123	0.015	4.184	0.655	0.303	0.028
13000.0	0.259	28.502	2.470	949.822	0.130	0.017	4.266	0.691	0.324	0.031
13500.0	0.257	28.089	2.545	949.499	0.136	0.018	4.344	0.727	0.345	0.035
14000.0	0.256	27.680	2.619	949.177	0.143	0.020	4.417	0.763	0.366	0.039
14500.0	0.254	27.275	2.693	948.855	0.150	0.021	4.487	0.800	0.387	0.043
15000.0	0.252	26.874	2.765	948.533	0.157	0.023	4.553	0.836	0.409	0.047
15500.0	0.250	26.476	2.836	948.212	0.164	0.025	4.615	0.872	0.430	0.051
16000.0	0.249	26.083	2.906	947.890	0.171	0.027	4.674	0.909	0.452	0.056
16500.0	0.247	25.694	2.975	947.568	0.178	0.028	4.730	0.945	0.473	0.061
17000.0	0.245	25.308	3.043	947.247	0.185	0.030	4.783	0.982	0.494	0.066
17500.0	0.244	24.926	3.110	946.925	0.192	0.032	4.832	1.018	0.516	0.071
18000.0	0.242	24.548	3.176	946.604	0.200	0.035	4.879	1.055	0.537	0.076
18500.0	0.240	24.173	3.241	946.282	0.207	0.037	4.924	1.091	0.558	0.082
19000.0	0.239	23.802	3.305	945.959	0.214	0.039	4.966	1.127	0.579	0.088
19500.0	0.237	23.434	3.368	945.636	0.221	0.041	5.006	1.163	0.600	0.094
20000.0	0.235	23.070	3.431	945.312	0.229	0.044	5.044	1.199	0.621	0.100
20500.0	0.234	22.710	3.492	944.986	0.236	0.046	5.079	1.235	0.642	0.107
21000.0	0.232	22.353	3.553	944.660	0.244	0.049	5.114	1.271	0.663	0.113
21500.0	0.230	22.000	3.613	944.333	0.251	0.052	5.146	1.306	0.684	0.120
22000.0	0.229	21.650	3.672	944.005	0.259	0.054	5.177	1.341	0.705	0.127
22500.0	0.227	21.304	3.730	943.675	0.266	0.057	5.206	1.376	0.725	0.135
23000.0	0.226	20.961	3.787	943.344	0.274	0.060	5.233	1.411	0.746	0.142
25000.0	0.219	19.626	4.007	942.007	0.305	0.073	5.331	1.548	0.827	0.174
27500.0	0.211	18.036	4.263	940.303	0.344	0.090	5.426	1.713	0.925	0.219
30000.0	0.204	16.531	4.499	938.562	0.383	0.110	5.493	1.871	1.018	0.269
32500.0	0.196	15.110	4.714	936.786	0.423	0.132	5.538	2.023	1.105	0.324
35000.0	0.189	13.772	4.910	934.971	0.462	0.156	5.562	2.167	1.185	0.383
37500.0	0.181	12.515	5.086	933.119	0.501	0.182	5.570	2.302	1.259	0.447
40000.0	0.174	11.337	5.244	931.227	0.539	0.210	5.563	2.430	1.326	0.514
42500.0	0.167	10.238	5.383	929.296	0.577	0.239	5.545	2.550	1.386	0.585
45000.0	0.161	9.214	5.504	927.325	0.613	0.270	5.518	2.660	1.439	0.660
47500.0	0.154	8.265	5.608	925.314	0.649	0.302	5.482	2.762	1.485	0.737
50000.0	0.148	7.388	5.695	923.262	0.683	0.335	5.441	2.856	1.526	0.817
52500.0	0.141	6.582	5.766	921.171	0.715	0.368	5.396	2.941	1.560	0.900
55000.0	0.135	5.843	5.821	919.041	0.746	0.402	5.348	3.017	1.589	0.984
57500.0	0.129	5.170	5.862	916.872	0.774	0.435	5.298	3.086	1.613	1.070
60000.0	0.124	4.558	5.889	914.666	0.801	0.469	5.248	3.146	1.633	1.158
62500.0	0.118	4.006	5.903	912.424	0.826	0.502	5.198	3.200	1.649	1.247
65000.0	0.113	3.509	5.905	910.148	0.848	0.534	5.149	3.246	1.661	1.337
67500.0	0.108	3.065	5.896	907.839	0.868	0.565	5.102	3.286	1.669	1.427
70000.0	0.104	2.670	5.876	905.499	0.887	0.594	5.057	3.320	1.676	1.518

**Table C.40 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.309	40.975	0.000	958.716	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.309	40.855	0.022	958.669	0.000	0.000	0.015	0.000	0.000	0.000
500.0	0.308	40.377	0.108	958.479	0.001	0.000	0.163	0.001	0.000	0.000
1000.0	0.306	39.787	0.214	958.242	0.003	0.000	0.361	0.006	0.000	0.000
1500.0	0.304	39.205	0.318	958.004	0.005	0.000	0.550	0.014	0.001	0.000
2000.0	0.303	38.631	0.421	957.766	0.007	0.000	0.729	0.024	0.002	0.000
2500.0	0.301	38.063	0.522	957.529	0.009	0.000	0.899	0.037	0.004	0.000
3000.0	0.300	37.503	0.622	957.292	0.011	0.000	1.061	0.052	0.006	0.000
3500.0	0.298	36.949	0.720	957.055	0.014	0.000	1.215	0.069	0.009	0.000
4000.0	0.296	36.402	0.817	956.818	0.016	0.001	1.361	0.088	0.013	0.000
4500.0	0.295	35.860	0.912	956.581	0.019	0.001	1.500	0.108	0.018	0.001
5000.0	0.293	35.324	1.006	956.344	0.022	0.001	1.631	0.130	0.023	0.001
5500.0	0.292	34.794	1.099	956.108	0.025	0.001	1.756	0.153	0.030	0.001
6000.0	0.290	34.270	1.191	955.872	0.028	0.001	1.875	0.177	0.037	0.002
6500.0	0.289	33.750	1.281	955.637	0.031	0.002	1.987	0.202	0.045	0.002
7000.0	0.287	33.236	1.371	955.402	0.034	0.002	2.093	0.227	0.053	0.003
7500.0	0.286	32.726	1.459	955.167	0.038	0.002	2.193	0.254	0.063	0.003
8000.0	0.284	32.221	1.546	954.933	0.041	0.003	2.288	0.281	0.072	0.004
8500.0	0.283	31.721	1.632	954.700	0.045	0.003	2.377	0.309	0.083	0.005
9000.0	0.281	31.225	1.717	954.467	0.048	0.003	2.461	0.337	0.094	0.006
9500.0	0.280	30.733	1.801	954.236	0.052	0.004	2.540	0.366	0.105	0.007
10000.0	0.278	30.245	1.883	954.004	0.056	0.004	2.614	0.396	0.117	0.009
10500.0	0.277	29.761	1.965	953.774	0.059	0.005	2.684	0.425	0.129	0.010
11000.0	0.276	29.281	2.046	953.543	0.063	0.005	2.749	0.455	0.141	0.012
11500.0	0.274	28.805	2.126	953.313	0.067	0.006	2.811	0.485	0.154	0.014
12000.0	0.273	28.332	2.205	953.082	0.071	0.006	2.869	0.516	0.167	0.016
12500.0	0.271	27.864	2.283	952.851	0.075	0.007	2.924	0.547	0.181	0.018
13000.0	0.270	27.399	2.360	952.618	0.080	0.008	2.977	0.577	0.195	0.020
13500.0	0.268	26.938	2.437	952.385	0.084	0.008	3.026	0.609	0.209	0.023
14000.0	0.267	26.481	2.512	952.151	0.088	0.009	3.073	0.640	0.223	0.025
14500.0	0.266	26.028	2.587	951.915	0.093	0.010	3.117	0.671	0.237	0.028
15000.0	0.264	25.579	2.661	951.679	0.097	0.011	3.159	0.702	0.252	0.031
15500.0	0.263	25.134	2.733	951.441	0.102	0.011	3.199	0.734	0.267	0.035
17500.0	0.257	23.391	3.017	950.474	0.122	0.015	3.338	0.860	0.329	0.050
20000.0	0.250	21.297	3.352	949.231	0.148	0.021	3.469	1.016	0.407	0.074
22500.0	0.242	19.299	3.667	947.949	0.175	0.028	3.560	1.171	0.485	0.105
25000.0	0.235	17.395	3.961	946.623	0.204	0.037	3.616	1.322	0.561	0.142
27500.0	0.228	15.587	4.235	945.250	0.234	0.047	3.645	1.469	0.632	0.185
30000.0	0.220	13.876	4.487	943.826	0.265	0.059	3.649	1.610	0.697	0.235
32500.0	0.213	12.264	4.719	942.347	0.297	0.072	3.633	1.744	0.756	0.293
35000.0	0.205	10.754	4.929	940.808	0.329	0.087	3.602	1.870	0.808	0.357
37500.0	0.198	9.348	5.117	939.205	0.361	0.103	3.560	1.987	0.854	0.428
40000.0	0.190	8.050	5.283	937.533	0.393	0.121	3.508	2.094	0.892	0.506
42500.0	0.182	6.861	5.426	935.788	0.425	0.139	3.451	2.191	0.923	0.590
45000.0	0.174	5.785	5.547	933.964	0.456	0.159	3.390	2.278	0.947	0.681
47500.0	0.166	4.821	5.645	932.060	0.486	0.180	3.329	2.354	0.966	0.777
50000.0	0.159	3.970	5.720	930.073	0.514	0.200	3.269	2.420	0.979	0.878
52500.0	0.151	3.231	5.774	928.003	0.541	0.221	3.213	2.474	0.987	0.984
55000.0	0.143	2.598	5.807	925.851	0.566	0.241	3.161	2.519	0.992	1.093
57500.0	0.135	2.065	5.821	923.622	0.588	0.261	3.114	2.555	0.994	1.205
60000.0	0.128	1.625	5.817	921.320	0.608	0.279	3.072	2.582	0.993	1.318
62500.0	0.121	1.266	5.798	918.954	0.626	0.297	3.036	2.603	0.991	1.432
65000.0	0.114	0.979	5.765	916.532	0.642	0.312	3.006	2.617	0.988	1.545
67500.0	0.107	0.752	5.722	914.061	0.655	0.326	2.980	2.627	0.985	1.658
70000.0	0.101	0.575	5.670	911.552	0.666	0.338	2.959	2.632	0.981	1.768

**Table C.41 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.309	40.975	0.000	958.716	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.309	40.855	0.022	958.662	0.000	0.000	0.017	0.000	0.000	0.000
500.0	0.307	40.379	0.112	958.443	0.002	0.000	0.186	0.001	0.000	0.000
1000.0	0.305	39.793	0.221	958.169	0.004	0.000	0.413	0.007	0.000	0.000
1500.0	0.304	39.215	0.329	957.896	0.006	0.000	0.628	0.016	0.001	0.000
2000.0	0.302	38.647	0.435	957.623	0.008	0.000	0.832	0.028	0.003	0.000
2500.0	0.300	38.086	0.539	957.350	0.011	0.000	1.026	0.042	0.005	0.000
3000.0	0.298	37.533	0.641	957.077	0.013	0.000	1.211	0.059	0.008	0.000
3500.0	0.297	36.988	0.742	956.805	0.016	0.001	1.386	0.078	0.012	0.000
4000.0	0.295	36.450	0.840	956.534	0.020	0.001	1.552	0.099	0.017	0.000
4500.0	0.293	35.918	0.938	956.262	0.023	0.001	1.709	0.122	0.024	0.001
5000.0	0.291	35.393	1.034	955.991	0.026	0.001	1.859	0.145	0.031	0.001
5500.0	0.290	34.874	1.128	955.721	0.030	0.001	2.001	0.170	0.039	0.001
6000.0	0.288	34.361	1.221	955.451	0.034	0.002	2.136	0.196	0.048	0.002
6500.0	0.286	33.854	1.313	955.182	0.037	0.002	2.264	0.223	0.058	0.003
7000.0	0.285	33.353	1.403	954.913	0.041	0.003	2.385	0.251	0.069	0.003
7500.0	0.283	32.857	1.492	954.645	0.045	0.003	2.499	0.280	0.081	0.004
8000.0	0.281	32.366	1.580	954.378	0.050	0.003	2.608	0.309	0.093	0.005
8500.0	0.280	31.880	1.666	954.111	0.054	0.004	2.710	0.339	0.106	0.006
9000.0	0.278	31.399	1.751	953.845	0.058	0.004	2.807	0.369	0.120	0.008
9500.0	0.276	30.923	1.835	953.580	0.063	0.005	2.898	0.400	0.134	0.009
10000.0	0.275	30.451	1.918	953.316	0.067	0.006	2.984	0.432	0.148	0.011
10500.0	0.273	29.984	2.000	953.052	0.072	0.006	3.064	0.463	0.163	0.013
11000.0	0.272	29.520	2.080	952.789	0.077	0.007	3.140	0.495	0.178	0.015
11500.0	0.270	29.061	2.160	952.527	0.082	0.008	3.212	0.527	0.194	0.017
12000.0	0.269	28.606	2.238	952.264	0.087	0.008	3.280	0.560	0.209	0.019
12500.0	0.267	28.155	2.316	952.001	0.092	0.009	3.345	0.592	0.225	0.022
13000.0	0.265	27.708	2.392	951.738	0.097	0.010	3.405	0.625	0.242	0.025
13500.0	0.264	27.265	2.468	951.474	0.102	0.011	3.463	0.658	0.259	0.028
14000.0	0.262	26.826	2.543	951.209	0.107	0.012	3.518	0.691	0.275	0.031
14500.0	0.261	26.391	2.616	950.943	0.112	0.013	3.570	0.724	0.293	0.034
15000.0	0.259	25.960	2.689	950.676	0.118	0.014	3.620	0.757	0.310	0.038
15500.0	0.258	25.533	2.761	950.407	0.123	0.015	3.667	0.790	0.328	0.041
16000.0	0.256	25.110	2.832	950.138	0.129	0.017	3.712	0.823	0.345	0.045
16500.0	0.255	24.691	2.902	949.867	0.135	0.018	3.755	0.856	0.363	0.050
17500.0	0.252	23.865	3.040	949.321	0.146	0.020	3.834	0.922	0.399	0.059
20000.0	0.244	21.868	3.368	947.930	0.177	0.028	3.998	1.085	0.490	0.086
22500.0	0.236	19.966	3.675	946.503	0.208	0.037	4.118	1.245	0.581	0.119
25000.0	0.229	18.160	3.960	945.036	0.242	0.048	4.202	1.402	0.668	0.158
27500.0	0.221	16.448	4.224	943.528	0.276	0.061	4.254	1.553	0.750	0.203
30000.0	0.214	14.829	4.466	941.976	0.311	0.076	4.280	1.698	0.826	0.255
32500.0	0.206	13.304	4.688	940.377	0.347	0.092	4.284	1.836	0.896	0.313
35000.0	0.198	11.871	4.890	938.730	0.383	0.110	4.270	1.966	0.958	0.376
37500.0	0.191	10.532	5.070	937.032	0.418	0.130	4.242	2.087	1.013	0.446
40000.0	0.184	9.287	5.231	935.279	0.453	0.151	4.202	2.199	1.061	0.521
42500.0	0.176	8.136	5.371	933.470	0.488	0.174	4.153	2.302	1.102	0.601
45000.0	0.169	7.078	5.491	931.603	0.521	0.198	4.098	2.395	1.135	0.685
47500.0	0.162	6.115	5.591	929.675	0.553	0.222	4.040	2.478	1.162	0.774
50000.0	0.155	5.243	5.671	927.686	0.584	0.248	3.980	2.551	1.183	0.867
52500.0	0.148	4.462	5.733	925.636	0.613	0.273	3.920	2.615	1.198	0.963
55000.0	0.141	3.769	5.777	923.524	0.640	0.298	3.861	2.669	1.209	1.062
57500.0	0.134	3.160	5.804	921.353	0.665	0.323	3.805	2.714	1.215	1.162
60000.0	0.127	2.630	5.815	919.124	0.688	0.346	3.753	2.751	1.218	1.264
62500.0	0.121	2.174	5.810	916.841	0.709	0.369	3.705	2.780	1.219	1.367
65000.0	0.115	1.786	5.793	914.508	0.728	0.390	3.661	2.803	1.217	1.470
67500.0	0.109	1.458	5.764	912.129	0.744	0.410	3.622	2.820	1.214	1.572
70000.0	0.103	1.185	5.724	909.710	0.758	0.428	3.587	2.832	1.210	1.674

**Table C.42 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.309	40.975	0.000	958.716	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.309	40.856	0.024	958.652	0.000	0.000	0.020	0.000	0.000	0.000
500.0	0.307	40.383	0.118	958.391	0.002	0.000	0.219	0.002	0.000	0.000
1000.0	0.305	39.803	0.233	958.066	0.004	0.000	0.484	0.008	0.000	0.000
1500.0	0.303	39.233	0.346	957.742	0.007	0.000	0.736	0.018	0.002	0.000
2000.0	0.301	38.673	0.456	957.418	0.010	0.000	0.976	0.032	0.004	0.000
2500.0	0.298	38.122	0.564	957.095	0.014	0.000	1.203	0.049	0.007	0.000
3000.0	0.296	37.580	0.671	956.772	0.017	0.001	1.419	0.068	0.012	0.000
3500.0	0.294	37.047	0.775	956.450	0.021	0.001	1.624	0.089	0.017	0.000
4000.0	0.292	36.522	0.877	956.128	0.025	0.001	1.820	0.112	0.024	0.001
4500.0	0.290	36.004	0.978	955.807	0.029	0.001	2.006	0.137	0.033	0.001
5000.0	0.288	35.493	1.077	955.486	0.033	0.002	2.182	0.163	0.043	0.001
5500.0	0.286	34.990	1.174	955.166	0.038	0.002	2.351	0.190	0.053	0.002
6000.0	0.284	34.493	1.269	954.847	0.043	0.003	2.511	0.218	0.065	0.003
6500.0	0.282	34.003	1.363	954.528	0.048	0.003	2.663	0.247	0.078	0.003
7000.0	0.280	33.519	1.455	954.210	0.053	0.004	2.808	0.278	0.092	0.004
7500.0	0.278	33.041	1.546	953.892	0.058	0.004	2.946	0.308	0.107	0.006
8000.0	0.277	32.569	1.635	953.575	0.064	0.005	3.077	0.340	0.123	0.007
8500.0	0.275	32.103	1.723	953.259	0.069	0.006	3.202	0.372	0.139	0.008
9000.0	0.273	31.642	1.809	952.944	0.075	0.007	3.320	0.405	0.156	0.010
9500.0	0.271	31.186	1.894	952.630	0.081	0.008	3.432	0.438	0.173	0.012
10000.0	0.269	30.735	1.978	952.316	0.087	0.008	3.538	0.472	0.191	0.014
10500.0	0.267	30.289	2.060	952.003	0.092	0.009	3.639	0.506	0.210	0.016
11000.0	0.266	29.847	2.141	951.691	0.098	0.010	3.735	0.540	0.228	0.018
11500.0	0.264	29.410	2.221	951.379	0.105	0.012	3.826	0.575	0.247	0.021
12000.0	0.262	28.978	2.300	951.067	0.111	0.013	3.912	0.609	0.267	0.024
12500.0	0.260	28.550	2.378	950.756	0.117	0.014	3.995	0.644	0.286	0.027
13000.0	0.259	28.126	2.454	950.444	0.123	0.015	4.073	0.680	0.306	0.030
13500.0	0.257	27.707	2.530	950.133	0.130	0.017	4.148	0.715	0.326	0.033
14000.0	0.255	27.292	2.604	949.821	0.136	0.018	4.219	0.750	0.346	0.037
14500.0	0.253	26.881	2.677	949.508	0.143	0.020	4.287	0.786	0.367	0.040
15000.0	0.252	26.474	2.750	949.195	0.150	0.021	4.352	0.821	0.387	0.044
15500.0	0.250	26.071	2.821	948.881	0.156	0.023	4.414	0.857	0.408	0.049
16000.0	0.248	25.673	2.891	948.566	0.163	0.025	4.473	0.893	0.429	0.053
16500.0	0.247	25.278	2.961	948.249	0.170	0.026	4.530	0.928	0.450	0.058
17000.0	0.245	24.888	3.029	947.932	0.177	0.028	4.585	0.964	0.471	0.062
17500.0	0.243	24.501	3.096	947.613	0.184	0.030	4.637	0.999	0.492	0.068
18000.0	0.242	24.119	3.162	947.293	0.192	0.032	4.687	1.035	0.513	0.073
20000.0	0.235	22.628	3.418	946.000	0.221	0.041	4.867	1.176	0.598	0.096
22500.0	0.227	20.853	3.717	944.352	0.259	0.054	5.051	1.349	0.704	0.130
25000.0	0.219	19.172	3.994	942.670	0.298	0.070	5.195	1.519	0.807	0.170
27500.0	0.211	17.582	4.249	940.951	0.338	0.087	5.304	1.683	0.905	0.215
30000.0	0.203	16.081	4.483	939.197	0.377	0.107	5.384	1.842	0.998	0.265
32500.0	0.195	14.667	4.696	937.404	0.417	0.129	5.438	1.995	1.085	0.320
35000.0	0.188	13.338	4.889	935.574	0.457	0.153	5.471	2.140	1.166	0.379
37500.0	0.180	12.092	5.062	933.704	0.496	0.179	5.485	2.277	1.239	0.443
40000.0	0.173	10.928	5.216	931.795	0.535	0.207	5.484	2.407	1.306	0.511
42500.0	0.166	9.844	5.351	929.845	0.573	0.236	5.471	2.528	1.366	0.582
45000.0	0.159	8.838	5.468	927.855	0.609	0.267	5.447	2.640	1.419	0.657
47500.0	0.153	7.907	5.568	925.824	0.645	0.299	5.415	2.743	1.466	0.735
50000.0	0.146	7.050	5.650	923.753	0.678	0.332	5.377	2.838	1.507	0.816
52500.0	0.140	6.264	5.717	921.641	0.711	0.365	5.335	2.924	1.541	0.899
55000.0	0.134	5.546	5.768	919.490	0.741	0.399	5.290	3.001	1.571	0.984
57500.0	0.128	4.893	5.805	917.300	0.769	0.433	5.243	3.071	1.595	1.071
60000.0	0.122	4.303	5.827	915.073	0.796	0.466	5.196	3.132	1.615	1.159
62500.0	0.117	3.772	5.837	912.810	0.820	0.499	5.149	3.186	1.631	1.249
65000.0	0.112	3.296	5.835	910.513	0.842	0.531	5.103	3.232	1.644	1.339
67500.0	0.107	2.872	5.822	908.185	0.862	0.561	5.059	3.273	1.653	1.430
70000.0	0.102	2.495	5.799	905.826	0.880	0.591	5.016	3.307	1.660	1.521

**Table C.43 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.339	44.888	0.000	954.773	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.338	44.768	0.023	954.721	0.000	0.000	0.019	0.000	0.000	0.000
500.0	0.337	44.290	0.113	954.510	0.002	0.000	0.189	0.001	0.000	0.000
1000.0	0.335	43.700	0.224	954.245	0.003	0.000	0.409	0.006	0.000	0.000
1500.0	0.333	43.118	0.333	953.979	0.005	0.000	0.620	0.014	0.001	0.000
2000.0	0.331	42.544	0.441	953.714	0.008	0.000	0.821	0.025	0.002	0.000
2500.0	0.329	41.978	0.547	953.448	0.010	0.000	1.013	0.039	0.004	0.000
3000.0	0.327	41.419	0.651	953.181	0.013	0.000	1.197	0.054	0.007	0.000
3500.0	0.325	40.867	0.754	952.915	0.016	0.000	1.373	0.072	0.011	0.000
4000.0	0.324	40.321	0.856	952.648	0.019	0.001	1.541	0.091	0.016	0.000
4500.0	0.322	39.781	0.956	952.382	0.022	0.001	1.702	0.112	0.021	0.001
5000.0	0.320	39.248	1.054	952.114	0.026	0.001	1.855	0.134	0.028	0.001
5500.0	0.318	38.721	1.152	951.847	0.029	0.001	2.002	0.157	0.035	0.001
6000.0	0.316	38.200	1.247	951.580	0.033	0.002	2.143	0.181	0.044	0.002
6500.0	0.315	37.684	1.342	951.312	0.037	0.002	2.277	0.206	0.053	0.002
7000.0	0.313	37.173	1.435	951.044	0.041	0.002	2.406	0.233	0.063	0.003
7500.0	0.311	36.668	1.527	950.776	0.045	0.003	2.529	0.259	0.074	0.004
8000.0	0.309	36.168	1.618	950.508	0.050	0.003	2.646	0.287	0.086	0.005
8500.0	0.307	35.673	1.708	950.239	0.054	0.004	2.758	0.315	0.099	0.006
9000.0	0.306	35.183	1.797	949.971	0.059	0.004	2.865	0.343	0.112	0.007
9500.0	0.304	34.698	1.884	949.702	0.063	0.005	2.967	0.373	0.125	0.008
10000.0	0.302	34.217	1.970	949.434	0.068	0.005	3.064	0.402	0.140	0.010
10500.0	0.300	33.741	2.055	949.165	0.073	0.006	3.157	0.432	0.155	0.011
11000.0	0.299	33.270	2.139	948.896	0.078	0.007	3.245	0.462	0.170	0.013
11500.0	0.297	32.802	2.222	948.628	0.083	0.008	3.329	0.493	0.186	0.015
12000.0	0.295	32.339	2.304	948.359	0.088	0.008	3.408	0.524	0.202	0.017
12500.0	0.294	31.880	2.385	948.090	0.094	0.009	3.484	0.555	0.218	0.020
13000.0	0.292	31.425	2.465	947.821	0.099	0.010	3.556	0.587	0.235	0.022
13500.0	0.290	30.974	2.544	947.552	0.105	0.011	3.625	0.618	0.252	0.025
14000.0	0.289	30.527	2.622	947.283	0.110	0.012	3.690	0.650	0.269	0.028
14500.0	0.287	30.084	2.699	947.014	0.116	0.013	3.751	0.682	0.286	0.031
15000.0	0.285	29.645	2.775	946.744	0.122	0.014	3.809	0.714	0.304	0.034
15500.0	0.284	29.209	2.850	946.475	0.128	0.015	3.864	0.746	0.322	0.038
16000.0	0.282	28.776	2.924	946.205	0.133	0.017	3.916	0.778	0.340	0.041
16500.0	0.280	28.348	2.997	945.935	0.139	0.018	3.966	0.810	0.357	0.045
17000.0	0.279	27.922	3.069	945.665	0.145	0.019	4.012	0.842	0.375	0.049
17500.0	0.277	27.500	3.141	945.395	0.151	0.021	4.056	0.875	0.393	0.054
18000.0	0.276	27.082	3.212	945.124	0.157	0.022	4.097	0.907	0.411	0.058
18500.0	0.274	26.667	3.282	944.852	0.164	0.024	4.136	0.939	0.429	0.063
19000.0	0.272	26.256	3.351	944.580	0.170	0.025	4.173	0.971	0.447	0.068
19500.0	0.271	25.847	3.419	944.307	0.176	0.027	4.208	1.003	0.465	0.073
20000.0	0.269	25.443	3.486	944.033	0.182	0.028	4.240	1.035	0.483	0.078
20500.0	0.267	25.042	3.553	943.758	0.189	0.030	4.271	1.067	0.501	0.084
21000.0	0.266	24.644	3.618	943.481	0.195	0.032	4.301	1.098	0.519	0.089
21500.0	0.264	24.249	3.683	943.204	0.202	0.034	4.328	1.130	0.537	0.095
22000.0	0.263	23.858	3.747	942.925	0.208	0.036	4.354	1.161	0.555	0.101
22500.0	0.261	23.471	3.811	942.645	0.215	0.038	4.379	1.193	0.573	0.108
23000.0	0.260	23.087	3.873	942.364	0.222	0.040	4.402	1.224	0.591	0.114
23500.0	0.258	22.706	3.935	942.082	0.228	0.042	4.424	1.255	0.609	0.121
25000.0	0.253	21.585	4.115	941.225	0.249	0.049	4.481	1.346	0.661	0.143
27500.0	0.245	19.785	4.400	939.768	0.284	0.062	4.552	1.495	0.747	0.184
30000.0	0.237	18.070	4.664	938.273	0.320	0.077	4.597	1.638	0.828	0.230
32500.0	0.230	16.440	4.909	936.738	0.357	0.093	4.619	1.774	0.904	0.282
35000.0	0.222	14.895	5.134	935.161	0.394	0.112	4.620	1.904	0.973	0.339
37500.0	0.214	13.435	5.340	933.540	0.431	0.132	4.605	2.027	1.036	0.402
40000.0	0.207	12.061	5.527	931.873	0.468	0.154	4.577	2.142	1.091	0.469
42500.0	0.199	10.772	5.694	930.158	0.505	0.178	4.537	2.249	1.140	0.542
45000.0	0.192	9.569	5.842	928.393	0.542	0.203	4.488	2.348	1.181	0.619
47500.0	0.184	8.452	5.971	926.576	0.577	0.229	4.433	2.438	1.216	0.700
50000.0	0.177	7.421	6.081	924.706	0.611	0.256	4.373	2.519	1.245	0.785
52500.0	0.170	6.476	6.173	922.781	0.644	0.284	4.310	2.591	1.268	0.874
55000.0	0.163	5.615	6.247	920.800	0.676	0.312	4.247	2.655	1.285	0.965
57500.0	0.156	4.836	6.302	918.763	0.706	0.340	4.183	2.711	1.297	1.059
60000.0	0.149	4.139	6.341	916.670	0.733	0.368	4.121	2.758	1.305	1.155
62500.0	0.142	3.519	6.364	914.523	0.759	0.395	4.061	2.797	1.309	1.253
65000.0	0.136	2.973	6.372	912.323	0.783	0.420	4.005	2.830	1.310	1.351
67500.0	0.129	2.496	6.365	910.072	0.804	0.445	3.952	2.855	1.309	1.450
70000.0	0.123	2.084	6.346	907.774	0.823	0.468	3.904	2.875	1.305	1.549

**Table C.44 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.339	44.888	0.000	954.773	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.338	44.768	0.024	954.714	0.000	0.000	0.021	0.000	0.000	0.000
500.0	0.336	44.292	0.117	954.474	0.002	0.000	0.213	0.002	0.000	0.000
1000.0	0.334	43.705	0.233	954.173	0.004	0.000	0.462	0.007	0.000	0.000
1500.0	0.332	43.128	0.346	953.871	0.007	0.000	0.699	0.016	0.001	0.000
2000.0	0.330	42.559	0.457	953.570	0.009	0.000	0.926	0.029	0.003	0.000
2500.0	0.328	41.999	0.566	953.268	0.012	0.000	1.142	0.043	0.006	0.000
3000.0	0.326	41.447	0.674	952.966	0.016	0.000	1.349	0.061	0.009	0.000
3500.0	0.324	40.902	0.779	952.664	0.019	0.001	1.547	0.080	0.014	0.000
4000.0	0.322	40.365	0.884	952.362	0.023	0.001	1.737	0.101	0.020	0.000
4500.0	0.320	39.834	0.986	952.060	0.027	0.001	1.918	0.123	0.027	0.001
5000.0	0.318	39.310	1.087	951.758	0.031	0.001	2.092	0.147	0.035	0.001
5500.0	0.316	38.793	1.186	951.455	0.035	0.002	2.259	0.172	0.044	0.002
6000.0	0.314	38.282	1.284	951.152	0.039	0.002	2.418	0.197	0.055	0.002
6500.0	0.312	37.778	1.380	950.849	0.044	0.003	2.571	0.224	0.066	0.003
7000.0	0.310	37.279	1.475	950.546	0.049	0.003	2.717	0.252	0.078	0.004
7500.0	0.308	36.786	1.569	950.243	0.054	0.004	2.857	0.280	0.092	0.005
8000.0	0.306	36.298	1.661	949.940	0.059	0.004	2.991	0.310	0.106	0.006
8500.0	0.304	35.816	1.752	949.636	0.064	0.005	3.120	0.339	0.120	0.007
9000.0	0.302	35.339	1.841	949.333	0.070	0.006	3.242	0.370	0.136	0.008
9500.0	0.300	34.867	1.930	949.030	0.075	0.006	3.360	0.400	0.152	0.010
10000.0	0.298	34.401	2.017	948.726	0.081	0.007	3.472	0.432	0.169	0.011
10500.0	0.296	33.939	2.102	948.423	0.087	0.008	3.580	0.463	0.186	0.013
11000.0	0.294	33.482	2.187	948.120	0.093	0.009	3.682	0.495	0.204	0.015
11500.0	0.292	33.029	2.270	947.816	0.099	0.010	3.780	0.527	0.222	0.018
12000.0	0.291	32.582	2.352	947.513	0.105	0.011	3.874	0.560	0.241	0.020
12500.0	0.289	32.138	2.433	947.209	0.111	0.012	3.964	0.593	0.260	0.023
13000.0	0.287	31.699	2.513	946.906	0.118	0.013	4.049	0.626	0.279	0.026
13500.0	0.285	31.264	2.592	946.602	0.124	0.015	4.131	0.659	0.299	0.029
14000.0	0.283	30.833	2.670	946.298	0.131	0.016	4.209	0.692	0.319	0.032
14500.0	0.281	30.407	2.747	945.994	0.137	0.017	4.283	0.726	0.339	0.035
15000.0	0.280	29.984	2.823	945.690	0.144	0.019	4.354	0.759	0.359	0.039
15500.0	0.278	29.566	2.897	945.385	0.151	0.020	4.421	0.793	0.380	0.043
16000.0	0.276	29.151	2.971	945.081	0.158	0.022	4.485	0.827	0.400	0.047
16500.0	0.274	28.740	3.044	944.776	0.165	0.024	4.546	0.861	0.421	0.051
17000.0	0.273	28.332	3.116	944.472	0.171	0.025	4.604	0.895	0.441	0.055
17500.0	0.271	27.929	3.187	944.166	0.178	0.027	4.659	0.929	0.462	0.060
18000.0	0.269	27.529	3.257	943.861	0.185	0.029	4.712	0.963	0.482	0.065
18500.0	0.267	27.132	3.326	943.555	0.192	0.031	4.761	0.996	0.503	0.070
19000.0	0.266	26.739	3.394	943.249	0.200	0.033	4.809	1.030	0.524	0.075
19500.0	0.264	26.349	3.462	942.942	0.207	0.035	4.854	1.064	0.544	0.081
20000.0	0.262	25.963	3.528	942.635	0.214	0.037	4.897	1.098	0.565	0.086
20500.0	0.261	25.581	3.594	942.326	0.221	0.039	4.937	1.131	0.585	0.092
21000.0	0.259	25.202	3.658	942.017	0.229	0.042	4.976	1.165	0.606	0.098
21500.0	0.257	24.826	3.722	941.707	0.236	0.044	5.013	1.198	0.626	0.104
22000.0	0.255	24.454	3.785	941.395	0.244	0.047	5.048	1.231	0.646	0.111
22500.0	0.254	24.086	3.847	941.083	0.251	0.049	5.082	1.264	0.667	0.118
23000.0	0.252	23.721	3.909	940.770	0.259	0.052	5.113	1.297	0.687	0.124
23500.0	0.250	23.359	3.969	940.455	0.266	0.054	5.144	1.330	0.707	0.132
24000.0	0.249	23.000	4.029	940.139	0.274	0.057	5.173	1.363	0.727	0.139
24500.0	0.247	22.646	4.087	939.822	0.282	0.060	5.200	1.395	0.747	0.146
25000.0	0.246	22.294	4.145	939.503	0.289	0.063	5.226	1.427	0.767	0.154
25500.0	0.244	21.946	4.202	939.184	0.297	0.066	5.251	1.459	0.786	0.162
26000.0	0.242	21.601	4.259	938.863	0.305	0.069	5.274	1.491	0.806	0.170
27500.0	0.237	20.587	4.423	937.891	0.329	0.079	5.337	1.585	0.864	0.196
30000.0	0.229	18.965	4.679	936.244	0.369	0.098	5.419	1.737	0.957	0.242
32500.0	0.221	17.424	4.916	934.561	0.410	0.118	5.477	1.882	1.045	0.294
35000.0	0.213	15.966	5.134	932.841	0.451	0.141	5.513	2.021	1.128	0.350
37500.0	0.206	14.587	5.332	931.085	0.491	0.166	5.530	2.153	1.203	0.410
40000.0	0.198	13.287	5.512	929.290	0.531	0.192	5.531	2.278	1.273	0.475
42500.0	0.191	12.065	5.674	927.456	0.571	0.221	5.518	2.395	1.335	0.544
45000.0	0.184	10.920	5.817	925.582	0.610	0.251	5.495	2.505	1.391	0.616
47500.0	0.177	9.849	5.943	923.668	0.647	0.282	5.462	2.607	1.440	0.691
50000.0	0.170	8.853	6.052	921.713	0.684	0.315	5.422	2.700	1.483	0.769
52500.0	0.163	7.929	6.144	919.717	0.719	0.348	5.376	2.786	1.520	0.850
55000.0	0.156	7.076	6.220	917.680	0.752	0.382	5.326	2.864	1.551	0.933
57500.0	0.150	6.292	6.281	915.602	0.784	0.417	5.274	2.934	1.577	1.018
60000.0	0.144	5.575	6.326	913.484	0.814	0.451	5.220	2.996	1.598	1.105
62500.0	0.138	4.921	6.357	911.326	0.842	0.485	5.166	3.052	1.614	1.192
65000.0	0.132	4.329	6.375	909.130	0.868	0.518	5.112	3.100	1.627	1.281
67500.0	0.127	3.794	6.380	906.897	0.892	0.551	5.059	3.142	1.636	1.370
70000.0	0.122	3.315	6.374	904.628	0.913	0.582	5.008	3.178	1.642	1.459

**Table C.45 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.339	44.888	0.000	954.773	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.338	44.769	0.025	954.705	0.000	0.000	0.024	0.000	0.000	0.000
500.0	0.336	44.296	0.123	954.428	0.002	0.000	0.243	0.002	0.000	0.000
1000.0	0.334	43.715	0.243	954.081	0.005	0.000	0.526	0.008	0.000	0.000
1500.0	0.331	43.144	0.361	953.733	0.008	0.000	0.796	0.018	0.002	0.000
2000.0	0.329	42.583	0.477	953.386	0.011	0.000	1.055	0.032	0.004	0.000
2500.0	0.326	42.031	0.591	953.039	0.015	0.000	1.303	0.048	0.007	0.000
3000.0	0.324	41.488	0.702	952.691	0.019	0.001	1.540	0.066	0.012	0.000
3500.0	0.322	40.953	0.812	952.344	0.023	0.001	1.767	0.087	0.018	0.000
4000.0	0.319	40.426	0.919	951.996	0.028	0.001	1.985	0.109	0.025	0.001
4500.0	0.317	39.907	1.025	951.648	0.032	0.002	2.194	0.133	0.034	0.001
5000.0	0.315	39.395	1.129	951.300	0.037	0.002	2.395	0.158	0.044	0.001
5500.0	0.312	38.890	1.232	950.952	0.043	0.003	2.588	0.184	0.055	0.002
6000.0	0.310	38.391	1.332	950.604	0.048	0.003	2.774	0.212	0.068	0.003
6500.0	0.308	37.899	1.431	950.256	0.054	0.004	2.952	0.240	0.081	0.003
7000.0	0.306	37.414	1.529	949.907	0.060	0.004	3.123	0.269	0.096	0.004
7500.0	0.303	36.935	1.625	949.558	0.066	0.005	3.288	0.299	0.111	0.005
8000.0	0.301	36.461	1.719	949.210	0.072	0.006	3.447	0.329	0.128	0.007
8500.0	0.299	35.994	1.812	948.861	0.079	0.007	3.599	0.361	0.145	0.008
9000.0	0.297	35.532	1.903	948.512	0.085	0.008	3.746	0.392	0.163	0.009
9500.0	0.295	35.075	1.993	948.163	0.092	0.009	3.887	0.425	0.181	0.011
10000.0	0.293	34.624	2.082	947.815	0.099	0.010	4.022	0.457	0.201	0.013
10500.0	0.291	34.178	2.169	947.466	0.106	0.011	4.153	0.491	0.220	0.015
11000.0	0.288	33.737	2.255	947.117	0.113	0.013	4.278	0.524	0.241	0.017
11500.0	0.286	33.301	2.340	946.768	0.120	0.014	4.399	0.559	0.261	0.020
12000.0	0.284	32.869	2.423	946.419	0.127	0.015	4.515	0.593	0.282	0.022
12500.0	0.282	32.443	2.506	946.070	0.135	0.017	4.626	0.628	0.304	0.025
13000.0	0.280	32.021	2.587	945.721	0.142	0.019	4.733	0.663	0.325	0.028
13500.0	0.278	31.604	2.666	945.371	0.150	0.020	4.837	0.698	0.347	0.031
14000.0	0.276	31.191	2.745	945.021	0.158	0.022	4.936	0.733	0.370	0.035
14500.0	0.274	30.782	2.823	944.671	0.166	0.024	5.031	0.769	0.392	0.038
15000.0	0.272	30.378	2.899	944.321	0.174	0.026	5.123	0.805	0.415	0.042
15500.0	0.270	29.978	2.974	943.971	0.182	0.028	5.211	0.841	0.438	0.046
16000.0	0.268	29.582	3.049	943.620	0.190	0.030	5.296	0.877	0.460	0.050
16500.0	0.266	29.190	3.122	943.270	0.198	0.033	5.378	0.913	0.483	0.055
17000.0	0.264	28.802	3.194	942.918	0.206	0.035	5.456	0.949	0.506	0.059
17500.0	0.263	28.417	3.265	942.567	0.214	0.037	5.531	0.986	0.530	0.064
18000.0	0.261	28.037	3.335	942.215	0.222	0.040	5.603	1.022	0.553	0.069
18500.0	0.259	27.660	3.404	941.863	0.231	0.043	5.673	1.059	0.576	0.074
19000.0	0.257	27.288	3.472	941.511	0.239	0.045	5.739	1.095	0.599	0.079
19500.0	0.255	26.918	3.539	941.158	0.247	0.048	5.803	1.132	0.622	0.085
20000.0	0.253	26.553	3.605	940.805	0.256	0.051	5.865	1.169	0.645	0.090
20500.0	0.251	26.191	3.670	940.451	0.264	0.054	5.924	1.205	0.668	0.096
21000.0	0.250	25.832	3.735	940.097	0.273	0.057	5.980	1.242	0.691	0.102
21500.0	0.248	25.478	3.798	939.742	0.281	0.061	6.035	1.278	0.714	0.108
22000.0	0.246	25.126	3.860	939.386	0.290	0.064	6.087	1.314	0.736	0.115
22500.0	0.244	24.778	3.922	939.029	0.298	0.067	6.138	1.350	0.759	0.121
23000.0	0.242	24.434	3.983	938.672	0.307	0.071	6.186	1.387	0.782	0.128
23500.0	0.241	24.093	4.042	938.313	0.315	0.074	6.233	1.423	0.804	0.135
24000.0	0.239	23.755	4.101	937.954	0.324	0.078	6.278	1.459	0.827	0.142
24500.0	0.237	23.421	4.159	937.594	0.333	0.082	6.321	1.494	0.849	0.149
25000.0	0.235	23.090	4.216	937.232	0.341	0.086	6.363	1.530	0.871	0.156
25500.0	0.234	22.762	4.273	936.870	0.350	0.090	6.403	1.565	0.893	0.164
26000.0	0.232	22.438	4.328	936.506	0.359	0.094	6.442	1.601	0.915	0.172
26500.0	0.230	22.117	4.383	936.141	0.367	0.098	6.480	1.636	0.937	0.180
27000.0	0.228	21.799	4.437	935.776	0.376	0.103	6.516	1.671	0.959	0.188
27500.0	0.227	21.485	4.490	935.408	0.385	0.107	6.550	1.706	0.981	0.196
28000.0	0.225	21.174	4.542	935.040	0.394	0.111	6.584	1.740	1.002	0.205
28500.0	0.223	20.866	4.593	934.671	0.402	0.116	6.616	1.775	1.024	0.213
29000.0	0.222	20.561	4.643	934.300	0.411	0.121	6.647	1.809	1.045	0.222
29500.0	0.220	20.260	4.693	933.928	0.420	0.126	6.676	1.843	1.066	0.231
30000.0	0.218	19.962	4.742	933.555	0.429	0.131	6.705	1.877	1.087	0.240
30500.0	0.217	19.667	4.790	933.181	0.438	0.136	6.733	1.910	1.108	0.249
31000.0	0.215	19.375	4.837	932.805	0.446	0.141	6.759	1.944	1.128	0.258
32500.0	0.210	18.518	4.974	931.670	0.473	0.157	6.832	2.043	1.189	0.287
35000.0	0.202	17.151	5.187	929.754	0.517	0.186	6.936	2.202	1.287	0.339
37500.0	0.195	15.860	5.381	927.805	0.560	0.217	7.018	2.355	1.380	0.393
40000.0	0.187	14.642	5.556	925.826	0.603	0.250	7.081	2.502	1.468	0.451
42500.0	0.180	13.495	5.714	923.814	0.645	0.285	7.128	2.643	1.549	0.512
45000.0	0.173	12.417	5.854	921.771	0.686	0.323	7.161	2.776	1.625	0.576
47500.0	0.166	11.406	5.977	919.698	0.726	0.362	7.182	2.903	1.696	0.642
50000.0	0.160	10.460	6.085	917.594	0.764	0.402	7.192	3.023	1.760	0.710
52500.0	0.154	9.576	6.176	915.459	0.801	0.444	7.194	3.136	1.820	0.780
55000.0	0.148	8.753	6.254	913.296	0.836	0.486	7.187	3.242	1.874	0.853
57500.0	0.142	7.987	6.317	911.104	0.870	0.530	7.175	3.341	1.924	0.927
60000.0	0.136	7.276	6.366	908.884	0.901	0.573	7.158	3.433	1.968	1.002
62500.0	0.131	6.619	6.403	906.637	0.931	0.617	7.136	3.519	2.008	1.079
65000.0	0.126	6.012	6.429	904.365	0.959	0.661	7.112	3.598	2.044	1.157
67500.0	0.122	5.452	6.442	902.068	0.985	0.704	7.085	3.672	2.077	1.236
70000.0	0.117	4.938	6.446	899.748	1.008	0.747	7.057	3.739	2.105	1.316

**Table C.46 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.342	45.279	0.000	954.379	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.341	45.159	0.022	954.330	0.000	0.000	0.016	0.000	0.000	0.000
500.0	0.340	44.680	0.111	954.131	0.001	0.000	0.173	0.001	0.000	0.000
1000.0	0.338	44.089	0.221	953.882	0.003	0.000	0.380	0.006	0.000	0.000
1500.0	0.336	43.505	0.330	953.633	0.005	0.000	0.579	0.013	0.001	0.000
2000.0	0.335	42.928	0.436	953.384	0.007	0.000	0.768	0.023	0.002	0.000
2500.0	0.333	42.358	0.541	953.135	0.010	0.000	0.950	0.036	0.004	0.000
3000.0	0.331	41.795	0.645	952.886	0.012	0.000	1.123	0.050	0.006	0.000
3500.0	0.329	41.238	0.747	952.636	0.015	0.000	1.288	0.067	0.009	0.000
4000.0	0.327	40.688	0.848	952.387	0.018	0.001	1.447	0.085	0.014	0.000
4500.0	0.326	40.143	0.947	952.137	0.021	0.001	1.598	0.104	0.018	0.001
5000.0	0.324	39.605	1.045	951.887	0.024	0.001	1.743	0.125	0.024	0.001
5500.0	0.322	39.071	1.142	951.637	0.027	0.001	1.881	0.147	0.031	0.001
6000.0	0.320	38.544	1.237	951.387	0.031	0.001	2.013	0.170	0.038	0.001
6500.0	0.319	38.021	1.332	951.137	0.034	0.002	2.139	0.194	0.047	0.002
7000.0	0.317	37.504	1.425	950.887	0.038	0.002	2.259	0.219	0.056	0.003
7500.0	0.315	36.992	1.517	950.637	0.042	0.002	2.374	0.244	0.066	0.003
8000.0	0.314	36.484	1.608	950.387	0.046	0.003	2.483	0.271	0.076	0.004
8500.0	0.312	35.981	1.697	950.137	0.050	0.003	2.587	0.298	0.087	0.005
9000.0	0.310	35.483	1.786	949.888	0.054	0.004	2.686	0.325	0.099	0.006
9500.0	0.309	34.989	1.873	949.638	0.058	0.004	2.781	0.353	0.112	0.007
10000.0	0.307	34.500	1.960	949.389	0.063	0.005	2.870	0.382	0.125	0.009
10500.0	0.305	34.015	2.045	949.139	0.067	0.005	2.956	0.410	0.138	0.010
11000.0	0.304	33.534	2.129	948.890	0.072	0.006	3.037	0.440	0.152	0.012
11500.0	0.302	33.057	2.213	948.641	0.077	0.007	3.113	0.469	0.166	0.013
12000.0	0.300	32.584	2.295	948.391	0.081	0.007	3.186	0.499	0.181	0.015
12500.0	0.299	32.115	2.376	948.142	0.086	0.008	3.255	0.529	0.195	0.017
13000.0	0.297	31.649	2.457	947.893	0.091	0.009	3.321	0.559	0.211	0.020
13500.0	0.296	31.188	2.536	947.644	0.096	0.010	3.382	0.590	0.226	0.022
14000.0	0.294	30.730	2.614	947.395	0.101	0.011	3.441	0.621	0.242	0.025
14500.0	0.292	30.275	2.692	947.146	0.107	0.011	3.496	0.652	0.257	0.028
15000.0	0.291	29.824	2.769	946.897	0.112	0.012	3.548	0.683	0.273	0.031
15500.0	0.289	29.376	2.845	946.649	0.117	0.013	3.596	0.714	0.289	0.034
16000.0	0.288	28.932	2.920	946.400	0.122	0.014	3.642	0.745	0.306	0.037
16500.0	0.286	28.491	2.994	946.151	0.128	0.016	3.686	0.776	0.322	0.041
17000.0	0.284	28.054	3.067	945.901	0.133	0.017	3.726	0.807	0.338	0.044
17500.0	0.283	27.619	3.140	945.651	0.139	0.018	3.765	0.838	0.354	0.048
18000.0	0.281	27.188	3.212	945.400	0.144	0.019	3.801	0.869	0.371	0.052
18500.0	0.280	26.760	3.283	945.149	0.150	0.020	3.835	0.901	0.387	0.057
19000.0	0.278	26.336	3.353	944.896	0.156	0.022	3.867	0.932	0.404	0.061
19500.0	0.277	25.915	3.422	944.643	0.161	0.023	3.897	0.963	0.420	0.066
20000.0	0.275	25.497	3.491	944.389	0.167	0.025	3.925	0.994	0.437	0.071
20500.0	0.274	25.083	3.559	944.133	0.173	0.026	3.952	1.025	0.454	0.076
21000.0	0.272	24.672	3.626	943.876	0.179	0.028	3.977	1.055	0.470	0.081
21500.0	0.270	24.264	3.692	943.618	0.185	0.029	4.001	1.086	0.487	0.087
22000.0	0.269	23.860	3.758	943.359	0.191	0.031	4.023	1.117	0.503	0.092
22500.0	0.267	23.459	3.822	943.099	0.197	0.033	4.043	1.147	0.520	0.098
23000.0	0.266	23.061	3.886	942.837	0.203	0.034	4.063	1.177	0.536	0.104
25000.0	0.260	21.504	4.134	941.774	0.229	0.042	4.127	1.297	0.601	0.131
27500.0	0.252	19.634	4.427	940.412	0.261	0.053	4.182	1.442	0.681	0.170
30000.0	0.244	17.850	4.700	939.010	0.295	0.066	4.210	1.582	0.755	0.215
32500.0	0.236	16.150	4.953	937.566	0.329	0.081	4.217	1.716	0.824	0.265
35000.0	0.229	14.538	5.187	936.077	0.364	0.097	4.205	1.843	0.887	0.321
37500.0	0.221	13.014	5.402	934.540	0.400	0.115	4.178	1.964	0.944	0.383
40000.0	0.213	11.579	5.596	932.952	0.435	0.134	4.138	2.076	0.993	0.450
42500.0	0.205	10.234	5.771	931.310	0.470	0.155	4.088	2.181	1.036	0.523
45000.0	0.197	8.983	5.925	929.610	0.505	0.177	4.031	2.277	1.072	0.601
47500.0	0.190	7.825	6.060	927.850	0.539	0.201	3.968	2.364	1.101	0.684
50000.0	0.182	6.762	6.174	926.027	0.572	0.225	3.903	2.442	1.124	0.771
52500.0	0.174	5.795	6.268	924.139	0.604	0.249	3.835	2.510	1.141	0.863
55000.0	0.167	4.923	6.342	922.184	0.634	0.274	3.769	2.570	1.153	0.959
57500.0	0.159	4.145	6.397	920.161	0.662	0.299	3.704	2.620	1.160	1.057
60000.0	0.152	3.460	6.433	918.071	0.688	0.323	3.642	2.662	1.163	1.158
62500.0	0.144	2.862	6.451	915.915	0.712	0.347	3.585	2.696	1.163	1.261
65000.0	0.137	2.347	6.452	913.696	0.734	0.369	3.532	2.722	1.161	1.365
67500.0	0.130	1.910	6.439	911.418	0.754	0.390	3.484	2.742	1.157	1.470
70000.0	0.124	1.543	6.411	909.086	0.771	0.409	3.441	2.756	1.151	1.575

**Table C.47 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.342	45.279	0.000	954.379	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.341	45.159	0.023	954.323	0.000	0.000	0.018	0.000	0.000	0.000
500.0	0.340	44.682	0.116	954.096	0.002	0.000	0.196	0.001	0.000	0.000
1000.0	0.338	44.093	0.230	953.812	0.004	0.000	0.431	0.007	0.000	0.000
1500.0	0.336	43.513	0.342	953.528	0.006	0.000	0.656	0.015	0.001	0.000
2000.0	0.334	42.941	0.452	953.244	0.009	0.000	0.871	0.026	0.003	0.000
2500.0	0.332	42.377	0.560	952.959	0.011	0.000	1.076	0.040	0.005	0.000
3000.0	0.330	41.821	0.667	952.675	0.015	0.000	1.272	0.056	0.008	0.000
3500.0	0.328	41.271	0.772	952.391	0.018	0.001	1.460	0.075	0.012	0.000
4000.0	0.326	40.729	0.875	952.107	0.021	0.001	1.639	0.094	0.018	0.000
4500.0	0.324	40.193	0.977	951.823	0.025	0.001	1.810	0.116	0.024	0.001
5000.0	0.322	39.663	1.078	951.539	0.029	0.001	1.974	0.138	0.031	0.001
5500.0	0.320	39.140	1.177	951.254	0.033	0.002	2.131	0.162	0.040	0.001
6000.0	0.318	38.622	1.274	950.970	0.037	0.002	2.281	0.187	0.049	0.002
6500.0	0.316	38.111	1.370	950.686	0.041	0.002	2.424	0.212	0.059	0.002
7000.0	0.314	37.605	1.465	950.402	0.045	0.003	2.562	0.239	0.070	0.003
7500.0	0.312	37.104	1.558	950.119	0.050	0.003	2.692	0.266	0.082	0.004
8000.0	0.310	36.609	1.650	949.835	0.055	0.004	2.818	0.294	0.095	0.005
8500.0	0.308	36.119	1.741	949.551	0.060	0.004	2.937	0.323	0.109	0.006
9000.0	0.307	35.633	1.830	949.268	0.065	0.005	3.051	0.352	0.123	0.007
9500.0	0.305	35.153	1.919	948.985	0.070	0.006	3.160	0.382	0.138	0.009
10000.0	0.303	34.678	2.006	948.702	0.075	0.006	3.263	0.412	0.153	0.010
10500.0	0.301	34.207	2.092	948.419	0.081	0.007	3.362	0.443	0.169	0.012
11000.0	0.299	33.740	2.176	948.137	0.086	0.008	3.456	0.474	0.186	0.014
11500.0	0.298	33.278	2.260	947.854	0.092	0.009	3.546	0.505	0.202	0.016
12000.0	0.296	32.820	2.342	947.572	0.097	0.010	3.631	0.536	0.220	0.018
12500.0	0.294	32.367	2.424	947.289	0.103	0.011	3.712	0.568	0.237	0.021
13000.0	0.292	31.917	2.504	947.007	0.109	0.012	3.789	0.600	0.255	0.023
13500.0	0.290	31.472	2.584	946.725	0.115	0.013	3.863	0.632	0.273	0.026
14000.0	0.289	31.031	2.662	946.443	0.121	0.014	3.932	0.665	0.291	0.029
14500.0	0.287	30.593	2.739	946.161	0.127	0.015	3.999	0.697	0.310	0.032
15000.0	0.285	30.159	2.816	945.878	0.133	0.016	4.061	0.730	0.329	0.035
15500.0	0.284	29.729	2.891	945.597	0.140	0.018	4.121	0.763	0.347	0.039
16000.0	0.282	29.302	2.966	945.315	0.146	0.019	4.177	0.796	0.366	0.043
16500.0	0.280	28.879	3.039	945.033	0.152	0.021	4.230	0.829	0.385	0.047
17000.0	0.278	28.460	3.112	944.750	0.158	0.022	4.280	0.862	0.404	0.051
17500.0	0.277	28.043	3.184	944.468	0.165	0.024	4.328	0.895	0.423	0.055
18000.0	0.275	27.631	3.255	944.185	0.171	0.025	4.373	0.927	0.442	0.060
18500.0	0.273	27.222	3.325	943.902	0.178	0.027	4.415	0.960	0.461	0.064
19000.0	0.272	26.816	3.394	943.618	0.184	0.029	4.456	0.993	0.480	0.069
19500.0	0.270	26.413	3.463	943.333	0.191	0.030	4.494	1.026	0.499	0.074
20000.0	0.268	26.014	3.530	943.048	0.198	0.032	4.530	1.059	0.518	0.080
20500.0	0.267	25.619	3.597	942.761	0.204	0.034	4.564	1.091	0.537	0.085
21000.0	0.265	25.226	3.663	942.474	0.211	0.036	4.597	1.124	0.556	0.091
21500.0	0.263	24.838	3.728	942.185	0.218	0.038	4.628	1.156	0.575	0.097
22000.0	0.262	24.452	3.792	941.896	0.225	0.040	4.657	1.188	0.594	0.103
22500.0	0.260	24.070	3.856	941.605	0.232	0.043	4.685	1.220	0.613	0.109
23000.0	0.259	23.692	3.918	941.313	0.239	0.045	4.711	1.252	0.632	0.116
23500.0	0.257	23.316	3.980	941.019	0.246	0.047	4.735	1.284	0.650	0.123
24000.0	0.255	22.945	4.041	940.725	0.253	0.050	4.758	1.315	0.669	0.130
24500.0	0.254	22.576	4.101	940.429	0.261	0.052	4.780	1.347	0.687	0.137
25000.0	0.252	22.211	4.160	940.132	0.268	0.055	4.801	1.378	0.706	0.144
27500.0	0.244	20.436	4.445	938.624	0.305	0.069	4.886	1.531	0.796	0.185
30000.0	0.236	18.745	4.709	937.080	0.343	0.085	4.944	1.678	0.883	0.230
32500.0	0.228	17.137	4.954	935.499	0.382	0.103	4.977	1.819	0.964	0.281
35000.0	0.220	15.612	5.180	933.879	0.420	0.123	4.990	1.954	1.038	0.337
37500.0	0.213	14.169	5.386	932.219	0.459	0.145	4.985	2.082	1.107	0.397
40000.0	0.205	12.808	5.573	930.517	0.497	0.168	4.966	2.202	1.168	0.463
42500.0	0.197	11.529	5.741	928.770	0.535	0.194	4.934	2.315	1.222	0.532
45000.0	0.190	10.332	5.891	926.979	0.572	0.220	4.892	2.419	1.270	0.606
47500.0	0.183	9.216	6.022	925.141	0.609	0.248	4.843	2.516	1.311	0.684
50000.0	0.175	8.180	6.135	923.256	0.644	0.277	4.787	2.603	1.345	0.765
52500.0	0.168	7.224	6.231	921.322	0.677	0.307	4.728	2.683	1.373	0.849
55000.0	0.161	6.347	6.309	919.338	0.709	0.337	4.666	2.753	1.396	0.936
57500.0	0.154	5.547	6.370	917.305	0.740	0.368	4.603	2.816	1.413	1.026
60000.0	0.148	4.822	6.415	915.223	0.768	0.398	4.540	2.870	1.426	1.117
62500.0	0.141	4.170	6.444	913.092	0.795	0.427	4.479	2.917	1.434	1.210
65000.0	0.135	3.587	6.458	910.914	0.819	0.456	4.420	2.956	1.439	1.304
67500.0	0.129	3.070	6.458	908.691	0.842	0.484	4.363	2.988	1.441	1.398
70000.0	0.123	2.615	6.446	906.424	0.862	0.510	4.310	3.015	1.441	1.493

**Table C.48 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure Mwd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.342	45.279	0.000	954.379	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.341	45.160	0.024	954.313	0.000	0.000	0.021	0.000	0.000	0.000
500.0	0.339	44.686	0.122	954.049	0.002	0.000	0.226	0.002	0.000	0.000
1000.0	0.337	44.102	0.241	953.719	0.005	0.000	0.496	0.007	0.000	0.000
1500.0	0.335	43.528	0.358	953.388	0.008	0.000	0.755	0.017	0.001	0.000
2000.0	0.332	42.963	0.473	953.058	0.011	0.000	1.002	0.030	0.003	0.000
2500.0	0.330	42.407	0.586	952.728	0.014	0.000	1.239	0.045	0.007	0.000
3000.0	0.328	41.860	0.697	952.398	0.018	0.001	1.465	0.063	0.011	0.000
3500.0	0.325	41.320	0.806	952.068	0.022	0.001	1.682	0.082	0.016	0.000
4000.0	0.323	40.788	0.913	951.738	0.026	0.001	1.889	0.104	0.023	0.001
4500.0	0.321	40.263	1.019	951.408	0.031	0.001	2.088	0.127	0.031	0.001
5000.0	0.319	39.745	1.122	951.078	0.035	0.002	2.279	0.151	0.040	0.001
5500.0	0.316	39.234	1.224	950.748	0.040	0.002	2.462	0.176	0.051	0.002
6000.0	0.314	38.729	1.325	950.418	0.045	0.003	2.638	0.202	0.063	0.002
6500.0	0.312	38.230	1.424	950.089	0.051	0.003	2.806	0.230	0.075	0.003
7000.0	0.310	37.738	1.521	949.759	0.056	0.004	2.968	0.258	0.089	0.004
7500.0	0.308	37.252	1.617	949.430	0.062	0.005	3.122	0.287	0.103	0.005
8000.0	0.306	36.771	1.711	949.101	0.068	0.005	3.271	0.317	0.119	0.006
8500.0	0.303	36.296	1.804	948.772	0.074	0.006	3.414	0.347	0.135	0.007
9000.0	0.301	35.826	1.895	948.443	0.080	0.007	3.550	0.378	0.152	0.009
9500.0	0.299	35.361	1.985	948.115	0.087	0.008	3.681	0.409	0.169	0.010
10000.0	0.297	34.902	2.074	947.786	0.093	0.009	3.807	0.441	0.187	0.012
10500.0	0.295	34.448	2.161	947.458	0.100	0.010	3.927	0.474	0.206	0.014
11000.0	0.293	33.998	2.248	947.130	0.106	0.011	4.043	0.506	0.225	0.016
11500.0	0.291	33.553	2.333	946.802	0.113	0.013	4.153	0.539	0.245	0.018
12000.0	0.289	33.113	2.416	946.475	0.120	0.014	4.259	0.573	0.265	0.021
12500.0	0.287	32.678	2.499	946.147	0.127	0.015	4.361	0.607	0.285	0.023
13000.0	0.285	32.246	2.580	945.819	0.134	0.017	4.458	0.641	0.306	0.026
13500.0	0.283	31.820	2.661	945.491	0.141	0.018	4.551	0.675	0.326	0.029
14000.0	0.281	31.397	2.740	945.163	0.149	0.020	4.641	0.710	0.348	0.033
14500.0	0.279	30.979	2.818	944.835	0.156	0.022	4.726	0.744	0.369	0.036
15000.0	0.277	30.564	2.895	944.507	0.163	0.023	4.808	0.779	0.390	0.040
15500.0	0.276	30.154	2.970	944.179	0.171	0.025	4.886	0.815	0.412	0.043
16000.0	0.274	29.748	3.045	943.851	0.178	0.027	4.961	0.850	0.434	0.047
16500.0	0.272	29.345	3.119	943.523	0.186	0.029	5.033	0.885	0.455	0.051
17000.0	0.270	28.946	3.192	943.195	0.194	0.031	5.101	0.921	0.477	0.056
17500.0	0.268	28.552	3.263	942.867	0.201	0.034	5.166	0.956	0.499	0.060
18000.0	0.266	28.160	3.334	942.538	0.209	0.036	5.228	0.992	0.521	0.065
18500.0	0.264	27.773	3.404	942.210	0.217	0.038	5.288	1.027	0.543	0.070
19000.0	0.263	27.388	3.473	941.881	0.225	0.041	5.345	1.063	0.565	0.075
19500.0	0.261	27.008	3.541	941.551	0.233	0.043	5.399	1.098	0.586	0.080
20000.0	0.259	26.631	3.608	941.221	0.241	0.046	5.451	1.134	0.608	0.086
20500.0	0.257	26.257	3.674	940.891	0.249	0.048	5.501	1.169	0.630	0.091
21000.0	0.255	25.887	3.739	940.559	0.257	0.051	5.548	1.205	0.651	0.097
21500.0	0.254	25.521	3.803	940.228	0.265	0.054	5.594	1.240	0.673	0.103
22000.0	0.252	25.157	3.867	939.895	0.273	0.057	5.637	1.276	0.695	0.109
22500.0	0.250	24.797	3.929	939.561	0.281	0.060	5.679	1.311	0.716	0.116
23000.0	0.248	24.441	3.991	939.227	0.289	0.063	5.719	1.346	0.738	0.122
23500.0	0.247	24.088	4.052	938.891	0.297	0.066	5.757	1.381	0.759	0.129
24000.0	0.245	23.738	4.112	938.554	0.305	0.070	5.793	1.415	0.780	0.136
24500.0	0.243	23.392	4.171	938.216	0.314	0.073	5.828	1.450	0.801	0.143
25000.0	0.241	23.049	4.229	937.878	0.322	0.077	5.862	1.485	0.822	0.151
25500.0	0.240	22.710	4.287	937.537	0.330	0.080	5.894	1.519	0.843	0.158
26000.0	0.238	22.373	4.343	937.196	0.338	0.084	5.925	1.553	0.864	0.166
26500.0	0.236	22.040	4.399	936.854	0.347	0.088	5.954	1.587	0.885	0.174
27000.0	0.235	21.711	4.454	936.510	0.355	0.091	5.982	1.621	0.905	0.182
27500.0	0.233	21.384	4.508	936.165	0.363	0.095	6.009	1.655	0.926	0.190
28000.0	0.231	21.061	4.562	935.819	0.372	0.099	6.034	1.688	0.946	0.198
28500.0	0.230	20.741	4.614	935.471	0.380	0.104	6.059	1.721	0.966	0.207
29000.0	0.228	20.425	4.666	935.123	0.388	0.108	6.082	1.754	0.986	0.216
30000.0	0.225	19.801	4.767	934.421	0.405	0.117	6.125	1.820	1.026	0.233
32500.0	0.217	18.298	5.005	932.644	0.447	0.140	6.216	1.979	1.122	0.281
35000.0	0.209	16.873	5.224	930.833	0.490	0.166	6.284	2.132	1.213	0.333
37500.0	0.201	15.526	5.424	928.989	0.532	0.194	6.331	2.278	1.299	0.389
40000.0	0.193	14.254	5.605	927.111	0.573	0.224	6.360	2.418	1.378	0.448
42500.0	0.186	13.056	5.768	925.198	0.614	0.256	6.374	2.551	1.452	0.511
45000.0	0.179	11.930	5.913	923.251	0.654	0.290	6.375	2.677	1.519	0.577
47500.0	0.172	10.875	6.040	921.269	0.693	0.325	6.364	2.796	1.580	0.646
50000.0	0.165	9.889	6.151	919.252	0.731	0.362	6.345	2.907	1.636	0.717
52500.0	0.158	8.971	6.246	917.201	0.767	0.400	6.318	3.010	1.685	0.791
55000.0	0.152	8.117	6.325	915.115	0.802	0.438	6.285	3.106	1.729	0.867
57500.0	0.146	7.326	6.389	912.995	0.834	0.477	6.247	3.194	1.768	0.945
60000.0	0.140	6.596	6.439	910.843	0.865	0.517	6.205	3.275	1.802	1.025
62500.0	0.134	5.925	6.475	908.658	0.894	0.556	6.161	3.348	1.831	1.106
65000.0	0.129	5.309	6.499	906.442	0.921	0.595	6.116	3.415	1.856	1.189
67500.0	0.124	4.746	6.510	904.196	0.946	0.633	6.070	3.475	1.877	1.273
70000.0	0.119	4.233	6.510	901.922	0.969	0.671	6.023	3.529	1.895	1.357

**Table C.49 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.341	45.159	0.000	954.501	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.340	45.038	0.022	954.452	0.000	0.000	0.016	0.000	0.000	0.000
500.0	0.339	44.559	0.111	954.257	0.001	0.000	0.170	0.001	0.000	0.000
1000.0	0.337	43.968	0.220	954.012	0.003	0.000	0.375	0.006	0.000	0.000
1500.0	0.335	43.384	0.328	953.766	0.005	0.000	0.570	0.013	0.001	0.000
2000.0	0.334	42.807	0.434	953.521	0.007	0.000	0.757	0.023	0.002	0.000
2500.0	0.332	42.237	0.539	953.275	0.010	0.000	0.935	0.035	0.004	0.000
3000.0	0.330	41.674	0.642	953.029	0.012	0.000	1.106	0.050	0.006	0.000
3500.0	0.328	41.117	0.744	952.783	0.015	0.000	1.269	0.066	0.009	0.000
4000.0	0.327	40.566	0.844	952.537	0.018	0.001	1.425	0.084	0.013	0.000
4500.0	0.325	40.021	0.943	952.290	0.021	0.001	1.574	0.103	0.018	0.001
5000.0	0.323	39.482	1.041	952.044	0.024	0.001	1.716	0.124	0.024	0.001
5500.0	0.322	38.948	1.137	951.797	0.027	0.001	1.852	0.146	0.030	0.001
6000.0	0.320	38.420	1.233	951.551	0.030	0.001	1.982	0.169	0.038	0.001
6500.0	0.318	37.897	1.327	951.304	0.034	0.002	2.106	0.193	0.046	0.002
7000.0	0.316	37.379	1.419	951.057	0.038	0.002	2.224	0.217	0.055	0.003
7500.0	0.315	36.866	1.511	950.810	0.041	0.002	2.337	0.243	0.064	0.003
8000.0	0.313	36.358	1.602	950.563	0.045	0.003	2.445	0.269	0.075	0.004
8500.0	0.311	35.854	1.691	950.316	0.049	0.003	2.547	0.295	0.086	0.005
9000.0	0.310	35.355	1.779	950.070	0.053	0.004	2.645	0.323	0.097	0.006
9500.0	0.308	34.861	1.867	949.823	0.058	0.004	2.737	0.351	0.109	0.007
10000.0	0.306	34.371	1.953	949.576	0.062	0.005	2.826	0.379	0.122	0.009
10500.0	0.305	33.885	2.038	949.330	0.066	0.005	2.909	0.408	0.135	0.010
11000.0	0.303	33.403	2.122	949.083	0.071	0.006	2.989	0.437	0.149	0.012
11500.0	0.302	32.925	2.205	948.836	0.075	0.007	3.064	0.466	0.162	0.013
12000.0	0.300	32.452	2.287	948.590	0.080	0.007	3.136	0.496	0.177	0.015
12500.0	0.298	31.982	2.369	948.343	0.085	0.008	3.204	0.526	0.191	0.017
13000.0	0.297	31.516	2.449	948.096	0.090	0.009	3.268	0.556	0.206	0.020
13500.0	0.295	31.054	2.528	947.849	0.095	0.009	3.329	0.586	0.221	0.022
14000.0	0.294	30.595	2.606	947.602	0.100	0.010	3.387	0.617	0.237	0.025
14500.0	0.292	30.140	2.684	947.356	0.105	0.011	3.441	0.648	0.252	0.028
15000.0	0.290	29.688	2.761	947.109	0.110	0.012	3.492	0.679	0.268	0.031
15500.0	0.289	29.240	2.836	946.862	0.115	0.013	3.540	0.709	0.284	0.034
16000.0	0.287	28.795	2.911	946.615	0.121	0.014	3.585	0.741	0.300	0.037
16500.0	0.286	28.353	2.985	946.368	0.126	0.015	3.627	0.772	0.316	0.041
17000.0	0.284	27.915	3.059	946.121	0.131	0.016	3.667	0.803	0.332	0.044
17500.0	0.283	27.480	3.131	945.873	0.137	0.018	3.704	0.834	0.348	0.048
18000.0	0.281	27.048	3.203	945.626	0.142	0.019	3.739	0.865	0.364	0.052
18500.0	0.280	26.619	3.274	945.377	0.148	0.020	3.771	0.896	0.380	0.057
19000.0	0.278	26.194	3.344	945.128	0.153	0.021	3.802	0.927	0.396	0.061
19500.0	0.276	25.772	3.413	944.878	0.159	0.023	3.831	0.958	0.412	0.066
20000.0	0.275	25.353	3.482	944.627	0.165	0.024	3.858	0.989	0.428	0.071
20500.0	0.273	24.937	3.550	944.375	0.171	0.026	3.883	1.020	0.444	0.076
21000.0	0.272	24.525	3.617	944.121	0.176	0.027	3.907	1.051	0.460	0.081
21500.0	0.270	24.116	3.683	943.866	0.182	0.029	3.929	1.081	0.477	0.087
22000.0	0.269	23.710	3.749	943.610	0.188	0.030	3.949	1.112	0.493	0.092
22500.0	0.267	23.308	3.813	943.353	0.194	0.032	3.969	1.142	0.509	0.098
25000.0	0.260	21.347	4.125	942.044	0.225	0.041	4.047	1.291	0.589	0.131
27500.0	0.252	19.470	4.418	940.696	0.257	0.052	4.096	1.435	0.666	0.170
30000.0	0.244	17.679	4.692	939.309	0.290	0.065	4.121	1.575	0.739	0.215
32500.0	0.236	15.974	4.946	937.878	0.324	0.079	4.124	1.708	0.806	0.265
35000.0	0.229	14.356	5.180	936.400	0.358	0.095	4.109	1.835	0.867	0.321
37500.0	0.221	12.827	5.395	934.874	0.393	0.112	4.079	1.955	0.922	0.383
40000.0	0.213	11.388	5.589	933.295	0.428	0.131	4.036	2.067	0.969	0.451
42500.0	0.205	10.042	5.764	931.660	0.462	0.151	3.985	2.170	1.010	0.524
45000.0	0.197	8.789	5.918	929.967	0.497	0.173	3.926	2.265	1.045	0.603
47500.0	0.190	7.632	6.052	928.210	0.530	0.196	3.863	2.351	1.072	0.686
50000.0	0.182	6.572	6.166	926.389	0.562	0.219	3.796	2.428	1.094	0.774
52500.0	0.174	5.610	6.259	924.500	0.593	0.243	3.729	2.495	1.110	0.867
55000.0	0.166	4.745	6.332	922.542	0.623	0.267	3.663	2.554	1.120	0.963
57500.0	0.159	3.976	6.386	920.514	0.651	0.291	3.599	2.603	1.127	1.063
60000.0	0.151	3.300	6.420	918.416	0.676	0.315	3.538	2.643	1.129	1.165
62500.0	0.144	2.714	6.436	916.251	0.700	0.337	3.482	2.676	1.129	1.270
65000.0	0.137	2.213	6.436	914.022	0.721	0.358	3.431	2.701	1.126	1.375
67500.0	0.130	1.789	6.421	911.733	0.740	0.378	3.384	2.720	1.122	1.481
70000.0	0.123	1.436	6.392	909.388	0.757	0.397	3.344	2.733	1.116	1.586

**Table C.50 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.341	45.159	0.000	954.501	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.340	45.039	0.023	954.445	0.000	0.000	0.018	0.000	0.000	0.000
500.0	0.339	44.561	0.115	954.221	0.002	0.000	0.194	0.001	0.000	0.000
1000.0	0.337	43.973	0.229	953.940	0.004	0.000	0.426	0.006	0.000	0.000
1500.0	0.335	43.393	0.340	953.659	0.006	0.000	0.648	0.015	0.001	0.000
2000.0	0.333	42.821	0.450	953.378	0.009	0.000	0.861	0.026	0.002	0.000
2500.0	0.331	42.257	0.558	953.097	0.011	0.000	1.063	0.040	0.005	0.000
3000.0	0.329	41.700	0.664	952.816	0.014	0.000	1.257	0.056	0.008	0.000
3500.0	0.327	41.150	0.769	952.535	0.018	0.001	1.442	0.074	0.012	0.000
4000.0	0.325	40.608	0.872	952.254	0.021	0.001	1.619	0.094	0.017	0.000
4500.0	0.323	40.072	0.973	951.973	0.025	0.001	1.788	0.115	0.023	0.001
5000.0	0.321	39.542	1.073	951.691	0.028	0.001	1.950	0.137	0.031	0.001
5500.0	0.319	39.018	1.172	951.410	0.032	0.002	2.105	0.161	0.039	0.001
6000.0	0.317	38.500	1.269	951.129	0.036	0.002	2.253	0.186	0.048	0.002
6500.0	0.315	37.988	1.365	950.848	0.041	0.002	2.394	0.211	0.058	0.002
7000.0	0.313	37.482	1.459	950.567	0.045	0.003	2.530	0.238	0.069	0.003
7500.0	0.312	36.981	1.552	950.286	0.050	0.003	2.659	0.265	0.081	0.004
8000.0	0.310	36.485	1.644	950.005	0.054	0.004	2.782	0.293	0.094	0.005
8500.0	0.308	35.994	1.735	949.724	0.059	0.004	2.900	0.321	0.107	0.006
9000.0	0.306	35.509	1.824	949.443	0.064	0.005	3.012	0.350	0.121	0.007
9500.0	0.304	35.028	1.912	949.163	0.069	0.006	3.119	0.380	0.136	0.009
10000.0	0.302	34.552	1.999	948.883	0.074	0.006	3.221	0.410	0.151	0.010
10500.0	0.301	34.081	2.084	948.602	0.080	0.007	3.319	0.441	0.167	0.012
11000.0	0.299	33.614	2.169	948.322	0.085	0.008	3.411	0.471	0.183	0.014
11500.0	0.297	33.151	2.252	948.042	0.091	0.009	3.499	0.502	0.199	0.016
12000.0	0.295	32.693	2.335	947.762	0.096	0.010	3.583	0.534	0.216	0.018
12500.0	0.294	32.239	2.416	947.482	0.102	0.011	3.663	0.565	0.234	0.021
13000.0	0.292	31.789	2.496	947.202	0.108	0.012	3.739	0.597	0.251	0.023
13500.0	0.290	31.343	2.575	946.922	0.114	0.013	3.812	0.629	0.269	0.026
14000.0	0.288	30.901	2.653	946.642	0.120	0.014	3.880	0.662	0.287	0.029
14500.0	0.287	30.463	2.731	946.362	0.126	0.015	3.946	0.694	0.306	0.032
15000.0	0.285	30.029	2.807	946.081	0.132	0.016	4.007	0.727	0.324	0.036
15500.0	0.283	29.598	2.882	945.801	0.138	0.018	4.066	0.759	0.343	0.039
16000.0	0.281	29.171	2.957	945.521	0.144	0.019	4.121	0.792	0.361	0.043
16500.0	0.280	28.748	3.030	945.241	0.151	0.020	4.173	0.825	0.380	0.047
17000.0	0.278	28.328	3.103	944.961	0.157	0.022	4.222	0.858	0.399	0.051
17500.0	0.276	27.912	3.174	944.680	0.163	0.023	4.269	0.891	0.417	0.055
18000.0	0.275	27.498	3.245	944.400	0.170	0.025	4.312	0.923	0.436	0.060
18500.0	0.273	27.089	3.315	944.119	0.176	0.027	4.354	0.956	0.455	0.065
19000.0	0.271	26.682	3.384	943.837	0.182	0.028	4.393	0.989	0.473	0.069
19500.0	0.270	26.279	3.453	943.556	0.189	0.030	4.429	1.022	0.492	0.075
20000.0	0.268	25.880	3.520	943.273	0.196	0.032	4.464	1.054	0.511	0.080
20500.0	0.266	25.483	3.587	942.990	0.202	0.034	4.497	1.087	0.529	0.085
21000.0	0.265	25.090	3.653	942.705	0.209	0.036	4.528	1.119	0.548	0.091
21500.0	0.263	24.701	3.718	942.420	0.216	0.038	4.557	1.152	0.566	0.097
22000.0	0.262	24.314	3.782	942.133	0.223	0.040	4.584	1.184	0.585	0.103
22500.0	0.260	23.932	3.845	941.846	0.229	0.042	4.610	1.216	0.603	0.110
23000.0	0.258	23.552	3.908	941.557	0.236	0.044	4.635	1.248	0.622	0.116
23500.0	0.257	23.176	3.969	941.267	0.243	0.047	4.658	1.279	0.640	0.123
24000.0	0.255	22.803	4.030	940.975	0.250	0.049	4.679	1.311	0.658	0.130
24500.0	0.254	22.434	4.090	940.683	0.258	0.051	4.700	1.342	0.676	0.137
25000.0	0.252	22.068	4.150	940.389	0.265	0.054	4.719	1.373	0.694	0.145
27500.0	0.244	20.288	4.434	938.896	0.301	0.068	4.797	1.525	0.783	0.185
30000.0	0.236	18.592	4.699	937.367	0.339	0.083	4.849	1.671	0.867	0.231
32500.0	0.228	16.979	4.944	935.800	0.377	0.101	4.877	1.812	0.946	0.282
35000.0	0.220	15.449	5.169	934.193	0.415	0.121	4.885	1.945	1.019	0.338
37500.0	0.213	14.002	5.375	932.545	0.453	0.142	4.875	2.072	1.085	0.399
40000.0	0.205	12.638	5.562	930.854	0.491	0.165	4.852	2.191	1.145	0.464
42500.0	0.197	11.356	5.731	929.118	0.528	0.190	4.817	2.302	1.197	0.534
45000.0	0.190	10.157	5.880	927.336	0.565	0.216	4.772	2.406	1.243	0.609
47500.0	0.183	9.040	6.012	925.506	0.601	0.243	4.720	2.500	1.282	0.687
50000.0	0.175	8.004	6.125	923.627	0.635	0.272	4.662	2.586	1.314	0.769
52500.0	0.168	7.050	6.219	921.698	0.668	0.301	4.601	2.664	1.341	0.854
55000.0	0.161	6.176	6.297	919.718	0.700	0.330	4.538	2.733	1.362	0.942
57500.0	0.154	5.380	6.357	917.687	0.730	0.359	4.474	2.793	1.378	1.032
60000.0	0.148	4.660	6.401	915.605	0.758	0.389	4.410	2.846	1.389	1.124
62500.0	0.141	4.014	6.429	913.473	0.784	0.417	4.348	2.890	1.396	1.218
65000.0	0.135	3.439	6.442	911.293	0.808	0.445	4.289	2.928	1.399	1.313
67500.0	0.129	2.930	6.441	909.066	0.830	0.471	4.233	2.959	1.400	1.409
70000.0	0.123	2.484	6.428	906.794	0.850	0.497	4.181	2.983	1.399	1.504

**Table C.51 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.341	45.159	0.000	954.501	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.340	45.039	0.024	954.435	0.000	0.000	0.021	0.000	0.000	0.000
500.0	0.338	44.565	0.121	954.173	0.002	0.000	0.225	0.002	0.000	0.000
1000.0	0.336	43.982	0.240	953.844	0.005	0.000	0.494	0.007	0.000	0.000
1500.0	0.334	43.408	0.357	953.515	0.008	0.000	0.751	0.017	0.001	0.000
2000.0	0.331	42.844	0.472	953.186	0.011	0.000	0.997	0.030	0.003	0.000
2500.0	0.329	42.288	0.584	952.857	0.014	0.000	1.232	0.045	0.007	0.000
3000.0	0.327	41.741	0.695	952.529	0.018	0.001	1.456	0.063	0.011	0.000
3500.0	0.325	41.201	0.804	952.200	0.022	0.001	1.672	0.082	0.016	0.000
4000.0	0.322	40.669	0.911	951.872	0.026	0.001	1.878	0.104	0.023	0.001
4500.0	0.320	40.145	1.016	951.543	0.031	0.001	2.076	0.126	0.031	0.001
5000.0	0.318	39.627	1.119	951.215	0.035	0.002	2.265	0.151	0.040	0.001
5500.0	0.316	39.116	1.221	950.886	0.040	0.002	2.447	0.176	0.051	0.002
6000.0	0.313	38.611	1.321	950.558	0.045	0.003	2.621	0.202	0.062	0.002
6500.0	0.311	38.113	1.420	950.230	0.051	0.003	2.789	0.229	0.075	0.003
7000.0	0.309	37.621	1.517	949.901	0.056	0.004	2.949	0.258	0.088	0.004
7500.0	0.307	37.135	1.612	949.573	0.062	0.005	3.103	0.287	0.103	0.005
8000.0	0.305	36.654	1.706	949.246	0.068	0.005	3.250	0.316	0.118	0.006
8500.0	0.303	36.179	1.799	948.918	0.074	0.006	3.392	0.346	0.134	0.007
9000.0	0.301	35.710	1.890	948.590	0.080	0.007	3.527	0.377	0.151	0.009
9500.0	0.299	35.245	1.980	948.263	0.086	0.008	3.657	0.409	0.168	0.010
10000.0	0.297	34.786	2.068	947.936	0.093	0.009	3.782	0.441	0.186	0.012
10500.0	0.295	34.332	2.155	947.609	0.099	0.010	3.901	0.473	0.205	0.014
11000.0	0.293	33.883	2.241	947.282	0.106	0.011	4.016	0.506	0.224	0.016
11500.0	0.291	33.438	2.326	946.955	0.113	0.013	4.125	0.539	0.243	0.018
12000.0	0.289	32.998	2.410	946.628	0.120	0.014	4.230	0.572	0.263	0.021
12500.0	0.287	32.563	2.492	946.302	0.127	0.015	4.331	0.606	0.284	0.024
13000.0	0.285	32.132	2.573	945.975	0.134	0.017	4.428	0.640	0.304	0.026
13500.0	0.283	31.705	2.653	945.648	0.141	0.018	4.520	0.674	0.325	0.030
14000.0	0.281	31.283	2.732	945.321	0.148	0.020	4.609	0.708	0.346	0.033
14500.0	0.279	30.865	2.810	944.994	0.155	0.022	4.694	0.743	0.367	0.036
15000.0	0.277	30.451	2.887	944.666	0.163	0.023	4.775	0.778	0.389	0.040
15500.0	0.275	30.041	2.962	944.339	0.170	0.025	4.852	0.813	0.410	0.044
16000.0	0.273	29.635	3.037	944.012	0.178	0.027	4.927	0.848	0.432	0.048
16500.0	0.271	29.233	3.111	943.684	0.186	0.029	4.997	0.883	0.454	0.052
17000.0	0.269	28.834	3.183	943.357	0.193	0.031	5.065	0.919	0.475	0.056
17500.0	0.268	28.440	3.255	943.029	0.201	0.033	5.129	0.954	0.497	0.061
18000.0	0.266	28.049	3.325	942.701	0.209	0.036	5.191	0.990	0.519	0.065
18500.0	0.264	27.662	3.395	942.373	0.216	0.038	5.250	1.025	0.541	0.070
19000.0	0.262	27.278	3.463	942.045	0.224	0.040	5.306	1.061	0.562	0.076
19500.0	0.260	26.898	3.531	941.717	0.232	0.043	5.359	1.096	0.584	0.081
20000.0	0.258	26.521	3.598	941.388	0.240	0.046	5.410	1.132	0.606	0.086
20500.0	0.257	26.148	3.664	941.058	0.248	0.048	5.458	1.167	0.627	0.092
21000.0	0.255	25.779	3.729	940.728	0.256	0.051	5.505	1.203	0.649	0.098
21500.0	0.253	25.412	3.793	940.398	0.264	0.054	5.549	1.238	0.670	0.104
22000.0	0.251	25.049	3.856	940.067	0.272	0.057	5.591	1.273	0.691	0.110
22500.0	0.250	24.690	3.919	939.735	0.280	0.060	5.631	1.308	0.713	0.117
23000.0	0.248	24.333	3.980	939.402	0.288	0.063	5.669	1.343	0.734	0.123
23500.0	0.246	23.981	4.041	939.068	0.296	0.066	5.706	1.378	0.755	0.130
24000.0	0.244	23.631	4.100	938.733	0.304	0.069	5.741	1.413	0.776	0.137
24500.0	0.243	23.285	4.159	938.397	0.312	0.073	5.775	1.448	0.797	0.144
25000.0	0.241	22.942	4.218	938.061	0.321	0.076	5.806	1.482	0.818	0.152
25500.0	0.239	22.602	4.275	937.723	0.329	0.080	5.837	1.516	0.838	0.159
26000.0	0.238	22.266	4.331	937.383	0.337	0.083	5.866	1.550	0.859	0.167
26500.0	0.236	21.933	4.387	937.043	0.345	0.087	5.894	1.584	0.879	0.175
27000.0	0.234	21.604	4.442	936.701	0.354	0.091	5.921	1.618	0.900	0.183
27500.0	0.233	21.277	4.496	936.358	0.362	0.095	5.946	1.652	0.920	0.191
28000.0	0.231	20.954	4.549	936.014	0.370	0.099	5.970	1.685	0.940	0.200
28500.0	0.229	20.634	4.601	935.669	0.378	0.103	5.993	1.718	0.960	0.208
30000.0	0.224	19.694	4.754	934.624	0.403	0.116	6.056	1.816	1.018	0.235
32500.0	0.216	18.190	4.992	932.857	0.445	0.139	6.140	1.974	1.113	0.283
35000.0	0.208	16.765	5.210	931.056	0.487	0.165	6.201	2.126	1.203	0.335
37500.0	0.201	15.417	5.410	929.221	0.529	0.192	6.243	2.271	1.287	0.391
40000.0	0.193	14.145	5.591	927.352	0.570	0.222	6.267	2.410	1.366	0.451
42500.0	0.186	12.947	5.753	925.448	0.611	0.254	6.276	2.542	1.438	0.514
45000.0	0.178	11.821	5.898	923.509	0.651	0.287	6.273	2.666	1.503	0.581
47500.0	0.172	10.766	6.025	921.534	0.689	0.322	6.259	2.783	1.563	0.650
50000.0	0.165	9.781	6.135	919.524	0.727	0.358	6.236	2.892	1.617	0.722
52500.0	0.158	8.863	6.230	917.479	0.763	0.396	6.205	2.993	1.665	0.796
55000.0	0.152	8.011	6.308	915.400	0.797	0.434	6.169	3.087	1.707	0.873
57500.0	0.146	7.221	6.372	913.286	0.829	0.472	6.129	3.174	1.745	0.951
60000.0	0.140	6.493	6.421	911.138	0.860	0.511	6.085	3.253	1.777	1.031
62500.0	0.134	5.824	6.457	908.958	0.889	0.549	6.039	3.324	1.805	1.113
65000.0	0.129	5.210	6.480	906.746	0.915	0.587	5.991	3.389	1.828	1.196
67500.0	0.124	4.650	6.491	904.503	0.940	0.625	5.943	3.447	1.848	1.281
70000.0	0.119	4.141	6.491	902.231	0.962	0.662	5.896	3.498	1.864	1.366

**Table C.52 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.338	44.776	0.000	954.886	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.338	44.655	0.022	954.839	0.000	0.000	0.014	0.000	0.000	0.000
500.0	0.336	44.176	0.110	954.649	0.001	0.000	0.163	0.001	0.000	0.000
1000.0	0.335	43.583	0.218	954.410	0.003	0.000	0.362	0.005	0.000	0.000
1500.0	0.333	42.999	0.325	954.172	0.005	0.000	0.553	0.013	0.001	0.000
2000.0	0.331	42.421	0.431	953.933	0.007	0.000	0.735	0.022	0.002	0.000
2500.0	0.330	41.849	0.535	953.694	0.009	0.000	0.909	0.035	0.003	0.000
3000.0	0.328	41.285	0.637	953.455	0.012	0.000	1.075	0.049	0.006	0.000
3500.0	0.326	40.726	0.738	953.216	0.014	0.000	1.234	0.065	0.009	0.000
4000.0	0.324	40.174	0.838	952.976	0.017	0.001	1.386	0.082	0.012	0.000
4500.0	0.323	39.627	0.936	952.737	0.020	0.001	1.530	0.101	0.017	0.000
5000.0	0.321	39.086	1.033	952.497	0.023	0.001	1.669	0.122	0.023	0.001
5500.0	0.319	38.551	1.129	952.258	0.026	0.001	1.801	0.143	0.029	0.001
6000.0	0.318	38.021	1.224	952.018	0.029	0.001	1.927	0.166	0.036	0.001
6500.0	0.316	37.496	1.317	951.779	0.032	0.002	2.047	0.189	0.044	0.002
7000.0	0.315	36.976	1.410	951.539	0.036	0.002	2.161	0.214	0.052	0.002
7500.0	0.313	36.460	1.501	951.300	0.040	0.002	2.270	0.239	0.061	0.003
8000.0	0.311	35.950	1.591	951.060	0.043	0.003	2.374	0.265	0.071	0.004
8500.0	0.310	35.444	1.680	950.821	0.047	0.003	2.473	0.291	0.082	0.005
9000.0	0.308	34.942	1.768	950.581	0.051	0.003	2.567	0.318	0.093	0.006
9500.0	0.306	34.445	1.855	950.342	0.055	0.004	2.656	0.346	0.105	0.007
10000.0	0.305	33.952	1.941	950.103	0.059	0.004	2.740	0.374	0.117	0.008
10500.0	0.303	33.464	2.025	949.865	0.063	0.005	2.820	0.402	0.129	0.010
11000.0	0.302	32.979	2.109	949.626	0.068	0.005	2.896	0.431	0.142	0.011
11500.0	0.300	32.498	2.192	949.387	0.072	0.006	2.968	0.461	0.156	0.013
12000.0	0.299	32.021	2.274	949.149	0.076	0.007	3.036	0.490	0.170	0.015
12500.0	0.297	31.548	2.355	948.911	0.081	0.007	3.100	0.520	0.184	0.017
13000.0	0.295	31.079	2.435	948.672	0.086	0.008	3.160	0.550	0.198	0.019
13500.0	0.294	30.613	2.514	948.434	0.090	0.009	3.218	0.580	0.212	0.021
14000.0	0.292	30.151	2.592	948.196	0.095	0.010	3.271	0.610	0.227	0.024
14500.0	0.291	29.692	2.670	947.958	0.100	0.010	3.322	0.641	0.242	0.027
15000.0	0.289	29.236	2.746	947.720	0.105	0.011	3.369	0.671	0.257	0.029
15500.0	0.288	28.784	2.822	947.482	0.110	0.012	3.413	0.702	0.272	0.033
16000.0	0.286	28.335	2.897	947.245	0.115	0.013	3.454	0.733	0.287	0.036
16500.0	0.285	27.889	2.971	947.007	0.120	0.014	3.493	0.764	0.303	0.039
17000.0	0.283	27.446	3.044	946.769	0.125	0.015	3.529	0.795	0.318	0.043
17500.0	0.282	27.007	3.117	946.530	0.130	0.016	3.563	0.826	0.333	0.047
18000.0	0.280	26.571	3.188	946.291	0.135	0.017	3.595	0.856	0.349	0.051
18500.0	0.279	26.138	3.259	946.051	0.141	0.018	3.624	0.887	0.364	0.055
19000.0	0.277	25.708	3.330	945.811	0.146	0.020	3.652	0.918	0.380	0.059
19500.0	0.276	25.281	3.399	945.569	0.151	0.021	3.678	0.949	0.395	0.064
20000.0	0.274	24.858	3.468	945.326	0.157	0.022	3.702	0.979	0.411	0.069
20500.0	0.273	24.438	3.536	945.082	0.162	0.024	3.725	1.010	0.427	0.074
21000.0	0.271	24.021	3.603	944.837	0.168	0.025	3.746	1.040	0.442	0.079
21500.0	0.270	23.607	3.669	944.590	0.173	0.026	3.766	1.071	0.458	0.084
22000.0	0.268	23.197	3.735	944.342	0.179	0.028	3.784	1.101	0.473	0.090
22500.0	0.267	22.790	3.800	944.093	0.185	0.030	3.801	1.131	0.489	0.096
25000.0	0.259	20.806	4.113	942.824	0.214	0.038	3.868	1.278	0.566	0.128
27500.0	0.251	18.907	4.407	941.515	0.245	0.048	3.907	1.421	0.640	0.167
30000.0	0.244	17.094	4.682	940.164	0.276	0.060	3.922	1.559	0.709	0.211
32500.0	0.236	15.369	4.937	938.767	0.309	0.073	3.917	1.691	0.774	0.262
35000.0	0.228	13.733	5.172	937.322	0.342	0.088	3.894	1.816	0.832	0.318
37500.0	0.221	12.188	5.388	935.823	0.376	0.104	3.858	1.934	0.883	0.381
40000.0	0.213	10.738	5.583	934.268	0.410	0.122	3.811	2.044	0.927	0.450
42500.0	0.205	9.384	5.757	932.652	0.443	0.141	3.755	2.146	0.965	0.525
45000.0	0.197	8.130	5.911	930.971	0.476	0.161	3.694	2.238	0.996	0.605
47500.0	0.189	6.978	6.043	929.221	0.509	0.182	3.628	2.321	1.020	0.691
50000.0	0.181	5.930	6.153	927.398	0.540	0.204	3.561	2.395	1.038	0.782
52500.0	0.173	4.986	6.242	925.499	0.570	0.227	3.495	2.458	1.051	0.878
55000.0	0.165	4.148	6.310	923.524	0.599	0.249	3.431	2.513	1.059	0.978
57500.0	0.157	3.413	6.357	921.471	0.625	0.272	3.370	2.558	1.063	1.082
60000.0	0.149	2.778	6.384	919.342	0.650	0.293	3.313	2.594	1.064	1.188
62500.0	0.142	2.237	6.393	917.139	0.672	0.314	3.262	2.623	1.062	1.296
65000.0	0.134	1.784	6.384	914.868	0.692	0.333	3.216	2.644	1.058	1.406
67500.0	0.127	1.410	6.361	912.534	0.710	0.351	3.176	2.659	1.053	1.515
70000.0	0.120	1.106	6.324	910.144	0.725	0.367	3.142	2.669	1.047	1.624

**Table C.53 [Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.338	44.776	0.000	954.886	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.338	44.655	0.023	954.832	0.000	0.000	0.017	0.000	0.000	0.000
500.0	0.336	44.177	0.114	954.613	0.002	0.000	0.186	0.001	0.000	0.000
1000.0	0.334	43.588	0.227	954.339	0.004	0.000	0.413	0.006	0.000	0.000
1500.0	0.332	43.007	0.338	954.065	0.006	0.000	0.631	0.014	0.001	0.000
2000.0	0.330	42.434	0.446	953.791	0.008	0.000	0.839	0.026	0.002	0.000
2500.0	0.328	41.868	0.554	953.517	0.011	0.000	1.037	0.039	0.004	0.000
3000.0	0.327	41.310	0.659	953.243	0.014	0.000	1.226	0.055	0.008	0.000
3500.0	0.325	40.759	0.763	952.969	0.017	0.001	1.407	0.073	0.011	0.000
4000.0	0.323	40.214	0.865	952.695	0.020	0.001	1.579	0.092	0.016	0.000
4500.0	0.321	39.676	0.966	952.421	0.024	0.001	1.744	0.113	0.022	0.001
5000.0	0.319	39.145	1.065	952.148	0.027	0.001	1.902	0.135	0.029	0.001
5500.0	0.317	38.619	1.163	951.874	0.031	0.001	2.052	0.159	0.037	0.001
6000.0	0.315	38.099	1.260	951.600	0.035	0.002	2.196	0.183	0.046	0.002
6500.0	0.313	37.585	1.355	951.327	0.039	0.002	2.333	0.209	0.056	0.002
7000.0	0.312	37.076	1.449	951.053	0.043	0.003	2.464	0.235	0.067	0.003
7500.0	0.310	36.573	1.541	950.780	0.047	0.003	2.589	0.262	0.078	0.004
8000.0	0.308	36.075	1.633	950.507	0.052	0.003	2.708	0.290	0.090	0.005
8500.0	0.306	35.582	1.723	950.234	0.056	0.004	2.822	0.318	0.103	0.006
9000.0	0.304	35.094	1.811	949.961	0.061	0.005	2.930	0.347	0.117	0.007
9500.0	0.303	34.611	1.899	949.689	0.066	0.005	3.033	0.376	0.131	0.008
10000.0	0.301	34.132	1.985	949.417	0.071	0.006	3.130	0.406	0.146	0.010
10500.0	0.299	33.658	2.071	949.145	0.076	0.007	3.223	0.437	0.161	0.012
11000.0	0.297	33.188	2.155	948.873	0.081	0.007	3.311	0.467	0.177	0.013
11500.0	0.296	32.723	2.238	948.602	0.087	0.008	3.395	0.498	0.193	0.015
12000.0	0.294	32.262	2.320	948.331	0.092	0.009	3.475	0.529	0.209	0.018
12500.0	0.292	31.804	2.400	948.060	0.098	0.010	3.550	0.561	0.226	0.020
13000.0	0.290	31.351	2.480	947.789	0.103	0.011	3.622	0.593	0.243	0.023
13500.0	0.289	30.902	2.559	947.518	0.109	0.012	3.690	0.625	0.261	0.025
14000.0	0.287	30.457	2.637	947.247	0.115	0.013	3.754	0.657	0.278	0.028
14500.0	0.285	30.015	2.714	946.976	0.120	0.014	3.814	0.689	0.296	0.031
15000.0	0.284	29.577	2.790	946.706	0.126	0.015	3.871	0.721	0.314	0.035
15500.0	0.282	29.143	2.865	946.435	0.132	0.016	3.925	0.754	0.332	0.038
16000.0	0.280	28.712	2.939	946.165	0.138	0.018	3.975	0.786	0.350	0.042
16500.0	0.279	28.285	3.013	945.895	0.144	0.019	4.023	0.819	0.368	0.046
17000.0	0.277	27.861	3.085	945.625	0.150	0.020	4.068	0.851	0.386	0.050
17500.0	0.276	27.440	3.157	945.355	0.156	0.022	4.110	0.884	0.404	0.054
18000.0	0.274	27.023	3.228	945.084	0.162	0.023	4.149	0.917	0.422	0.059
18500.0	0.272	26.609	3.298	944.813	0.168	0.025	4.186	0.949	0.440	0.063
19000.0	0.271	26.198	3.367	944.542	0.174	0.026	4.221	0.982	0.458	0.068
19500.0	0.269	25.791	3.435	944.270	0.180	0.028	4.253	1.014	0.476	0.073
20000.0	0.268	25.387	3.502	943.997	0.187	0.030	4.284	1.046	0.494	0.078
20500.0	0.266	24.986	3.569	943.723	0.193	0.031	4.313	1.078	0.512	0.084
21000.0	0.264	24.588	3.635	943.448	0.199	0.033	4.340	1.110	0.530	0.090
21500.0	0.263	24.194	3.700	943.172	0.206	0.035	4.366	1.142	0.548	0.096
22000.0	0.261	23.804	3.764	942.895	0.212	0.037	4.390	1.174	0.566	0.102
22500.0	0.260	23.416	3.828	942.616	0.219	0.039	4.413	1.206	0.584	0.108
23000.0	0.258	23.032	3.890	942.337	0.226	0.041	4.434	1.237	0.602	0.115
23500.0	0.256	22.652	3.952	942.056	0.232	0.043	4.453	1.268	0.619	0.121
24000.0	0.255	22.274	4.013	941.773	0.239	0.045	4.472	1.299	0.637	0.128
25000.0	0.252	21.530	4.133	941.204	0.253	0.050	4.505	1.361	0.672	0.143
27500.0	0.244	19.728	4.418	939.756	0.288	0.063	4.568	1.511	0.758	0.183
30000.0	0.236	18.010	4.683	938.270	0.324	0.077	4.606	1.655	0.839	0.229
32500.0	0.228	16.377	4.929	936.744	0.361	0.094	4.621	1.792	0.914	0.281
35000.0	0.220	14.829	5.155	935.176	0.398	0.112	4.617	1.923	0.983	0.338
37500.0	0.213	13.365	5.362	933.565	0.435	0.132	4.597	2.047	1.045	0.400
40000.0	0.205	11.986	5.549	931.907	0.472	0.154	4.563	2.162	1.100	0.467
42500.0	0.197	10.694	5.717	930.201	0.508	0.177	4.519	2.270	1.148	0.539
45000.0	0.190	9.487	5.866	928.445	0.544	0.201	4.467	2.369	1.189	0.616
47500.0	0.182	8.367	5.996	926.635	0.578	0.227	4.409	2.459	1.223	0.696
50000.0	0.175	7.333	6.107	924.772	0.612	0.253	4.346	2.540	1.251	0.781
52500.0	0.168	6.386	6.199	922.852	0.644	0.280	4.281	2.613	1.273	0.869
55000.0	0.161	5.525	6.273	920.876	0.675	0.308	4.215	2.676	1.289	0.961
57500.0	0.153	4.747	6.329	918.843	0.704	0.335	4.149	2.731	1.300	1.055
60000.0	0.147	4.051	6.367	916.753	0.731	0.362	4.086	2.777	1.307	1.151
62500.0	0.140	3.434	6.390	914.607	0.756	0.388	4.025	2.816	1.310	1.248
65000.0	0.133	2.892	6.396	912.407	0.778	0.413	3.968	2.847	1.310	1.347
67500.0	0.127	2.420	6.389	910.155	0.799	0.437	3.914	2.872	1.308	1.446
70000.0	0.121	2.013	6.368	907.856	0.817	0.460	3.866	2.890	1.304	1.545

**Table C.54 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.338	44.776	0.000	954.886	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.338	44.656	0.024	954.822	0.000	0.000	0.019	0.000	0.000	0.000
500.0	0.336	44.181	0.120	954.565	0.002	0.000	0.217	0.002	0.000	0.000
1000.0	0.334	43.596	0.239	954.242	0.004	0.000	0.482	0.007	0.000	0.000
1500.0	0.331	43.021	0.355	953.920	0.007	0.000	0.735	0.017	0.001	0.000
2000.0	0.329	42.455	0.469	953.597	0.010	0.000	0.976	0.029	0.003	0.000
2500.0	0.327	41.898	0.580	953.275	0.014	0.000	1.207	0.045	0.006	0.000
3000.0	0.324	41.349	0.690	952.953	0.017	0.001	1.428	0.062	0.010	0.000
3500.0	0.322	40.807	0.798	952.632	0.021	0.001	1.639	0.082	0.016	0.000
4000.0	0.320	40.274	0.905	952.310	0.025	0.001	1.841	0.103	0.022	0.001
4500.0	0.318	39.747	1.009	951.988	0.029	0.001	2.034	0.126	0.030	0.001
5000.0	0.316	39.228	1.112	951.667	0.034	0.002	2.219	0.150	0.039	0.001
5500.0	0.314	38.715	1.213	951.346	0.039	0.002	2.397	0.175	0.049	0.002
6000.0	0.311	38.209	1.313	951.025	0.044	0.003	2.567	0.201	0.061	0.002
6500.0	0.309	37.709	1.410	950.704	0.049	0.003	2.729	0.229	0.073	0.003
7000.0	0.307	37.215	1.507	950.384	0.054	0.004	2.885	0.257	0.087	0.004
7500.0	0.305	36.727	1.602	950.063	0.060	0.004	3.034	0.286	0.101	0.005
8000.0	0.303	36.244	1.695	949.743	0.065	0.005	3.177	0.315	0.116	0.006
8500.0	0.301	35.767	1.787	949.424	0.071	0.006	3.313	0.345	0.132	0.007
9000.0	0.299	35.296	1.878	949.104	0.077	0.007	3.444	0.376	0.148	0.009
9500.0	0.297	34.829	1.967	948.785	0.083	0.008	3.569	0.408	0.166	0.010
10000.0	0.295	34.368	2.055	948.466	0.090	0.009	3.688	0.439	0.183	0.012
10500.0	0.293	33.912	2.142	948.147	0.096	0.010	3.802	0.472	0.202	0.014
11000.0	0.291	33.460	2.227	947.829	0.102	0.011	3.911	0.504	0.221	0.016
11500.0	0.289	33.013	2.312	947.511	0.109	0.012	4.016	0.537	0.240	0.018
12000.0	0.287	32.571	2.395	947.193	0.115	0.013	4.115	0.571	0.259	0.021
12500.0	0.285	32.133	2.477	946.875	0.122	0.014	4.211	0.604	0.279	0.023
13000.0	0.283	31.700	2.557	946.557	0.129	0.016	4.302	0.638	0.300	0.026
13500.0	0.281	31.271	2.637	946.239	0.136	0.017	4.389	0.672	0.320	0.029
14000.0	0.279	30.846	2.715	945.922	0.143	0.019	4.471	0.707	0.341	0.033
14500.0	0.278	30.425	2.793	945.604	0.150	0.020	4.551	0.741	0.362	0.036
15000.0	0.276	30.009	2.869	945.286	0.157	0.022	4.626	0.776	0.383	0.040
15500.0	0.274	29.596	2.944	944.969	0.164	0.024	4.698	0.811	0.404	0.044
16000.0	0.272	29.187	3.018	944.651	0.172	0.026	4.766	0.846	0.425	0.048
16500.0	0.270	28.782	3.092	944.334	0.179	0.027	4.831	0.881	0.447	0.052
17000.0	0.268	28.381	3.164	944.016	0.186	0.029	4.893	0.916	0.468	0.056
17500.0	0.267	27.984	3.235	943.699	0.194	0.031	4.951	0.951	0.490	0.061
18000.0	0.265	27.590	3.305	943.382	0.201	0.034	5.007	0.986	0.511	0.066
18500.0	0.263	27.199	3.375	943.064	0.209	0.036	5.060	1.021	0.532	0.071
19000.0	0.261	26.812	3.443	942.746	0.216	0.038	5.110	1.057	0.553	0.076
19500.0	0.260	26.429	3.510	942.428	0.224	0.040	5.158	1.092	0.575	0.081
20000.0	0.258	26.049	3.577	942.110	0.231	0.043	5.203	1.127	0.596	0.087
20500.0	0.256	25.672	3.642	941.791	0.239	0.045	5.246	1.162	0.617	0.092
21000.0	0.254	25.299	3.707	941.472	0.247	0.048	5.286	1.197	0.638	0.098
21500.0	0.253	24.929	3.771	941.152	0.254	0.050	5.325	1.232	0.659	0.104
22000.0	0.251	24.563	3.834	940.831	0.262	0.053	5.362	1.267	0.680	0.111
22500.0	0.249	24.200	3.896	940.509	0.270	0.056	5.397	1.301	0.700	0.117
23000.0	0.247	23.840	3.958	940.187	0.278	0.059	5.430	1.336	0.721	0.124
23500.0	0.246	23.484	4.018	939.863	0.286	0.062	5.461	1.370	0.742	0.131
24000.0	0.244	23.131	4.078	939.538	0.293	0.065	5.492	1.405	0.762	0.138
24500.0	0.242	22.781	4.137	939.212	0.301	0.068	5.520	1.439	0.783	0.145
25000.0	0.241	22.435	4.195	938.885	0.309	0.071	5.547	1.472	0.803	0.153
25500.0	0.239	22.092	4.252	938.557	0.317	0.075	5.573	1.506	0.823	0.160
26000.0	0.237	21.752	4.308	938.227	0.325	0.078	5.598	1.539	0.843	0.168
26500.0	0.236	21.416	4.364	937.897	0.333	0.082	5.621	1.573	0.863	0.176
27000.0	0.234	21.082	4.419	937.565	0.341	0.085	5.643	1.606	0.883	0.185
27500.0	0.232	20.753	4.472	937.231	0.349	0.089	5.664	1.639	0.902	0.193
30000.0	0.224	19.152	4.730	935.544	0.390	0.109	5.753	1.799	0.999	0.238
32500.0	0.216	17.633	4.968	933.822	0.431	0.130	5.816	1.953	1.091	0.287
35000.0	0.208	16.193	5.186	932.066	0.472	0.154	5.858	2.100	1.177	0.341
37500.0	0.201	14.831	5.385	930.274	0.512	0.180	5.881	2.241	1.256	0.399
40000.0	0.193	13.547	5.565	928.446	0.553	0.209	5.888	2.374	1.330	0.461
42500.0	0.186	12.338	5.726	926.581	0.592	0.238	5.880	2.500	1.397	0.526
45000.0	0.179	11.205	5.869	924.679	0.631	0.270	5.862	2.618	1.457	0.595
47500.0	0.171	10.144	5.995	922.738	0.669	0.303	5.833	2.728	1.511	0.667
50000.0	0.165	9.156	6.104	920.760	0.706	0.337	5.797	2.831	1.559	0.742
52500.0	0.158	8.238	6.196	918.743	0.741	0.372	5.754	2.925	1.601	0.819
55000.0	0.152	7.388	6.272	916.688	0.775	0.408	5.707	3.011	1.637	0.899
57500.0	0.145	6.605	6.332	914.595	0.806	0.444	5.657	3.089	1.668	0.981
60000.0	0.139	5.886	6.378	912.465	0.836	0.480	5.604	3.160	1.694	1.064
62500.0	0.133	5.228	6.410	910.299	0.864	0.516	5.551	3.223	1.715	1.150
65000.0	0.128	4.630	6.429	908.097	0.890	0.551	5.497	3.278	1.732	1.236
67500.0	0.122	4.087	6.435	905.861	0.914	0.586	5.444	3.327	1.745	1.324
70000.0	0.117	3.598	6.429	903.593	0.935	0.619	5.393	3.370	1.755	1.412

**Table C.55 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.334	44.230	0.000	955.436	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.334	44.109	0.022	955.389	0.000	0.000	0.015	0.000	0.000	0.000
500.0	0.333	43.631	0.110	955.198	0.001	0.000	0.163	0.001	0.000	0.000
1000.0	0.331	43.039	0.218	954.958	0.003	0.000	0.363	0.005	0.000	0.000
1500.0	0.329	42.455	0.325	954.719	0.005	0.000	0.554	0.013	0.001	0.000
2000.0	0.327	41.877	0.430	954.480	0.007	0.000	0.736	0.023	0.002	0.000
2500.0	0.326	41.307	0.533	954.241	0.009	0.000	0.909	0.035	0.003	0.000
3000.0	0.324	40.743	0.635	954.002	0.012	0.000	1.075	0.049	0.006	0.000
3500.0	0.322	40.186	0.736	953.763	0.014	0.000	1.233	0.065	0.009	0.000
4000.0	0.321	39.634	0.835	953.525	0.017	0.001	1.383	0.083	0.013	0.000
4500.0	0.319	39.088	0.933	953.287	0.020	0.001	1.526	0.102	0.017	0.000
5000.0	0.317	38.548	1.030	953.049	0.023	0.001	1.662	0.123	0.023	0.001
5500.0	0.316	38.013	1.125	952.812	0.026	0.001	1.792	0.144	0.029	0.001
6000.0	0.314	37.483	1.220	952.575	0.029	0.001	1.915	0.167	0.036	0.001
6500.0	0.313	36.959	1.312	952.338	0.033	0.002	2.032	0.191	0.044	0.002
7000.0	0.311	36.439	1.404	952.102	0.036	0.002	2.143	0.215	0.052	0.002
7500.0	0.309	35.924	1.495	951.866	0.040	0.002	2.249	0.240	0.061	0.003
8000.0	0.308	35.414	1.584	951.631	0.043	0.003	2.349	0.266	0.071	0.004
8500.0	0.306	34.908	1.673	951.397	0.047	0.003	2.444	0.293	0.081	0.005
9000.0	0.305	34.406	1.760	951.163	0.051	0.003	2.533	0.320	0.092	0.006
9500.0	0.303	33.909	1.847	950.930	0.055	0.004	2.618	0.348	0.104	0.007
10000.0	0.301	33.415	1.932	950.697	0.059	0.004	2.697	0.376	0.115	0.008
10500.0	0.300	32.926	2.016	950.465	0.063	0.005	2.772	0.404	0.128	0.010
11000.0	0.298	32.440	2.099	950.234	0.067	0.005	2.843	0.433	0.140	0.011
11500.0	0.297	31.958	2.182	950.003	0.071	0.006	2.909	0.462	0.153	0.013
12000.0	0.295	31.480	2.263	949.773	0.075	0.007	2.972	0.492	0.166	0.015
12500.0	0.294	31.005	2.343	949.544	0.080	0.007	3.030	0.522	0.180	0.017
13000.0	0.292	30.534	2.423	949.315	0.084	0.008	3.085	0.552	0.193	0.019
13500.0	0.291	30.065	2.502	949.086	0.088	0.009	3.136	0.582	0.207	0.021
14000.0	0.289	29.600	2.580	948.858	0.093	0.009	3.185	0.612	0.221	0.024
14500.0	0.288	29.139	2.657	948.630	0.097	0.010	3.230	0.642	0.235	0.026
15000.0	0.286	28.680	2.733	948.401	0.102	0.011	3.272	0.673	0.249	0.029
15500.0	0.285	28.225	2.808	948.173	0.107	0.012	3.312	0.703	0.264	0.032
16000.0	0.283	27.773	2.883	947.943	0.111	0.013	3.349	0.734	0.278	0.035
16500.0	0.282	27.324	2.957	947.714	0.116	0.014	3.384	0.764	0.293	0.038
17000.0	0.280	26.878	3.030	947.483	0.121	0.015	3.417	0.795	0.307	0.042
17500.0	0.279	26.436	3.103	947.251	0.126	0.016	3.448	0.825	0.322	0.046
18000.0	0.278	25.997	3.174	947.018	0.131	0.017	3.477	0.856	0.337	0.050
18500.0	0.276	25.561	3.245	946.785	0.136	0.018	3.505	0.886	0.352	0.054
19000.0	0.275	25.128	3.315	946.549	0.141	0.019	3.531	0.917	0.367	0.058
19500.0	0.273	24.699	3.384	946.313	0.146	0.020	3.555	0.947	0.382	0.063
20000.0	0.272	24.274	3.453	946.075	0.152	0.021	3.578	0.977	0.398	0.067
22500.0	0.264	22.196	3.785	944.864	0.179	0.028	3.671	1.126	0.474	0.094
25000.0	0.257	20.203	4.097	943.614	0.207	0.037	3.732	1.272	0.549	0.127
27500.0	0.249	18.296	4.391	942.324	0.237	0.046	3.765	1.414	0.620	0.165
30000.0	0.242	16.476	4.665	940.990	0.268	0.057	3.775	1.551	0.687	0.210
32500.0	0.234	14.746	4.919	939.609	0.300	0.070	3.765	1.683	0.748	0.261
35000.0	0.226	13.108	5.154	938.175	0.332	0.084	3.738	1.807	0.803	0.318
37500.0	0.219	11.564	5.368	936.685	0.365	0.100	3.699	1.925	0.852	0.381
40000.0	0.211	10.118	5.561	935.135	0.398	0.117	3.649	2.034	0.893	0.451
42500.0	0.203	8.773	5.733	933.519	0.431	0.136	3.591	2.134	0.928	0.527
45000.0	0.195	7.533	5.883	931.833	0.463	0.155	3.528	2.226	0.956	0.610
47500.0	0.187	6.400	6.011	930.072	0.495	0.176	3.462	2.307	0.978	0.698
50000.0	0.179	5.377	6.117	928.232	0.525	0.197	3.396	2.379	0.994	0.791
52500.0	0.171	4.464	6.200	926.311	0.554	0.219	3.331	2.441	1.005	0.890
55000.0	0.163	3.662	6.261	924.307	0.582	0.240	3.268	2.493	1.011	0.992
57500.0	0.154	2.968	6.302	922.221	0.607	0.261	3.211	2.536	1.014	1.099
60000.0	0.147	2.377	6.321	920.054	0.630	0.282	3.158	2.570	1.013	1.208
62500.0	0.139	1.882	6.323	917.811	0.651	0.301	3.111	2.596	1.011	1.319
65000.0	0.131	1.476	6.307	915.498	0.670	0.319	3.070	2.615	1.007	1.431
67500.0	0.124	1.147	6.277	913.124	0.686	0.335	3.035	2.628	1.002	1.543
70000.0	0.117	0.884	6.235	910.695	0.700	0.350	3.005	2.636	0.997	1.654

**Table C.56 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.334	44.230	0.000	955.436	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.334	44.110	0.023	955.381	0.000	0.000	0.017	0.000	0.000	0.000
500.0	0.332	43.632	0.114	955.159	0.002	0.000	0.188	0.001	0.000	0.000
1000.0	0.330	43.044	0.227	954.882	0.004	0.000	0.418	0.006	0.000	0.000
1500.0	0.328	42.463	0.337	954.605	0.006	0.000	0.637	0.015	0.001	0.000
2000.0	0.326	41.891	0.446	954.329	0.009	0.000	0.846	0.026	0.002	0.000
2500.0	0.325	41.327	0.553	954.053	0.011	0.000	1.045	0.040	0.005	0.000
3000.0	0.323	40.770	0.658	953.777	0.014	0.000	1.235	0.056	0.008	0.000
3500.0	0.321	40.220	0.762	953.502	0.017	0.001	1.415	0.074	0.012	0.000
4000.0	0.319	39.678	0.864	953.227	0.021	0.001	1.588	0.094	0.017	0.000
4500.0	0.317	39.141	0.964	952.953	0.024	0.001	1.751	0.115	0.023	0.001
5000.0	0.315	38.611	1.063	952.680	0.028	0.001	1.908	0.137	0.030	0.001
5500.0	0.313	38.087	1.160	952.407	0.031	0.002	2.056	0.161	0.038	0.001
6000.0	0.311	37.568	1.256	952.134	0.035	0.002	2.197	0.186	0.047	0.002
6500.0	0.310	37.055	1.351	951.862	0.039	0.002	2.332	0.212	0.057	0.002
7000.0	0.308	36.548	1.444	951.591	0.044	0.003	2.460	0.238	0.068	0.003
7500.0	0.306	36.046	1.536	951.321	0.048	0.003	2.581	0.265	0.079	0.004
8000.0	0.304	35.549	1.626	951.051	0.052	0.004	2.696	0.293	0.091	0.005
8500.0	0.303	35.057	1.716	950.782	0.057	0.004	2.805	0.322	0.104	0.006
9000.0	0.301	34.570	1.804	950.514	0.061	0.005	2.909	0.351	0.118	0.007
9500.0	0.299	34.087	1.891	950.247	0.066	0.005	3.006	0.381	0.132	0.009
10000.0	0.297	33.609	1.976	949.981	0.071	0.006	3.099	0.411	0.146	0.010
10500.0	0.296	33.135	2.061	949.715	0.076	0.007	3.186	0.441	0.161	0.012
11000.0	0.294	32.665	2.144	949.451	0.081	0.007	3.269	0.472	0.177	0.014
11500.0	0.292	32.200	2.227	949.187	0.086	0.008	3.346	0.503	0.192	0.016
12000.0	0.291	31.738	2.308	948.923	0.091	0.009	3.420	0.535	0.208	0.018
12500.0	0.289	31.280	2.388	948.661	0.097	0.010	3.489	0.566	0.225	0.020
13000.0	0.287	30.826	2.467	948.399	0.102	0.011	3.554	0.598	0.241	0.023
13500.0	0.286	30.375	2.546	948.137	0.107	0.012	3.615	0.630	0.258	0.025
14000.0	0.284	29.929	2.623	947.875	0.113	0.013	3.673	0.662	0.274	0.028
14500.0	0.282	29.485	2.699	947.614	0.118	0.014	3.727	0.694	0.291	0.031
15000.0	0.281	29.045	2.775	947.353	0.124	0.015	3.779	0.727	0.309	0.035
15500.0	0.279	28.609	2.850	947.092	0.129	0.016	3.827	0.759	0.326	0.038
16000.0	0.278	28.176	2.923	946.831	0.135	0.017	3.872	0.791	0.343	0.042
16500.0	0.276	27.746	2.996	946.569	0.141	0.018	3.915	0.824	0.360	0.046
17000.0	0.274	27.320	3.068	946.307	0.146	0.020	3.955	0.856	0.378	0.050
17500.0	0.273	26.897	3.140	946.044	0.152	0.021	3.993	0.888	0.395	0.054
18000.0	0.271	26.478	3.210	945.781	0.158	0.022	4.029	0.920	0.413	0.058
18500.0	0.270	26.061	3.280	945.517	0.164	0.024	4.063	0.953	0.430	0.063
19000.0	0.268	25.649	3.349	945.252	0.170	0.025	4.094	0.985	0.448	0.068
19500.0	0.267	25.239	3.417	944.985	0.176	0.027	4.125	1.017	0.465	0.073
20000.0	0.265	24.833	3.484	944.718	0.182	0.029	4.153	1.048	0.483	0.078
20500.0	0.263	24.431	3.551	944.449	0.188	0.030	4.180	1.080	0.501	0.084
22500.0	0.257	22.855	3.808	943.360	0.214	0.038	4.273	1.205	0.571	0.108
25000.0	0.249	20.962	4.112	941.967	0.247	0.048	4.358	1.358	0.658	0.143
27500.0	0.242	19.155	4.396	940.538	0.281	0.061	4.414	1.505	0.741	0.183
30000.0	0.234	17.433	4.660	939.069	0.317	0.075	4.445	1.648	0.819	0.230
32500.0	0.226	15.797	4.905	937.560	0.353	0.091	4.453	1.784	0.891	0.282
35000.0	0.218	14.247	5.129	936.006	0.389	0.109	4.443	1.913	0.957	0.339
37500.0	0.211	12.784	5.335	934.407	0.425	0.128	4.418	2.035	1.016	0.402
40000.0	0.203	11.408	5.520	932.759	0.461	0.149	4.380	2.149	1.067	0.471
42500.0	0.196	10.121	5.686	931.060	0.497	0.171	4.331	2.255	1.112	0.544
45000.0	0.188	8.922	5.833	929.307	0.532	0.195	4.276	2.352	1.150	0.622
47500.0	0.180	7.814	5.959	927.499	0.566	0.220	4.214	2.439	1.180	0.704
50000.0	0.173	6.795	6.067	925.632	0.598	0.246	4.149	2.518	1.205	0.791
52500.0	0.166	5.867	6.155	923.705	0.630	0.272	4.083	2.588	1.223	0.881
55000.0	0.158	5.028	6.224	921.717	0.660	0.298	4.016	2.648	1.237	0.975
57500.0	0.151	4.276	6.275	919.669	0.688	0.324	3.951	2.700	1.245	1.071
60000.0	0.144	3.609	6.308	917.560	0.714	0.350	3.889	2.743	1.250	1.169
62500.0	0.137	3.023	6.325	915.392	0.738	0.374	3.830	2.778	1.251	1.269
65000.0	0.131	2.515	6.326	913.167	0.759	0.398	3.775	2.806	1.249	1.370
67500.0	0.124	2.077	6.313	910.889	0.779	0.420	3.725	2.828	1.246	1.471
70000.0	0.118	1.705	6.286	908.562	0.796	0.441	3.679	2.843	1.241	1.572

**Table C.57 [] Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.334	44.230	0.000	955.436	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.334	44.110	0.024	955.370	0.000	0.000	0.020	0.000	0.000	0.000
500.0	0.332	43.636	0.121	955.106	0.002	0.000	0.222	0.002	0.000	0.000
1000.0	0.330	43.053	0.239	954.776	0.005	0.000	0.493	0.008	0.000	0.000
1500.0	0.327	42.479	0.356	954.446	0.008	0.000	0.751	0.017	0.001	0.000
2000.0	0.325	41.915	0.470	954.117	0.011	0.000	0.997	0.030	0.004	0.000
2500.0	0.323	41.360	0.581	953.789	0.014	0.000	1.232	0.046	0.007	0.000
3000.0	0.320	40.813	0.691	953.461	0.018	0.001	1.455	0.064	0.011	0.000
3500.0	0.318	40.275	0.799	953.134	0.022	0.001	1.669	0.084	0.017	0.000
4000.0	0.316	39.744	0.905	952.808	0.026	0.001	1.872	0.105	0.023	0.001
4500.0	0.314	39.220	1.009	952.482	0.030	0.001	2.067	0.129	0.032	0.001
5000.0	0.312	38.703	1.112	952.157	0.035	0.002	2.252	0.153	0.041	0.001
5500.0	0.310	38.194	1.212	951.833	0.040	0.002	2.429	0.179	0.052	0.002
6000.0	0.307	37.690	1.311	951.510	0.045	0.003	2.598	0.206	0.063	0.002
6500.0	0.305	37.193	1.409	951.187	0.050	0.003	2.759	0.234	0.076	0.003
7000.0	0.303	36.702	1.504	950.866	0.056	0.004	2.913	0.262	0.090	0.004
7500.0	0.301	36.216	1.599	950.545	0.061	0.005	3.060	0.292	0.104	0.005
8000.0	0.299	35.737	1.691	950.225	0.067	0.005	3.199	0.322	0.120	0.006
8500.0	0.297	35.263	1.782	949.906	0.073	0.006	3.332	0.353	0.136	0.007
9000.0	0.295	34.794	1.872	949.587	0.079	0.007	3.459	0.384	0.153	0.009
9500.0	0.293	34.330	1.961	949.270	0.085	0.008	3.580	0.416	0.170	0.011
10000.0	0.291	33.871	2.048	948.954	0.091	0.009	3.695	0.448	0.188	0.012
10500.0	0.289	33.417	2.134	948.638	0.097	0.010	3.804	0.481	0.206	0.014
11000.0	0.287	32.968	2.218	948.324	0.103	0.011	3.907	0.514	0.225	0.017
11500.0	0.285	32.523	2.302	948.010	0.110	0.012	4.006	0.547	0.244	0.019
12000.0	0.283	32.083	2.384	947.697	0.116	0.013	4.100	0.581	0.264	0.021
12500.0	0.282	31.647	2.465	947.384	0.123	0.015	4.189	0.615	0.283	0.024
13000.0	0.280	31.215	2.545	947.072	0.130	0.016	4.274	0.649	0.303	0.027
13500.0	0.278	30.787	2.623	946.761	0.136	0.017	4.354	0.684	0.323	0.030
14000.0	0.276	30.363	2.701	946.450	0.143	0.019	4.431	0.718	0.344	0.033
14500.0	0.274	29.944	2.778	946.139	0.150	0.020	4.503	0.753	0.364	0.037
15000.0	0.272	29.528	2.853	945.828	0.157	0.022	4.573	0.788	0.385	0.041
15500.0	0.271	29.115	2.928	945.517	0.164	0.024	4.638	0.823	0.406	0.044
16000.0	0.269	28.707	3.001	945.206	0.171	0.026	4.701	0.858	0.426	0.048
16500.0	0.267	28.302	3.074	944.895	0.178	0.027	4.760	0.893	0.447	0.053
17000.0	0.265	27.901	3.145	944.585	0.185	0.029	4.817	0.928	0.468	0.057
17500.0	0.263	27.504	3.216	944.273	0.193	0.031	4.871	0.963	0.489	0.062
18000.0	0.262	27.110	3.285	943.962	0.200	0.033	4.922	0.998	0.510	0.067
18500.0	0.260	26.719	3.354	943.650	0.207	0.036	4.970	1.033	0.531	0.072
19000.0	0.258	26.332	3.422	943.337	0.215	0.038	5.016	1.068	0.552	0.077
19500.0	0.257	25.949	3.489	943.024	0.222	0.040	5.060	1.103	0.573	0.082
20000.0	0.255	25.569	3.555	942.711	0.229	0.042	5.102	1.138	0.593	0.088
20500.0	0.253	25.192	3.620	942.396	0.237	0.045	5.142	1.173	0.614	0.094
21000.0	0.251	24.819	3.684	942.081	0.244	0.047	5.180	1.207	0.635	0.100
21500.0	0.250	24.449	3.748	941.764	0.252	0.050	5.216	1.242	0.656	0.106
22000.0	0.248	24.083	3.810	941.447	0.260	0.053	5.250	1.276	0.676	0.112
22500.0	0.246	23.720	3.872	941.128	0.267	0.055	5.283	1.310	0.697	0.119
23000.0	0.245	23.361	3.933	940.809	0.275	0.058	5.314	1.344	0.717	0.126
23500.0	0.243	23.005	3.993	940.488	0.283	0.061	5.344	1.378	0.738	0.133
25000.0	0.238	21.957	4.168	939.517	0.306	0.070	5.425	1.479	0.798	0.155
27500.0	0.230	20.278	4.444	937.872	0.346	0.088	5.535	1.642	0.897	0.195
30000.0	0.222	18.681	4.699	936.194	0.386	0.107	5.617	1.799	0.992	0.241
32500.0	0.214	17.167	4.934	934.481	0.427	0.129	5.674	1.951	1.082	0.291
35000.0	0.206	15.732	5.150	932.733	0.467	0.152	5.709	2.096	1.166	0.346
37500.0	0.198	14.377	5.346	930.948	0.508	0.178	5.726	2.234	1.243	0.404
40000.0	0.191	13.099	5.523	929.126	0.548	0.206	5.727	2.365	1.314	0.467
42500.0	0.184	11.899	5.682	927.267	0.587	0.235	5.715	2.488	1.378	0.534
45000.0	0.176	10.774	5.823	925.368	0.625	0.266	5.691	2.604	1.435	0.604
47500.0	0.169	9.724	5.946	923.431	0.663	0.299	5.658	2.711	1.486	0.677
50000.0	0.163	8.747	6.051	921.454	0.699	0.332	5.618	2.810	1.531	0.753
52500.0	0.156	7.841	6.140	919.437	0.734	0.366	5.572	2.901	1.570	0.831
55000.0	0.150	7.004	6.213	917.381	0.767	0.401	5.522	2.984	1.603	0.912
57500.0	0.143	6.235	6.271	915.286	0.798	0.437	5.469	3.059	1.631	0.995
60000.0	0.137	5.532	6.313	913.153	0.827	0.472	5.414	3.126	1.654	1.080
62500.0	0.131	4.890	6.342	910.981	0.855	0.507	5.359	3.186	1.672	1.167
65000.0	0.126	4.309	6.357	908.774	0.880	0.541	5.305	3.238	1.687	1.254
67500.0	0.120	3.784	6.360	906.531	0.903	0.574	5.251	3.284	1.698	1.343
70000.0	0.115	3.313	6.351	904.255	0.924	0.607	5.199	3.323	1.706	1.432

**Table C.58 [Exposure-Dependent 0% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.322	42.654	0.000	957.024	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.322	42.533	0.022	956.978	0.000	0.000	0.014	0.000	0.000	0.000
500.0	0.320	42.055	0.109	956.790	0.001	0.000	0.161	0.001	0.000	0.000
1000.0	0.319	41.464	0.215	956.555	0.003	0.000	0.357	0.006	0.000	0.000
1500.0	0.317	40.880	0.321	956.321	0.005	0.000	0.543	0.013	0.001	0.000
2000.0	0.316	40.304	0.425	956.086	0.007	0.000	0.721	0.023	0.002	0.000
2500.0	0.314	39.734	0.527	955.852	0.009	0.000	0.890	0.035	0.003	0.000
3000.0	0.312	39.171	0.628	955.618	0.011	0.000	1.051	0.050	0.006	0.000
3500.0	0.311	38.614	0.727	955.385	0.014	0.000	1.204	0.066	0.009	0.000
4000.0	0.309	38.063	0.825	955.152	0.016	0.001	1.349	0.084	0.012	0.000
4500.0	0.308	37.518	0.922	954.920	0.019	0.001	1.488	0.103	0.017	0.000
5000.0	0.306	36.978	1.017	954.688	0.022	0.001	1.619	0.124	0.022	0.001
5500.0	0.304	36.444	1.111	954.456	0.025	0.001	1.743	0.146	0.028	0.001
6000.0	0.303	35.915	1.204	954.226	0.028	0.001	1.861	0.169	0.035	0.001
6500.0	0.301	35.390	1.296	953.996	0.031	0.002	1.973	0.193	0.043	0.002
7000.0	0.300	34.870	1.386	953.767	0.034	0.002	2.078	0.217	0.051	0.002
7500.0	0.298	34.355	1.476	953.539	0.038	0.002	2.178	0.243	0.059	0.003
8000.0	0.297	33.845	1.564	953.311	0.041	0.002	2.272	0.269	0.069	0.004
8500.0	0.295	33.338	1.651	953.085	0.044	0.003	2.361	0.296	0.079	0.005
9000.0	0.294	32.836	1.737	952.860	0.048	0.003	2.445	0.323	0.089	0.006
9500.0	0.292	32.337	1.822	952.635	0.052	0.004	2.524	0.350	0.100	0.007
10000.0	0.291	31.843	1.907	952.411	0.055	0.004	2.598	0.378	0.111	0.008
10500.0	0.289	31.352	1.990	952.187	0.059	0.005	2.669	0.407	0.123	0.009
11000.0	0.288	30.865	2.072	951.963	0.063	0.005	2.735	0.436	0.134	0.011
11500.0	0.286	30.381	2.154	951.739	0.067	0.006	2.798	0.465	0.147	0.012
12000.0	0.285	29.902	2.234	951.514	0.071	0.006	2.858	0.494	0.159	0.014
12500.0	0.284	29.426	2.314	951.289	0.075	0.007	2.914	0.523	0.172	0.016
13000.0	0.282	28.954	2.393	951.063	0.079	0.007	2.968	0.553	0.186	0.018
13500.0	0.281	28.485	2.471	950.836	0.083	0.008	3.019	0.583	0.199	0.021
14000.0	0.279	28.020	2.548	950.608	0.088	0.009	3.068	0.613	0.213	0.023
14500.0	0.278	27.559	2.624	950.378	0.092	0.009	3.114	0.643	0.227	0.026
15000.0	0.276	27.102	2.699	950.148	0.097	0.010	3.158	0.674	0.242	0.028
15500.0	0.275	26.648	2.774	949.916	0.102	0.011	3.199	0.704	0.256	0.031
16000.0	0.273	26.198	2.848	949.684	0.106	0.012	3.239	0.734	0.271	0.035
17500.0	0.269	24.870	3.064	948.977	0.121	0.015	3.345	0.826	0.316	0.045
20000.0	0.262	22.729	3.409	947.771	0.147	0.021	3.485	0.979	0.394	0.068
22500.0	0.254	20.680	3.734	946.527	0.175	0.028	3.585	1.130	0.471	0.096
25000.0	0.247	18.721	4.038	945.243	0.204	0.036	3.649	1.279	0.547	0.130
27500.0	0.239	16.854	4.323	943.915	0.234	0.046	3.685	1.423	0.618	0.170
30000.0	0.232	15.079	4.588	942.540	0.265	0.057	3.695	1.563	0.685	0.217
32500.0	0.224	13.401	4.832	941.114	0.297	0.070	3.685	1.697	0.745	0.270
35000.0	0.217	11.819	5.055	939.631	0.329	0.085	3.658	1.824	0.799	0.330
37500.0	0.209	10.339	5.256	938.088	0.362	0.101	3.617	1.942	0.846	0.397
40000.0	0.201	8.962	5.436	936.479	0.394	0.118	3.567	2.053	0.887	0.470
42500.0	0.193	7.692	5.594	934.799	0.427	0.137	3.510	2.153	0.920	0.550
45000.0	0.185	6.532	5.729	933.044	0.459	0.156	3.448	2.244	0.947	0.637
47500.0	0.177	5.484	5.841	931.210	0.489	0.177	3.384	2.324	0.967	0.729
50000.0	0.169	4.550	5.931	929.294	0.519	0.198	3.321	2.394	0.982	0.826
52500.0	0.161	3.729	5.998	927.294	0.547	0.219	3.260	2.453	0.992	0.929
55000.0	0.153	3.018	6.043	925.209	0.573	0.240	3.203	2.503	0.997	1.035
57500.0	0.145	2.414	6.068	923.042	0.598	0.261	3.151	2.542	1.000	1.145
60000.0	0.137	1.909	6.074	920.798	0.619	0.280	3.105	2.573	0.999	1.257
62500.0	0.130	1.494	6.062	918.483	0.639	0.298	3.065	2.597	0.997	1.370
65000.0	0.122	1.158	6.036	916.105	0.656	0.315	3.030	2.614	0.994	1.483
67500.0	0.115	0.892	5.997	913.671	0.671	0.330	3.000	2.625	0.990	1.596
70000.0	0.108	0.682	5.947	911.192	0.683	0.344	2.976	2.632	0.986	1.707

**Table C.59 [] Exposure-Dependent 40% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
0.0	0.322	42.654	0.000	957.024	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.322	42.534	0.023	956.971	0.000	0.000	0.016	0.000	0.000	0.000
500.0	0.320	42.057	0.113	956.754	0.002	0.000	0.184	0.001	0.000	0.000
1000.0	0.318	41.469	0.223	956.483	0.004	0.000	0.409	0.006	0.000	0.000
1500.0	0.317	40.890	0.332	956.213	0.006	0.000	0.622	0.015	0.001	0.000
2000.0	0.315	40.318	0.439	955.943	0.008	0.000	0.825	0.026	0.002	0.000
2500.0	0.313	39.755	0.545	955.674	0.011	0.000	1.018	0.040	0.005	0.000
3000.0	0.311	39.199	0.648	955.405	0.014	0.000	1.201	0.057	0.008	0.000
3500.0	0.309	38.650	0.750	955.137	0.016	0.001	1.376	0.075	0.012	0.000
4000.0	0.307	38.108	0.850	954.869	0.020	0.001	1.542	0.095	0.017	0.000
4500.0	0.306	37.572	0.949	954.602	0.023	0.001	1.699	0.116	0.022	0.001
5000.0	0.304	37.043	1.046	954.336	0.026	0.001	1.849	0.139	0.029	0.001
5500.0	0.302	36.519	1.142	954.071	0.030	0.001	1.990	0.163	0.037	0.001
6000.0	0.300	36.001	1.236	953.806	0.034	0.002	2.125	0.188	0.046	0.002
6500.0	0.299	35.489	1.329	953.542	0.037	0.002	2.253	0.214	0.055	0.002
7000.0	0.297	34.982	1.421	953.280	0.041	0.002	2.374	0.241	0.066	0.003
7500.0	0.295	34.480	1.512	953.018	0.045	0.003	2.488	0.268	0.077	0.004
8000.0	0.294	33.983	1.601	952.757	0.050	0.003	2.597	0.296	0.089	0.005
8500.0	0.292	33.490	1.689	952.497	0.054	0.004	2.699	0.325	0.101	0.006
9000.0	0.290	33.002	1.775	952.239	0.058	0.004	2.796	0.354	0.114	0.007
9500.0	0.289	32.519	1.861	951.981	0.063	0.005	2.887	0.384	0.127	0.008
10000.0	0.287	32.039	1.945	951.724	0.067	0.005	2.973	0.414	0.141	0.010
10500.0	0.285	31.564	2.028	951.468	0.072	0.006	3.055	0.444	0.155	0.012
11000.0	0.284	31.093	2.111	951.212	0.076	0.007	3.132	0.475	0.170	0.013
11500.0	0.282	30.626	2.192	950.957	0.081	0.008	3.205	0.506	0.185	0.015
12000.0	0.281	30.163	2.272	950.701	0.086	0.008	3.274	0.537	0.200	0.017
12500.0	0.279	29.704	2.351	950.445	0.091	0.009	3.340	0.569	0.216	0.020
13000.0	0.277	29.249	2.430	950.188	0.096	0.010	3.402	0.600	0.232	0.022
13500.0	0.276	28.797	2.507	949.930	0.101	0.011	3.462	0.632	0.248	0.025
14000.0	0.274	28.350	2.583	949.672	0.107	0.012	3.519	0.664	0.265	0.028
14500.0	0.273	27.906	2.659	949.412	0.112	0.013	3.573	0.696	0.281	0.031
15000.0	0.271	27.467	2.734	949.152	0.118	0.014	3.624	0.727	0.298	0.034
15500.0	0.270	27.031	2.807	948.890	0.123	0.015	3.674	0.759	0.316	0.038
16000.0	0.268	26.599	2.880	948.627	0.129	0.016	3.721	0.792	0.333	0.041
16500.0	0.266	26.171	2.952	948.363	0.134	0.017	3.765	0.824	0.350	0.045
17000.0	0.265	25.747	3.024	948.097	0.140	0.019	3.808	0.856	0.368	0.049
17500.0	0.263	25.326	3.094	947.830	0.146	0.020	3.848	0.888	0.386	0.054
20000.0	0.256	23.280	3.432	946.476	0.176	0.027	4.022	1.047	0.476	0.078
22500.0	0.248	21.327	3.750	945.086	0.208	0.036	4.151	1.204	0.566	0.109
25000.0	0.240	19.466	4.046	943.660	0.242	0.047	4.244	1.359	0.653	0.145
27500.0	0.232	17.695	4.321	942.194	0.276	0.060	4.304	1.509	0.736	0.187
30000.0	0.225	16.015	4.576	940.688	0.311	0.074	4.337	1.653	0.814	0.236
32500.0	0.217	14.426	4.810	939.137	0.347	0.090	4.347	1.791	0.885	0.290
35000.0	0.209	12.927	5.023	937.540	0.384	0.108	4.337	1.922	0.950	0.350
37500.0	0.202	11.519	5.217	935.894	0.420	0.128	4.312	2.046	1.007	0.416
40000.0	0.194	10.203	5.390	934.196	0.456	0.149	4.274	2.160	1.057	0.487
42500.0	0.186	8.980	5.543	932.443	0.491	0.172	4.226	2.266	1.100	0.563
45000.0	0.179	7.850	5.676	930.634	0.526	0.195	4.171	2.363	1.136	0.645
47500.0	0.172	6.814	5.788	928.765	0.559	0.220	4.111	2.450	1.165	0.730
50000.0	0.164	5.870	5.881	926.835	0.591	0.246	4.048	2.527	1.188	0.820
52500.0	0.157	5.019	5.955	924.843	0.621	0.272	3.985	2.595	1.205	0.913
55000.0	0.150	4.257	6.010	922.789	0.650	0.297	3.923	2.653	1.217	1.010
57500.0	0.143	3.583	6.047	920.673	0.677	0.323	3.862	2.702	1.225	1.109
60000.0	0.136	2.993	6.066	918.496	0.701	0.348	3.805	2.743	1.229	1.209
62500.0	0.129	2.482	6.070	916.262	0.724	0.372	3.752	2.775	1.230	1.311
65000.0	0.123	2.044	6.059	913.974	0.744	0.394	3.704	2.801	1.228	1.414
67500.0	0.116	1.673	6.036	911.635	0.762	0.415	3.660	2.820	1.225	1.516
70000.0	0.110	1.361	6.000	909.252	0.777	0.435	3.621	2.834	1.221	1.618

**Table C.60 [Exposure-Dependent 80% Void
Isotopics (kg/MTU Initial)**

Exposure MWd/MTU	U-234	U-235	U-236	U-238	NP-237	PU-238	PU-239	PU-240	PU-241	PU-242
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0.0	0.322	42.654	0.000	957.024	0.000	0.000	0.000	0.000	0.000	0.000
100.0	0.322	42.534	0.024	956.960	0.000	0.000	0.019	0.000	0.000	0.000
500.0	0.320	42.061	0.119	956.703	0.002	0.000	0.216	0.002	0.000	0.000
1000.0	0.318	41.478	0.235	956.382	0.005	0.000	0.479	0.008	0.000	0.000
1500.0	0.315	40.906	0.350	956.061	0.007	0.000	0.729	0.017	0.001	0.000
2000.0	0.313	40.343	0.461	955.741	0.010	0.000	0.967	0.031	0.003	0.000
2500.0	0.311	39.788	0.571	955.422	0.014	0.000	1.194	0.046	0.007	0.000
3000.0	0.309	39.243	0.679	955.103	0.017	0.001	1.409	0.065	0.011	0.000
3500.0	0.307	38.705	0.785	954.785	0.021	0.001	1.614	0.085	0.016	0.000
4000.0	0.305	38.175	0.889	954.468	0.025	0.001	1.809	0.107	0.023	0.001
4500.0	0.303	37.653	0.991	954.152	0.029	0.001	1.995	0.131	0.031	0.001
5000.0	0.301	37.137	1.092	953.836	0.033	0.002	2.172	0.155	0.040	0.001
5500.0	0.299	36.628	1.190	953.521	0.038	0.002	2.341	0.182	0.051	0.002
6000.0	0.297	36.125	1.288	953.207	0.043	0.003	2.502	0.209	0.062	0.002
6500.0	0.295	35.629	1.383	952.894	0.048	0.003	2.655	0.237	0.075	0.003
7000.0	0.293	35.139	1.477	952.581	0.053	0.004	2.800	0.266	0.088	0.004
7500.0	0.291	34.654	1.569	952.270	0.058	0.004	2.939	0.295	0.102	0.005
8000.0	0.289	34.175	1.660	951.959	0.064	0.005	3.070	0.326	0.117	0.006
8500.0	0.287	33.702	1.750	951.650	0.069	0.006	3.195	0.357	0.133	0.007
9000.0	0.285	33.233	1.838	951.341	0.075	0.007	3.314	0.388	0.149	0.009
9500.0	0.283	32.770	1.925	951.034	0.081	0.007	3.427	0.420	0.166	0.011
10000.0	0.281	32.311	2.010	950.727	0.086	0.008	3.535	0.453	0.183	0.012
10500.0	0.279	31.857	2.094	950.422	0.092	0.009	3.636	0.486	0.201	0.014
11000.0	0.277	31.407	2.177	950.117	0.098	0.010	3.733	0.519	0.219	0.017
11500.0	0.276	30.962	2.259	949.813	0.104	0.011	3.825	0.552	0.237	0.019
12000.0	0.274	30.521	2.340	949.509	0.111	0.013	3.913	0.586	0.256	0.021
12500.0	0.272	30.084	2.420	949.204	0.117	0.014	3.997	0.620	0.275	0.024
13000.0	0.270	29.652	2.498	948.900	0.123	0.015	4.076	0.654	0.294	0.027
13500.0	0.269	29.223	2.575	948.596	0.130	0.016	4.153	0.688	0.314	0.030
14000.0	0.267	28.799	2.652	948.291	0.136	0.018	4.226	0.723	0.334	0.033
14500.0	0.265	28.379	2.727	947.985	0.143	0.019	4.296	0.757	0.354	0.037
15000.0	0.263	27.963	2.802	947.678	0.150	0.021	4.363	0.792	0.374	0.040
15500.0	0.262	27.551	2.875	947.371	0.156	0.022	4.427	0.826	0.394	0.044
16000.0	0.260	27.143	2.947	947.062	0.163	0.024	4.489	0.861	0.415	0.048
16500.0	0.258	26.738	3.019	946.753	0.170	0.026	4.548	0.896	0.435	0.053
17000.0	0.256	26.338	3.089	946.442	0.177	0.028	4.605	0.930	0.456	0.057
17500.0	0.255	25.942	3.158	946.130	0.184	0.030	4.659	0.965	0.477	0.062
18000.0	0.253	25.550	3.227	945.817	0.192	0.032	4.712	1.000	0.498	0.067
18500.0	0.251	25.161	3.295	945.503	0.199	0.034	4.762	1.034	0.519	0.072
19000.0	0.249	24.777	3.361	945.187	0.206	0.036	4.810	1.069	0.540	0.077
19500.0	0.248	24.396	3.427	944.870	0.214	0.038	4.856	1.104	0.561	0.083
20000.0	0.246	24.019	3.492	944.552	0.221	0.040	4.900	1.138	0.582	0.088
22500.0	0.238	22.191	3.802	942.942	0.259	0.053	5.095	1.309	0.687	0.120
25000.0	0.229	20.455	4.090	941.297	0.299	0.068	5.248	1.476	0.791	0.157
27500.0	0.221	18.808	4.357	939.618	0.339	0.086	5.366	1.639	0.890	0.199
30000.0	0.213	17.249	4.603	937.904	0.379	0.105	5.454	1.798	0.984	0.246
32500.0	0.205	15.775	4.828	936.154	0.419	0.127	5.515	1.951	1.073	0.298
35000.0	0.198	14.385	5.033	934.367	0.460	0.151	5.554	2.097	1.155	0.355
37500.0	0.190	13.078	5.218	932.541	0.500	0.177	5.573	2.236	1.231	0.416
40000.0	0.183	11.852	5.384	930.676	0.539	0.205	5.575	2.367	1.301	0.481
42500.0	0.175	10.706	5.531	928.772	0.578	0.234	5.564	2.491	1.363	0.550
45000.0	0.168	9.638	5.659	926.828	0.616	0.265	5.542	2.606	1.419	0.622
47500.0	0.161	8.646	5.770	924.843	0.652	0.297	5.511	2.713	1.468	0.697
50000.0	0.155	7.729	5.863	922.817	0.687	0.331	5.472	2.812	1.511	0.776
52500.0	0.148	6.884	5.940	920.751	0.721	0.365	5.428	2.901	1.548	0.857
55000.0	0.142	6.110	6.001	918.645	0.752	0.399	5.381	2.983	1.579	0.940
57500.0	0.136	5.403	6.046	916.498	0.782	0.434	5.331	3.056	1.606	1.025
60000.0	0.130	4.761	6.077	914.313	0.810	0.468	5.281	3.121	1.627	1.112
62500.0	0.124	4.181	6.095	912.091	0.836	0.502	5.230	3.178	1.644	1.200
65000.0	0.119	3.659	6.099	909.832	0.859	0.535	5.180	3.228	1.658	1.289
67500.0	0.114	3.192	6.092	907.540	0.881	0.567	5.132	3.271	1.668	1.379
70000.0	0.109	2.777	6.074	905.215	0.900	0.598	5.085	3.308	1.675	1.470

Appendix D Lattice Enrichment Distribution Maps

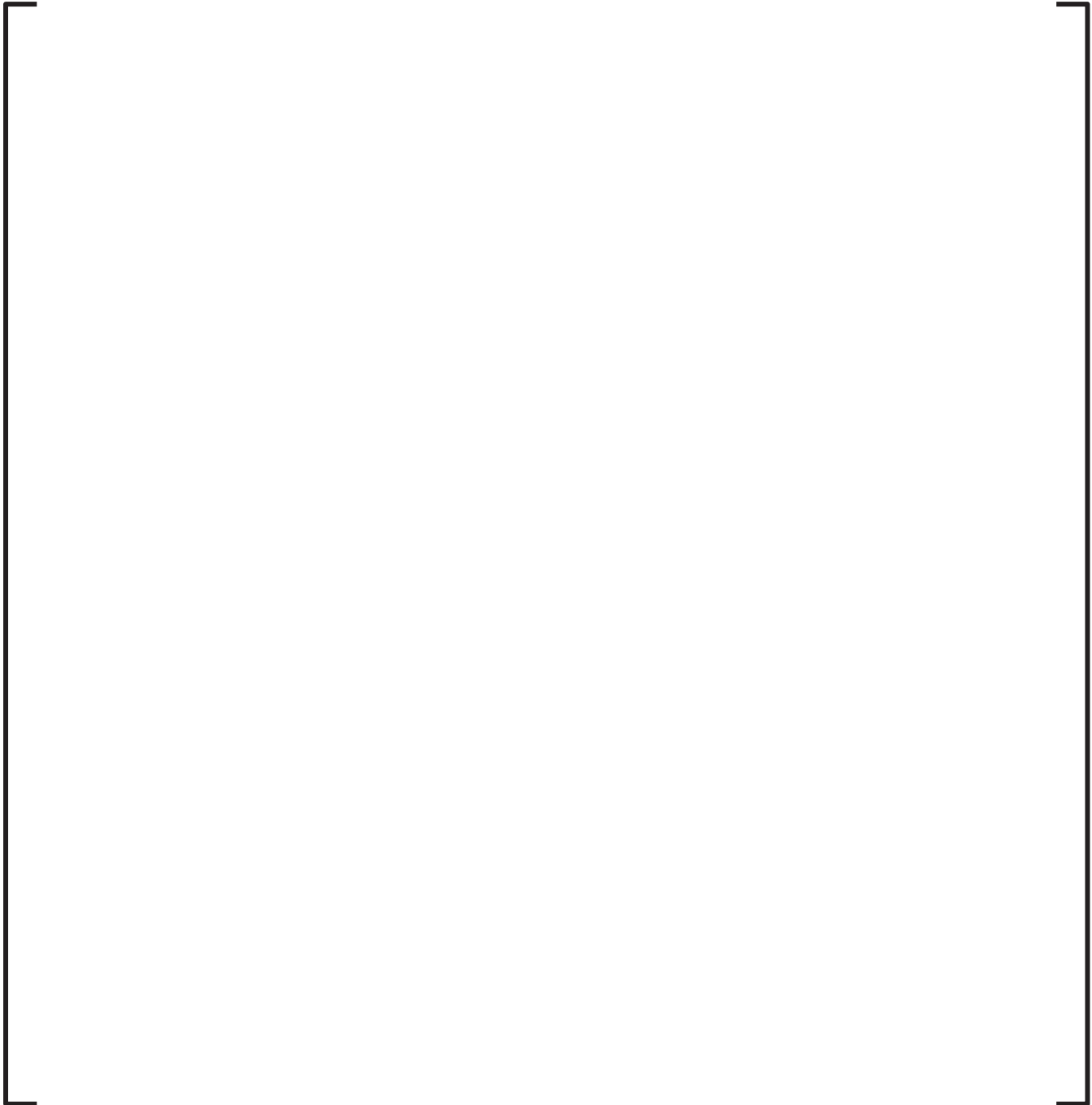


Figure D.1 [] Enrichment Distribution

Figure D.2 [] Enrichment Distribution

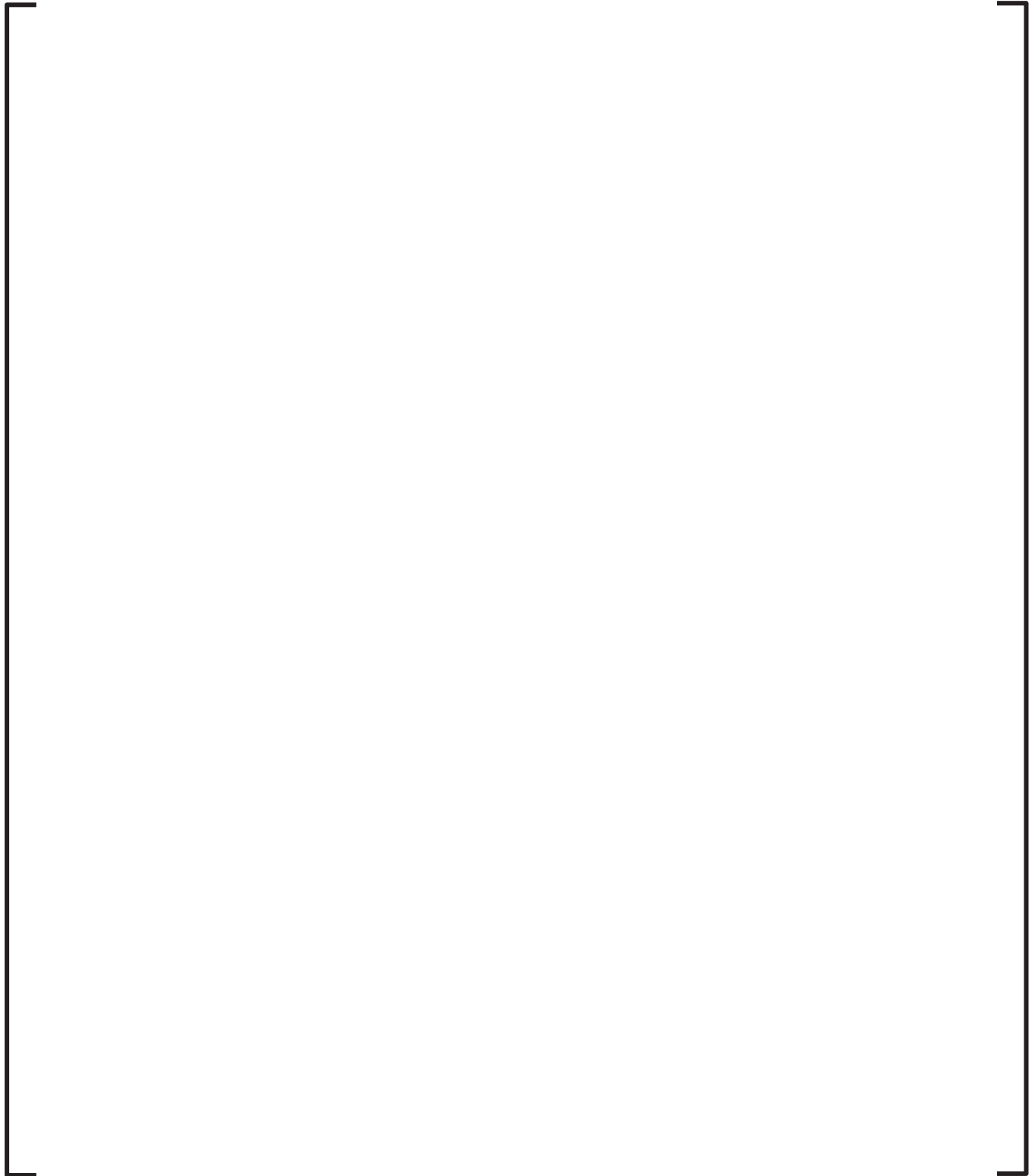


Figure D.3 [

] Enrichment Distribution

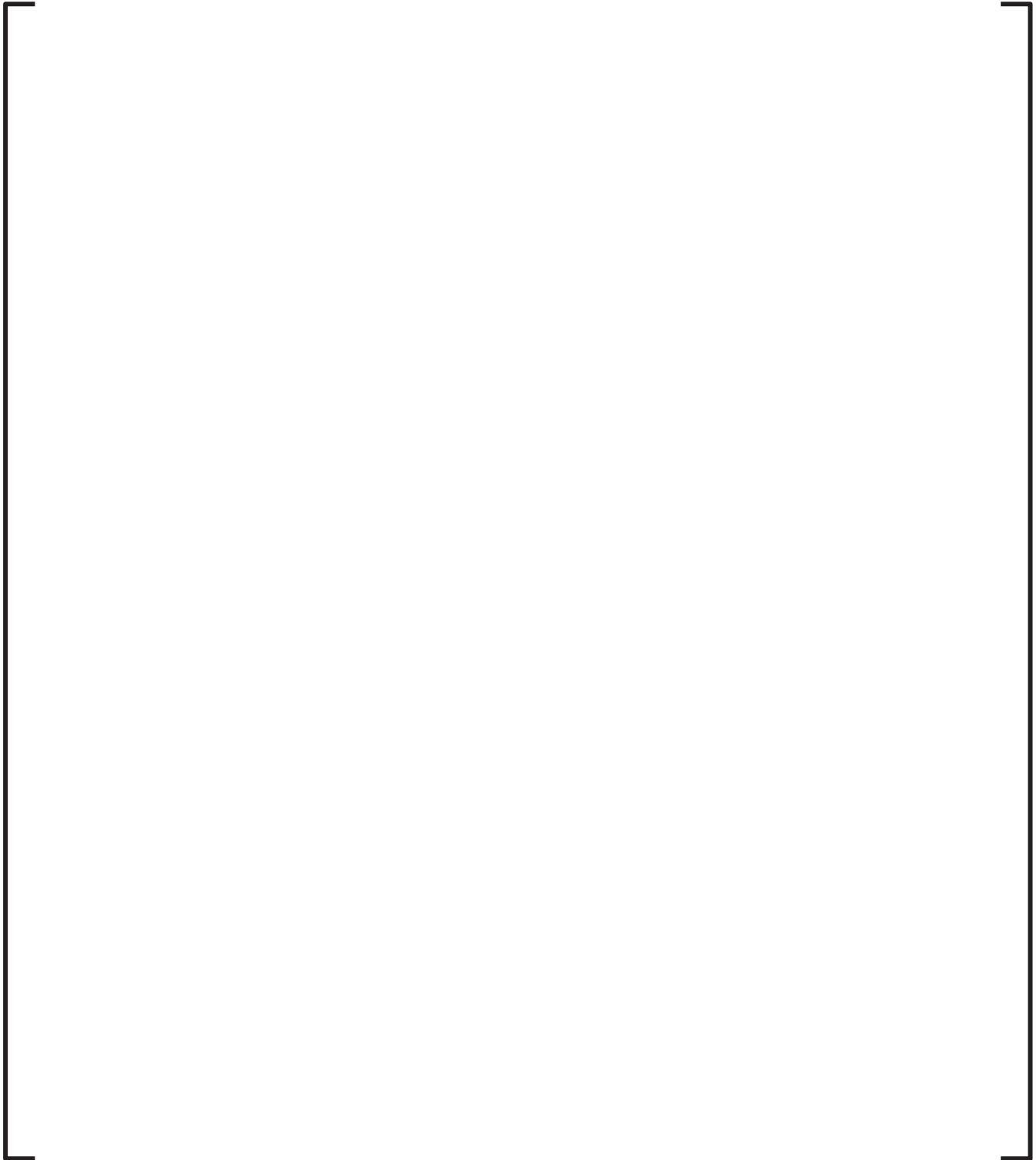


Figure D.4 [] Enrichment Distribution

Figure D.5 [

] Enrichment Distribution

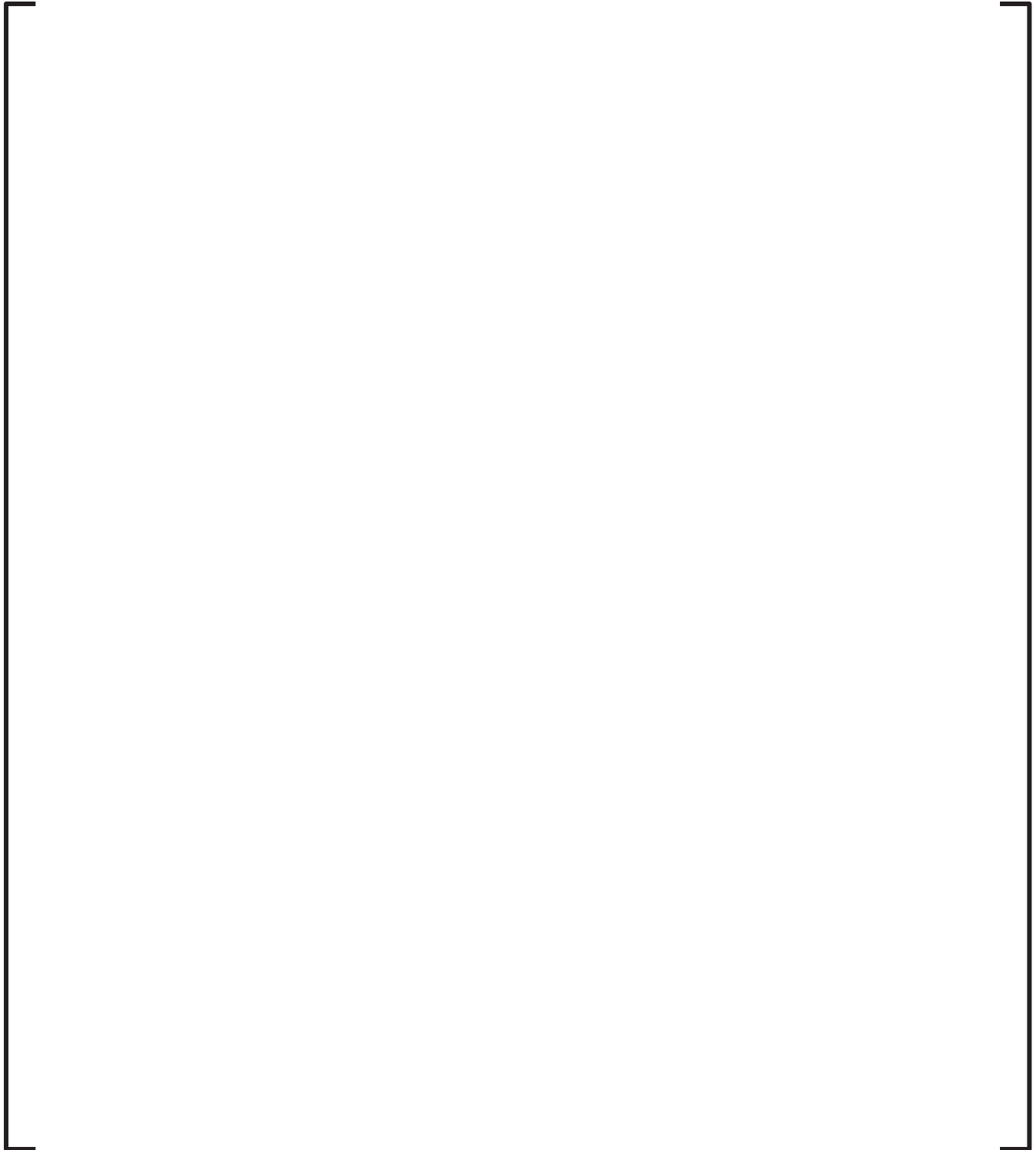


Figure D.6 [] Enrichment Distribution

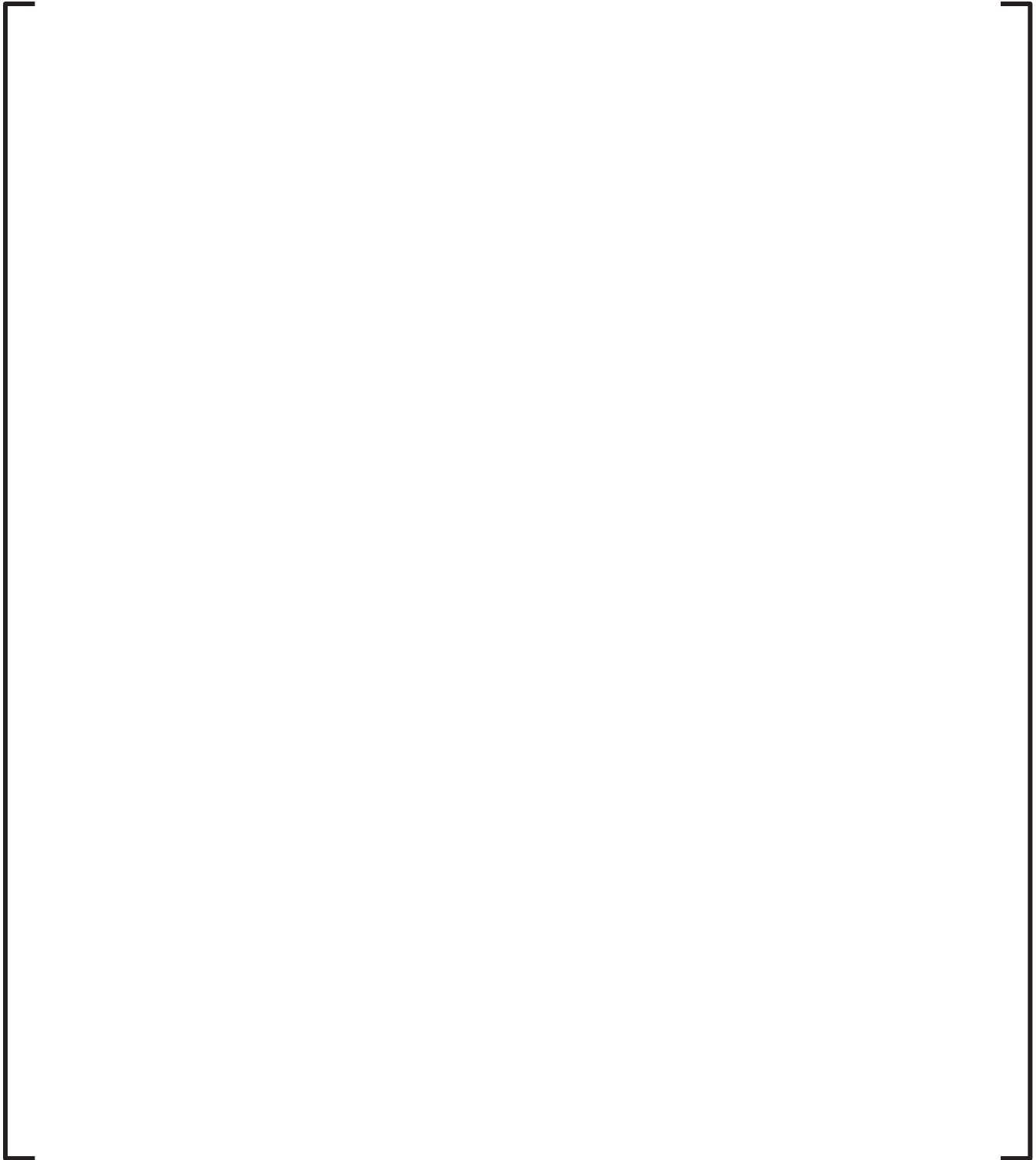


Figure D.7 [] Enrichment Distribution

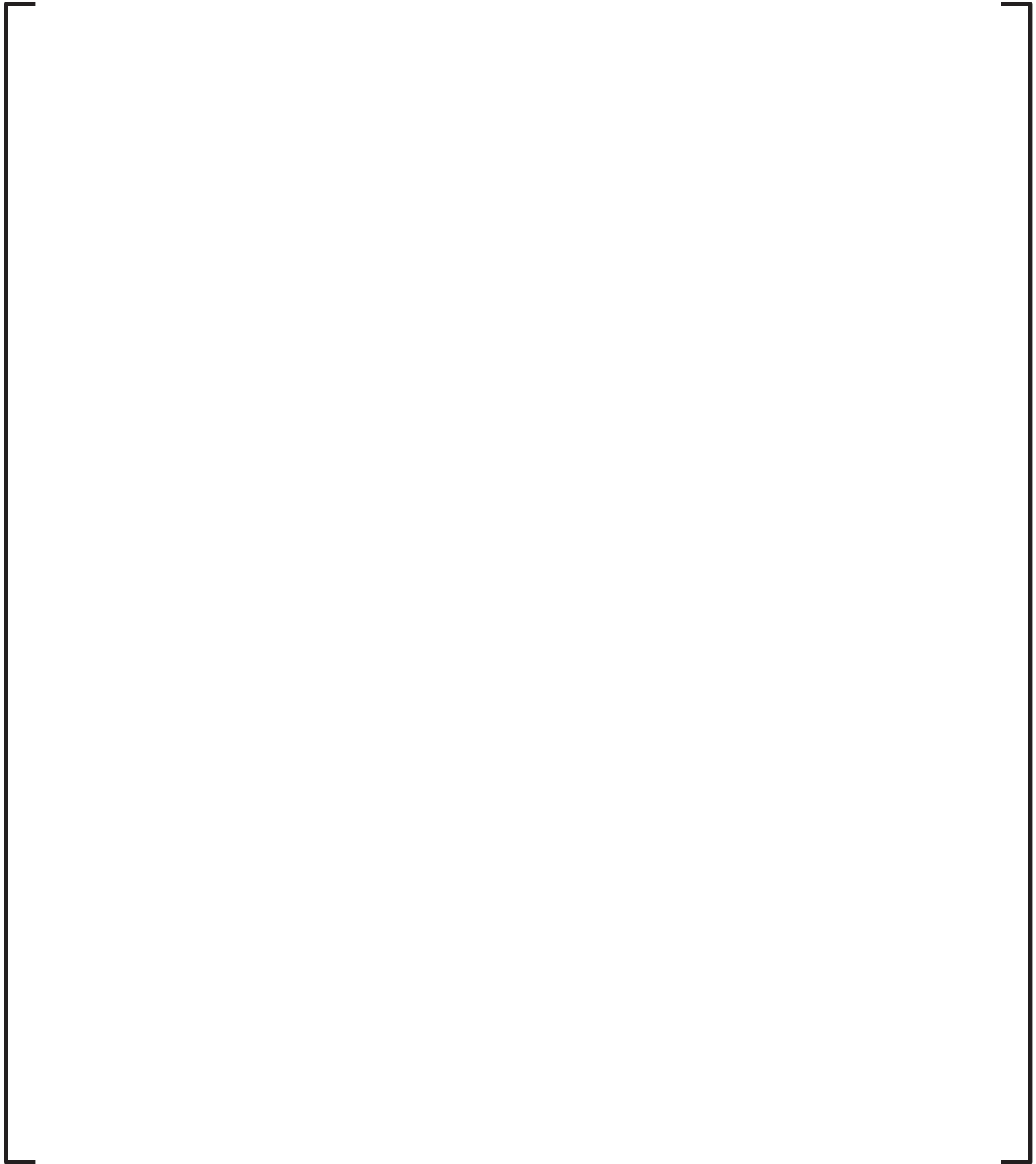


Figure D.8 [] Enrichment Distribution

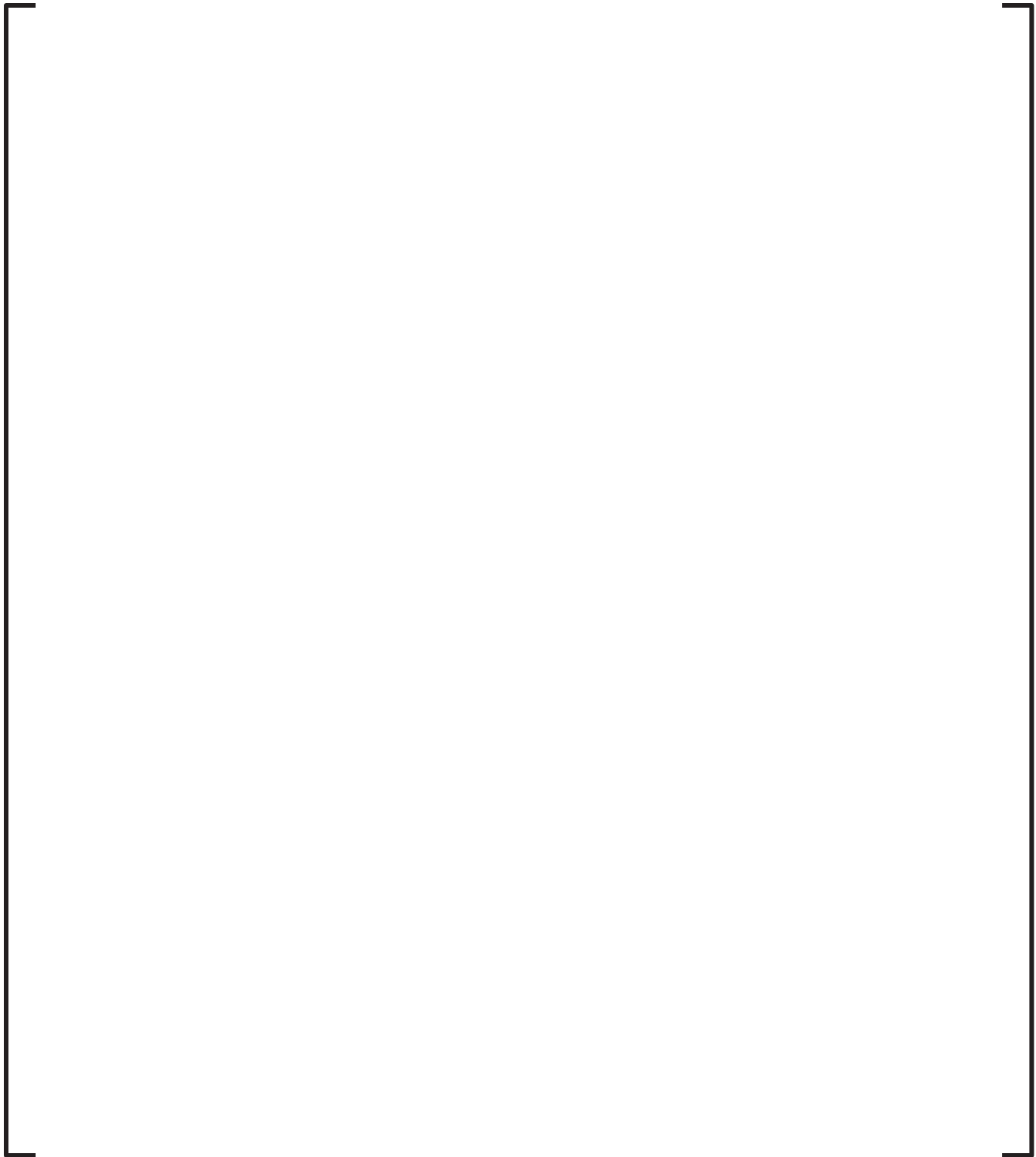


Figure D.9 [] Enrichment Distribution

Figure D.10 [] Enrichment Distribution

Figure D.11 [] Enrichment Distribution

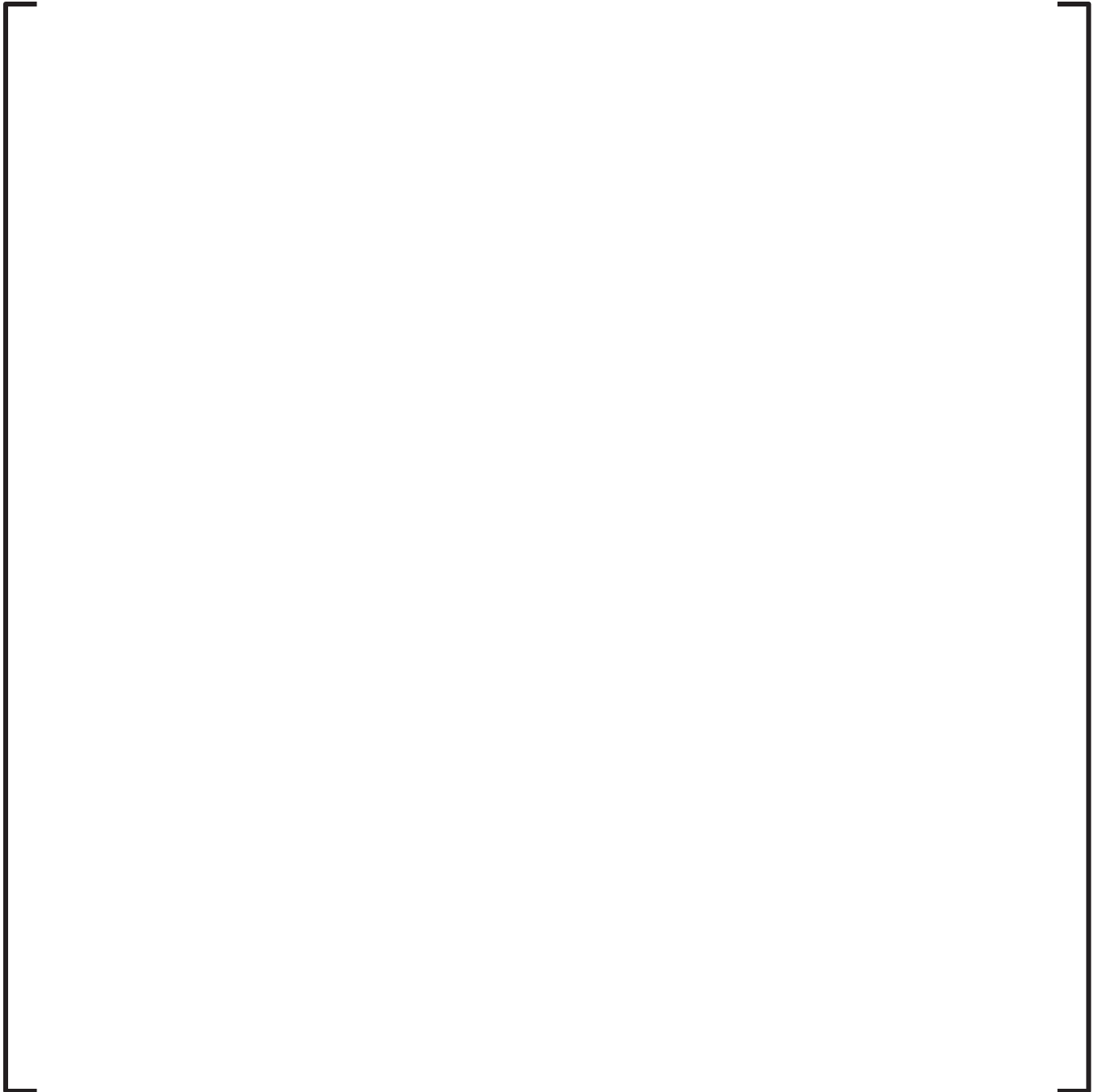


Figure D.12 [] Enrichment Distribution

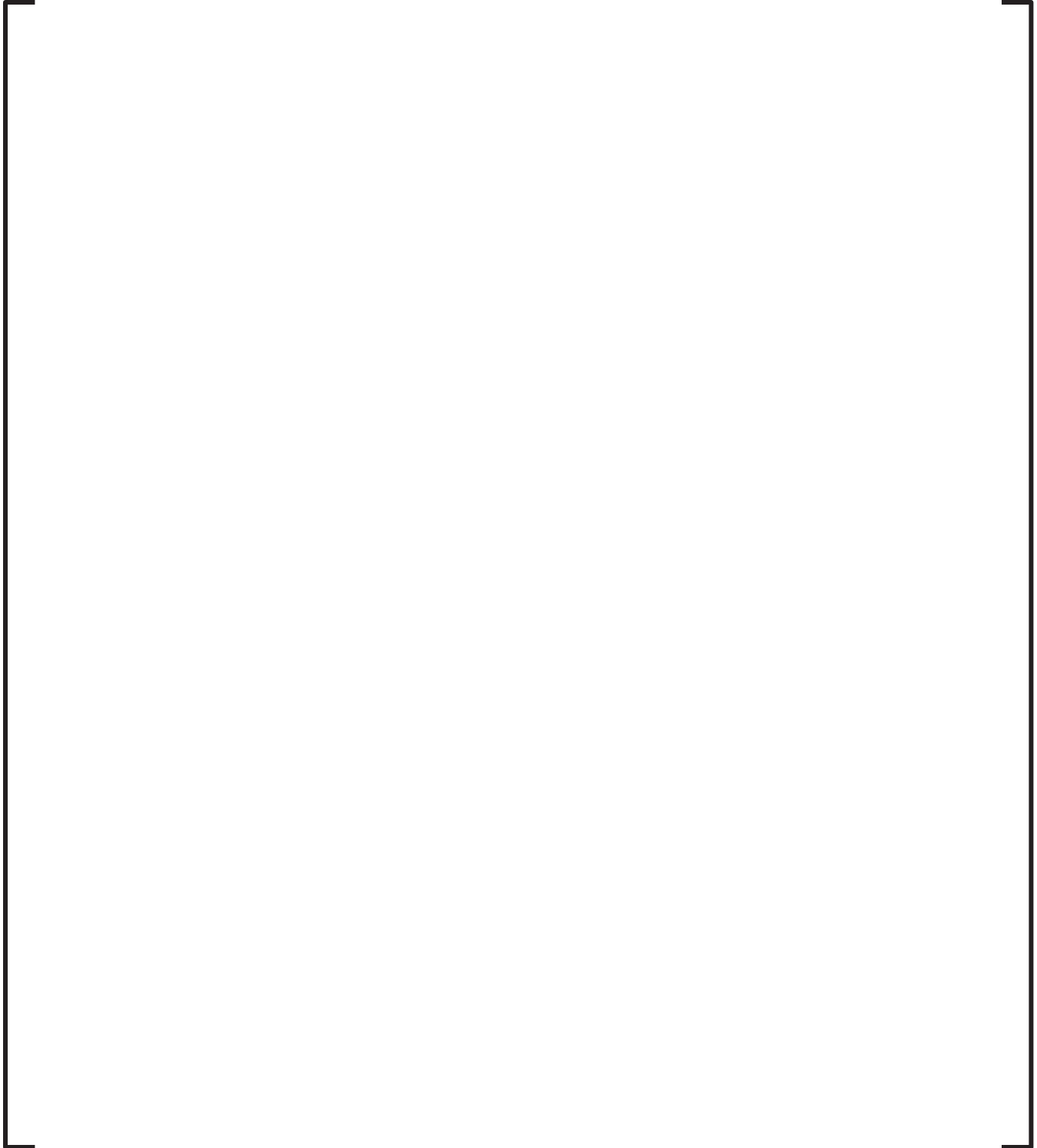


Figure D.13 [] Enrichment Distribution

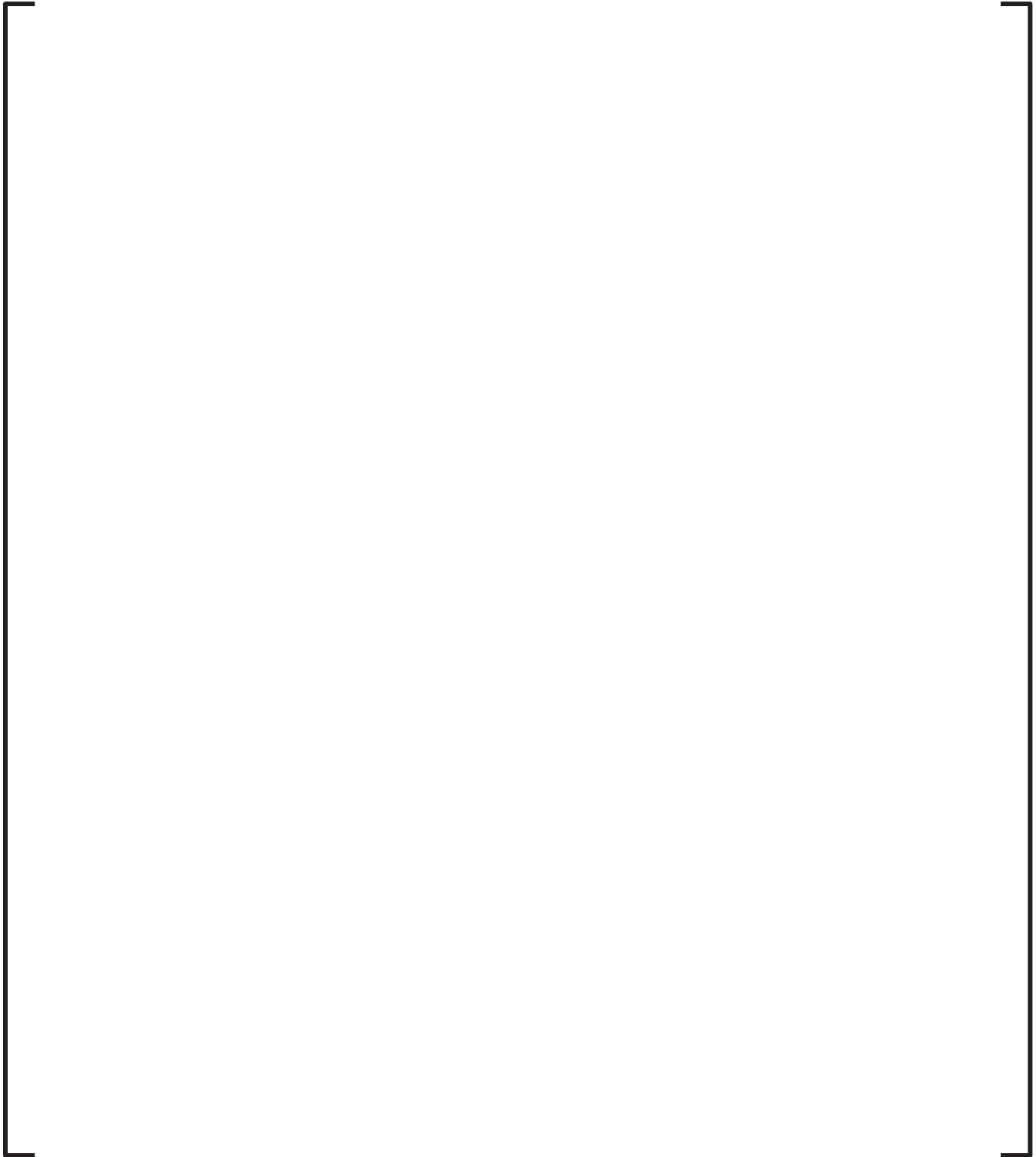


Figure D.14 [

] Enrichment Distribution

Figure D.15 [

] Enrichment Distribution

Figure D.16 [

] Enrichment Distribution

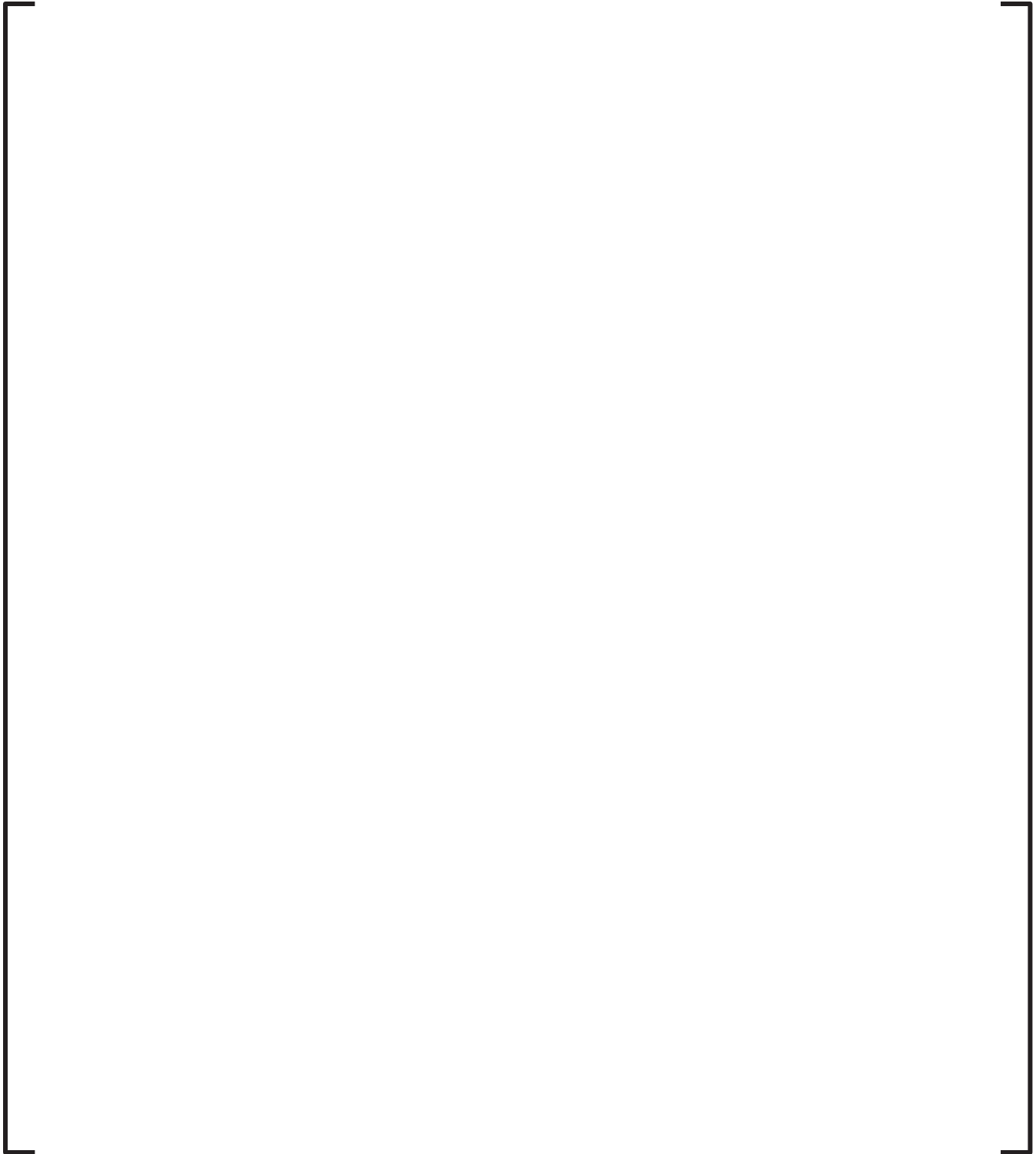


Figure D.17 [

] Enrichment Distribution

Figure D.18 [

] Enrichment Distribution

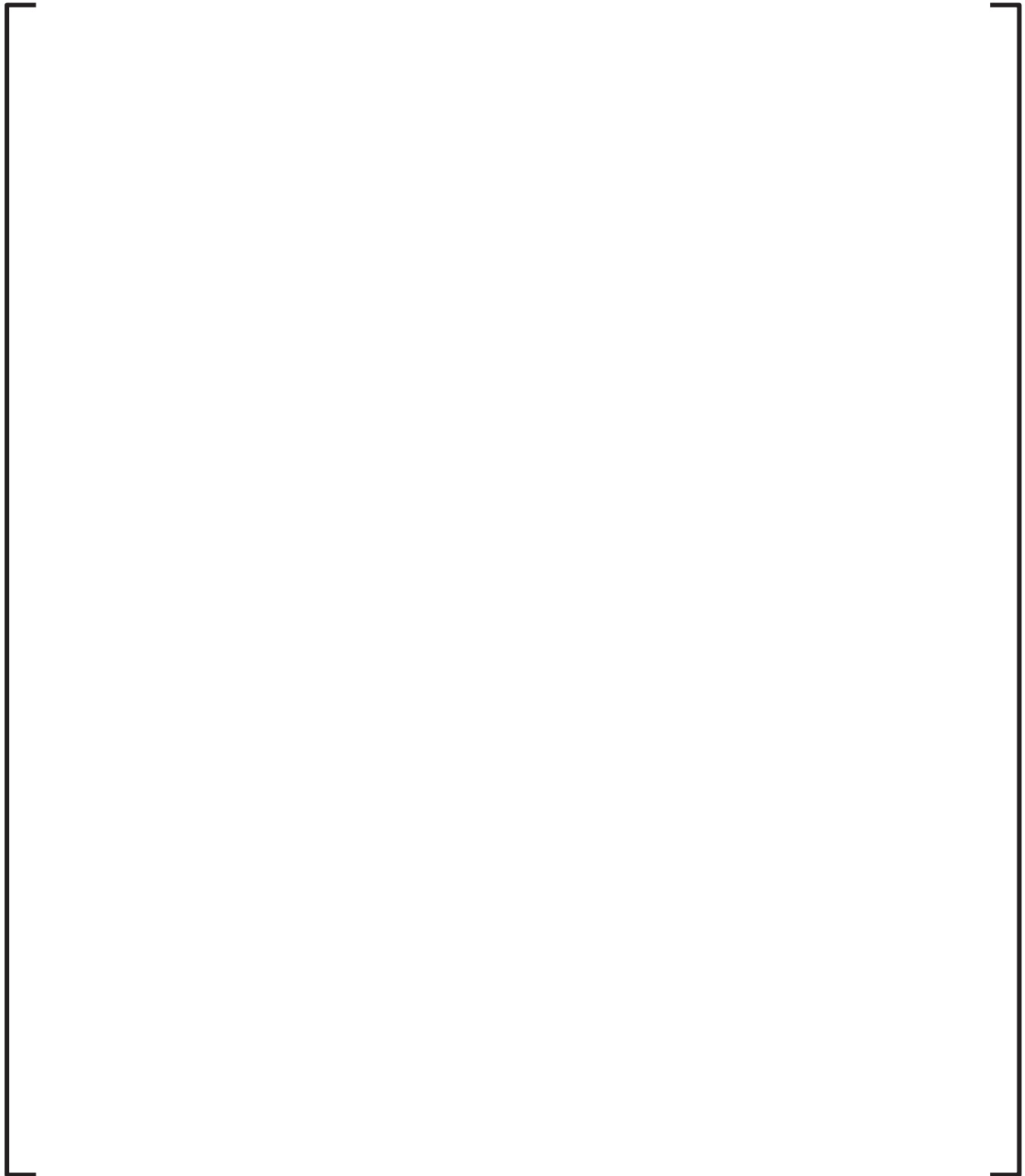


Figure D.19 [

] Enrichment Distribution



Figure D.20 [] Enrichment Distribution

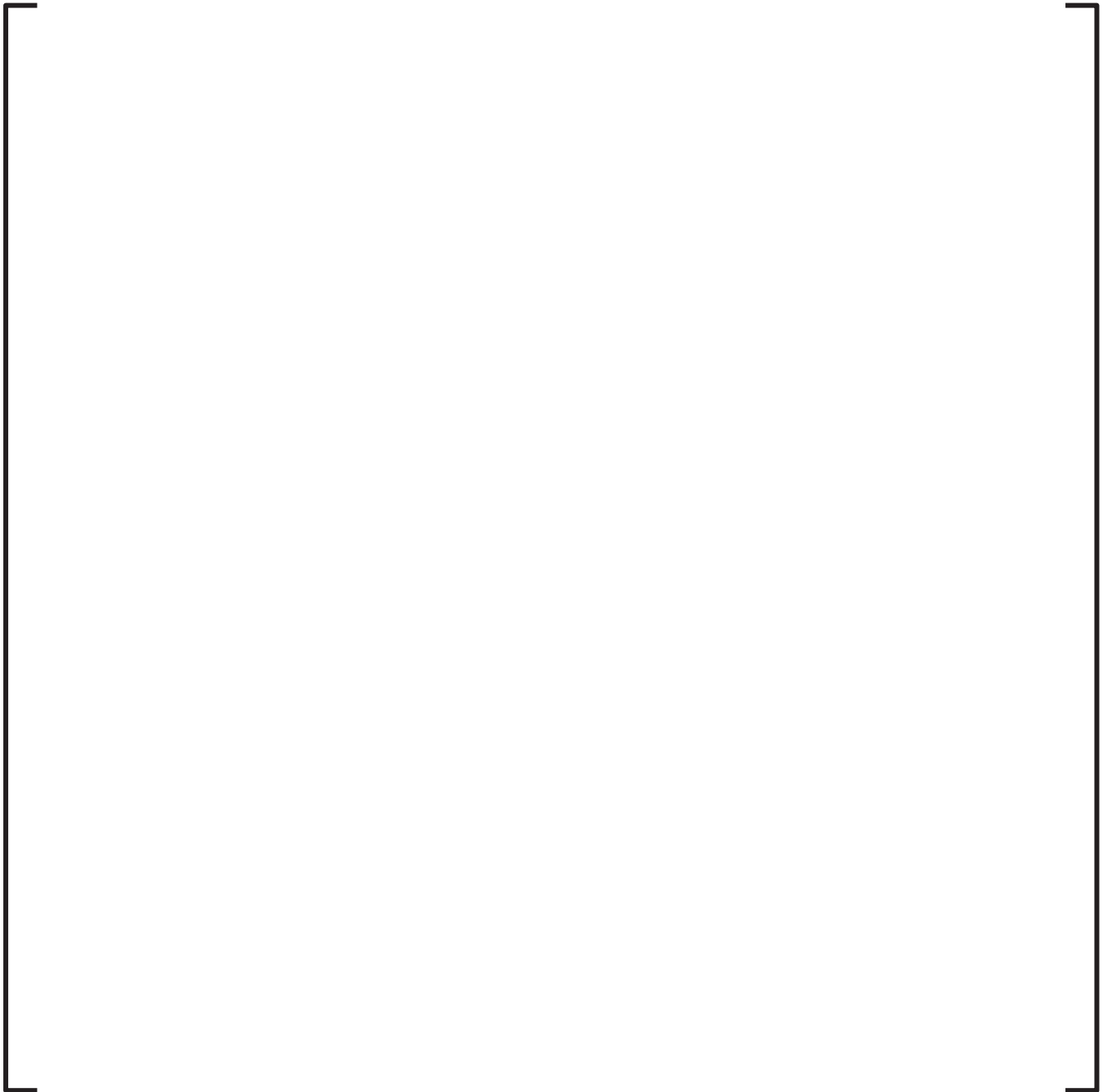


Figure D.21 [] Enrichment Distribution

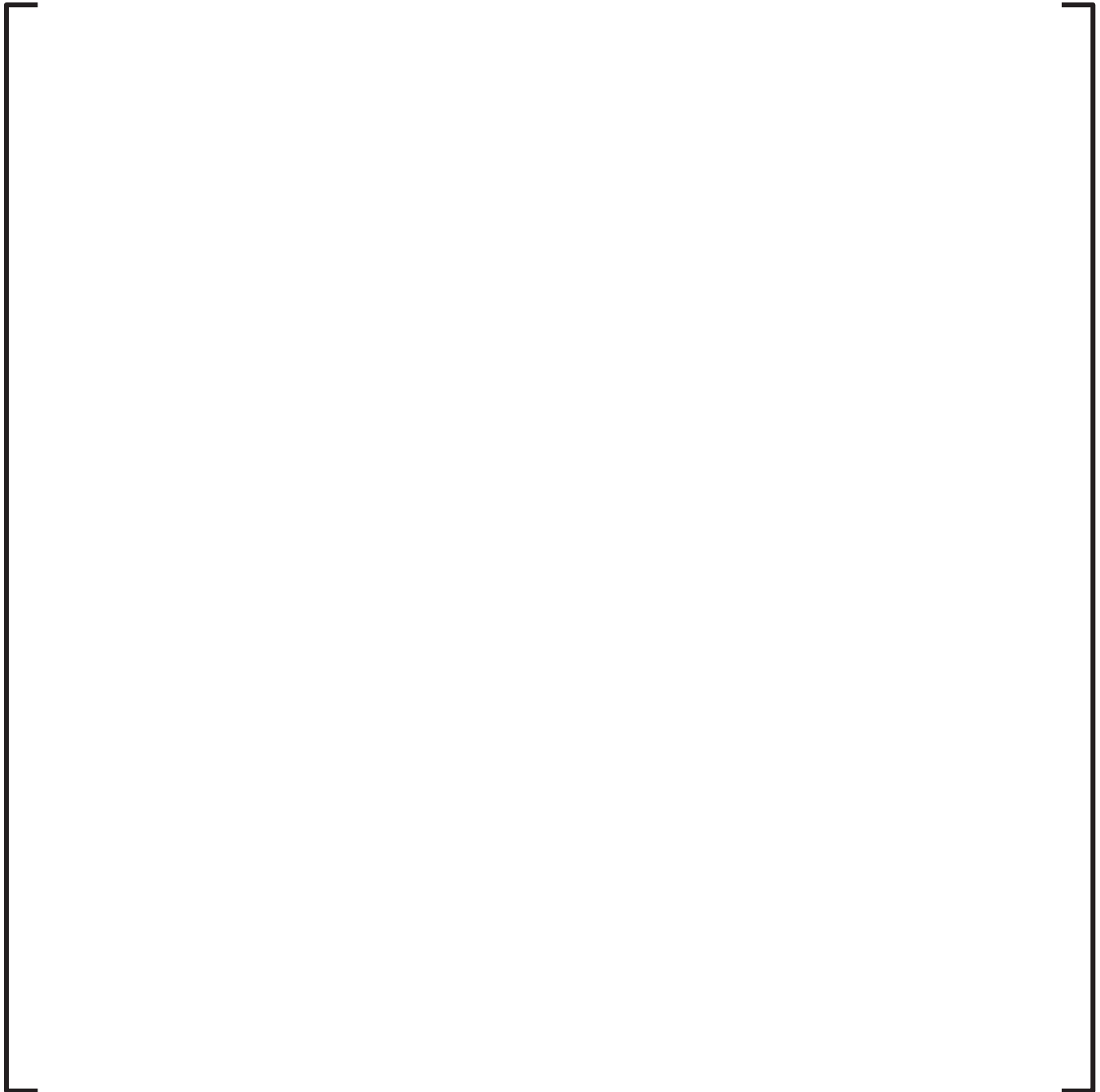


Figure D.22 [] Enrichment Distribution

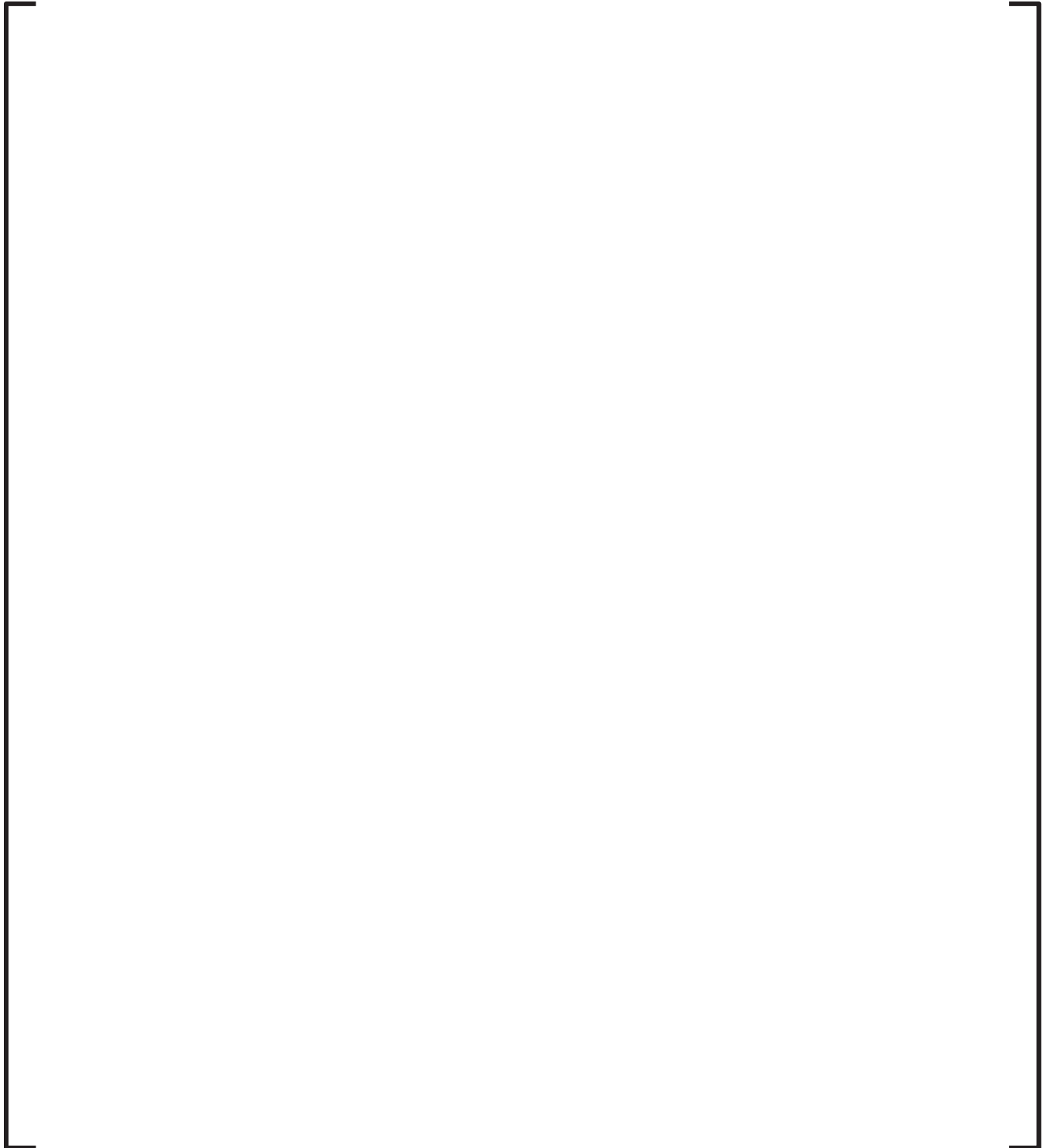


Figure D.23 [] Enrichment Distribution

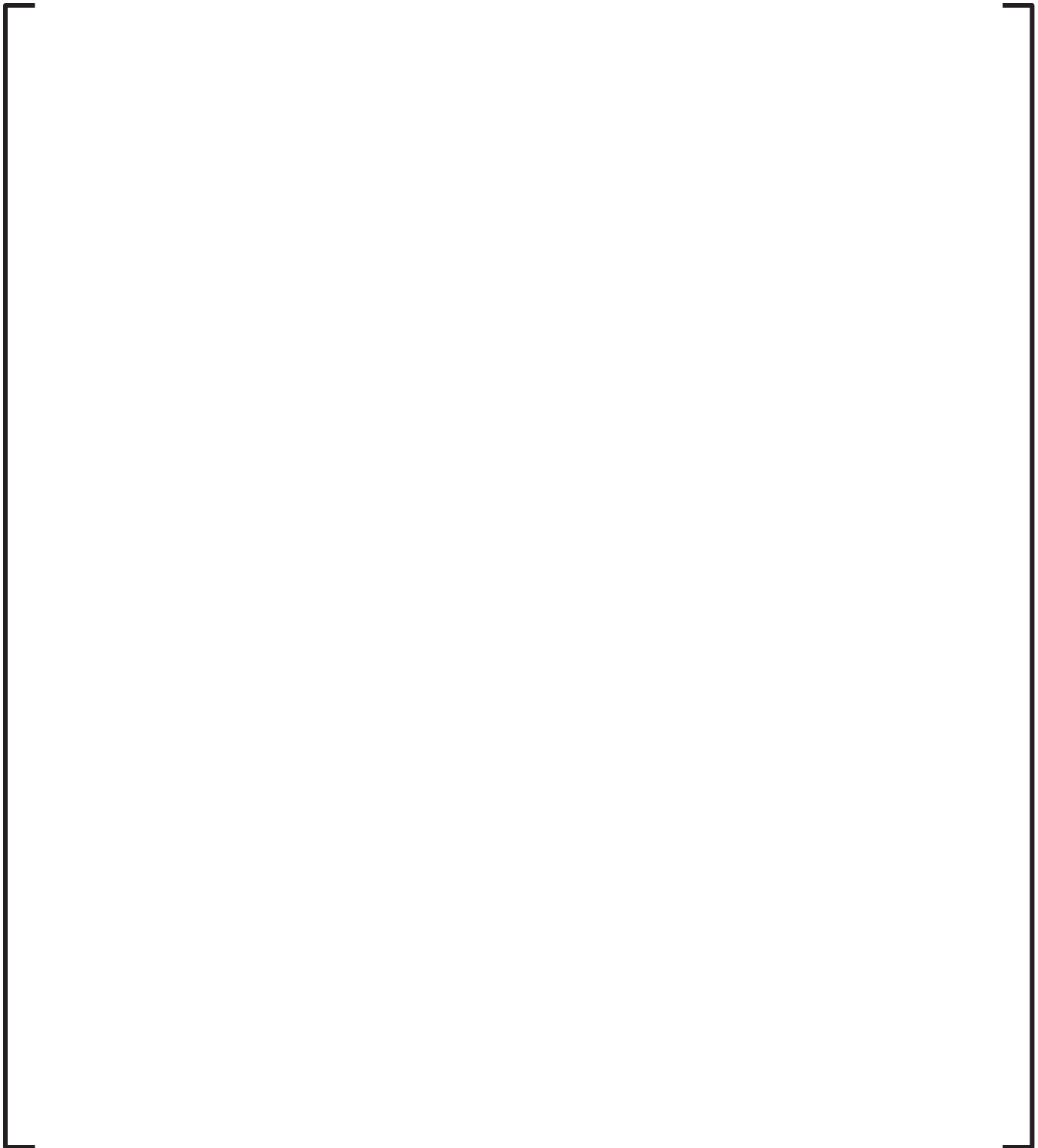


Figure D.24 [

] Enrichment Distribution

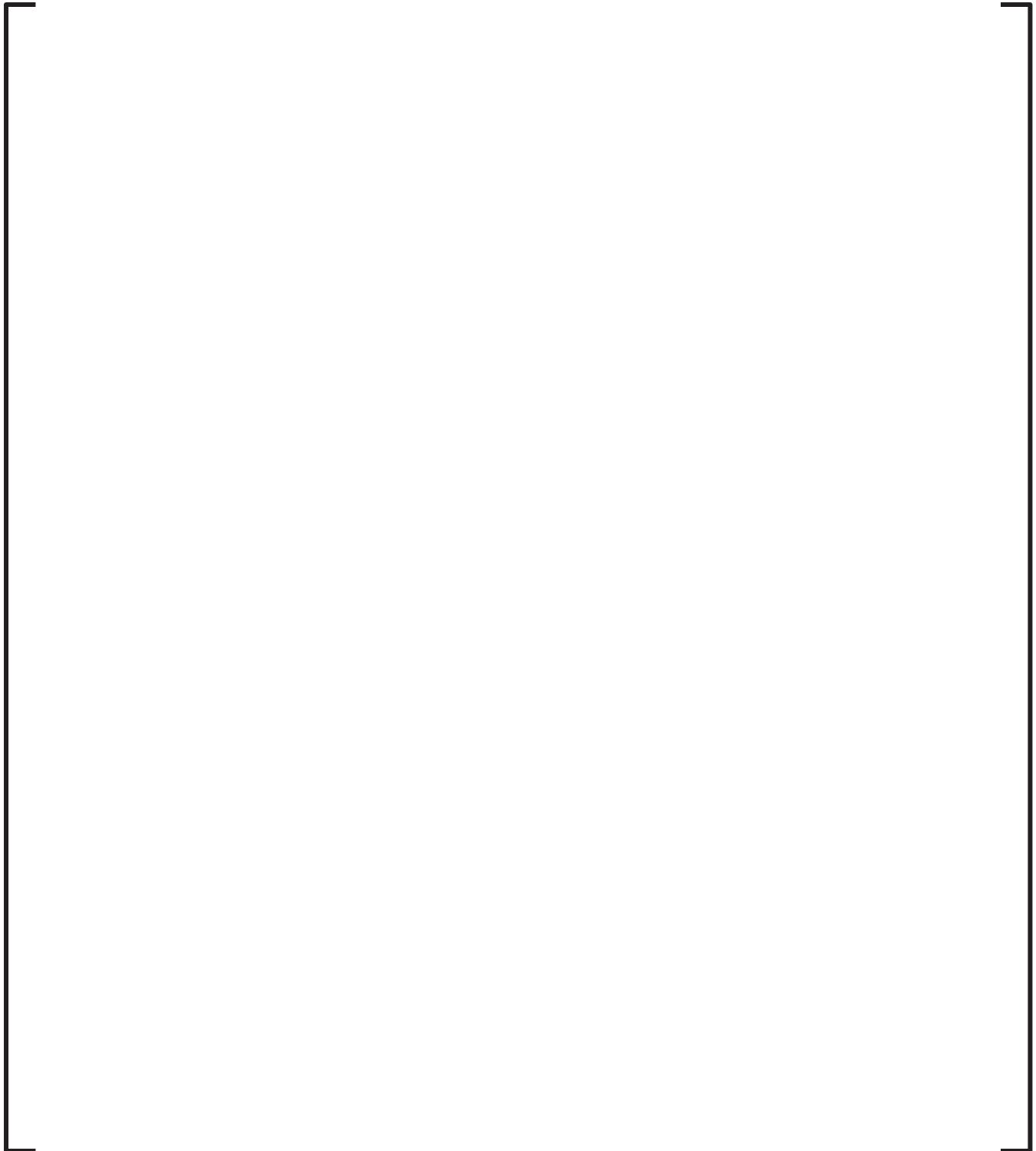


Figure D.25 [

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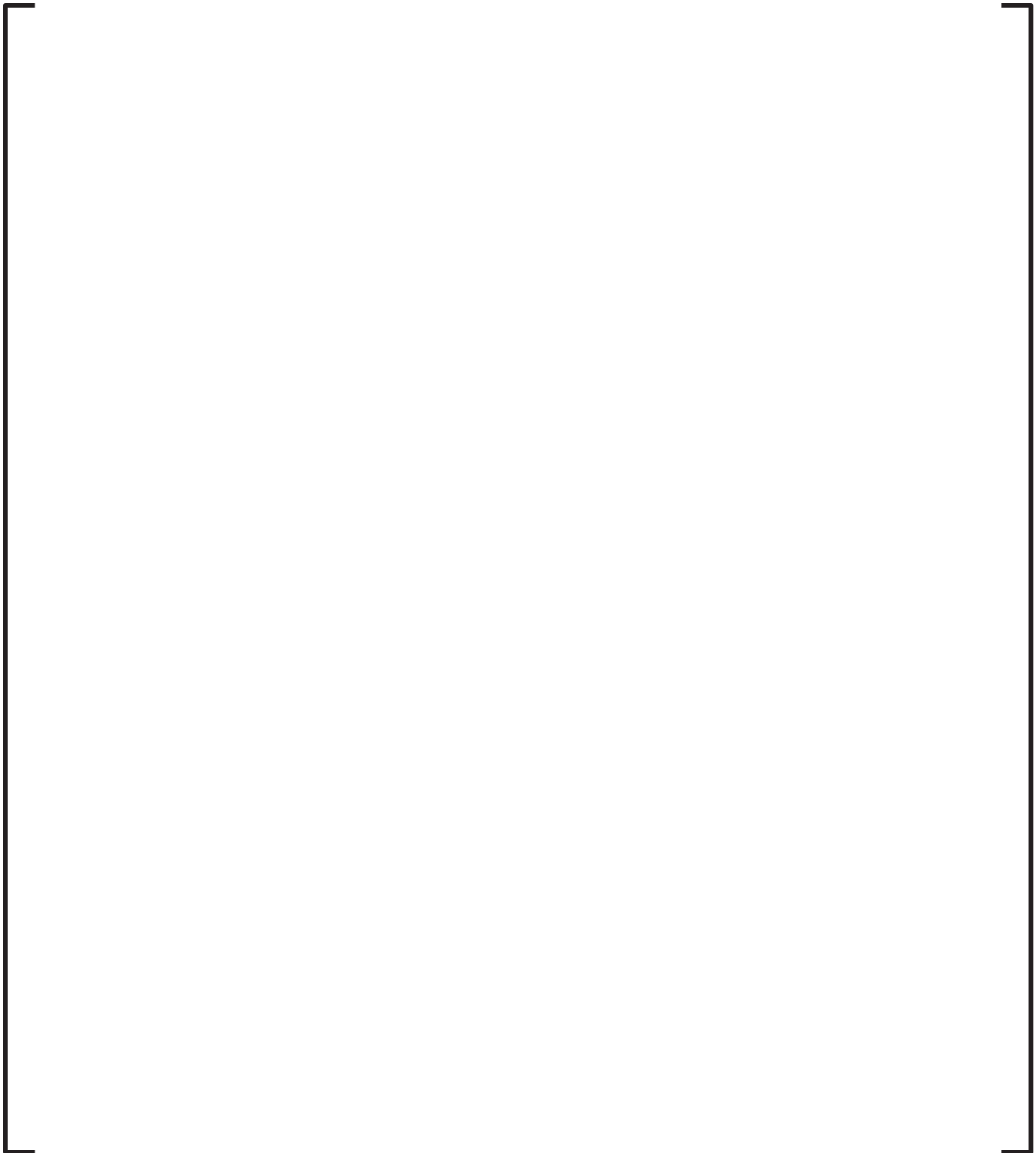


Figure D.26 [

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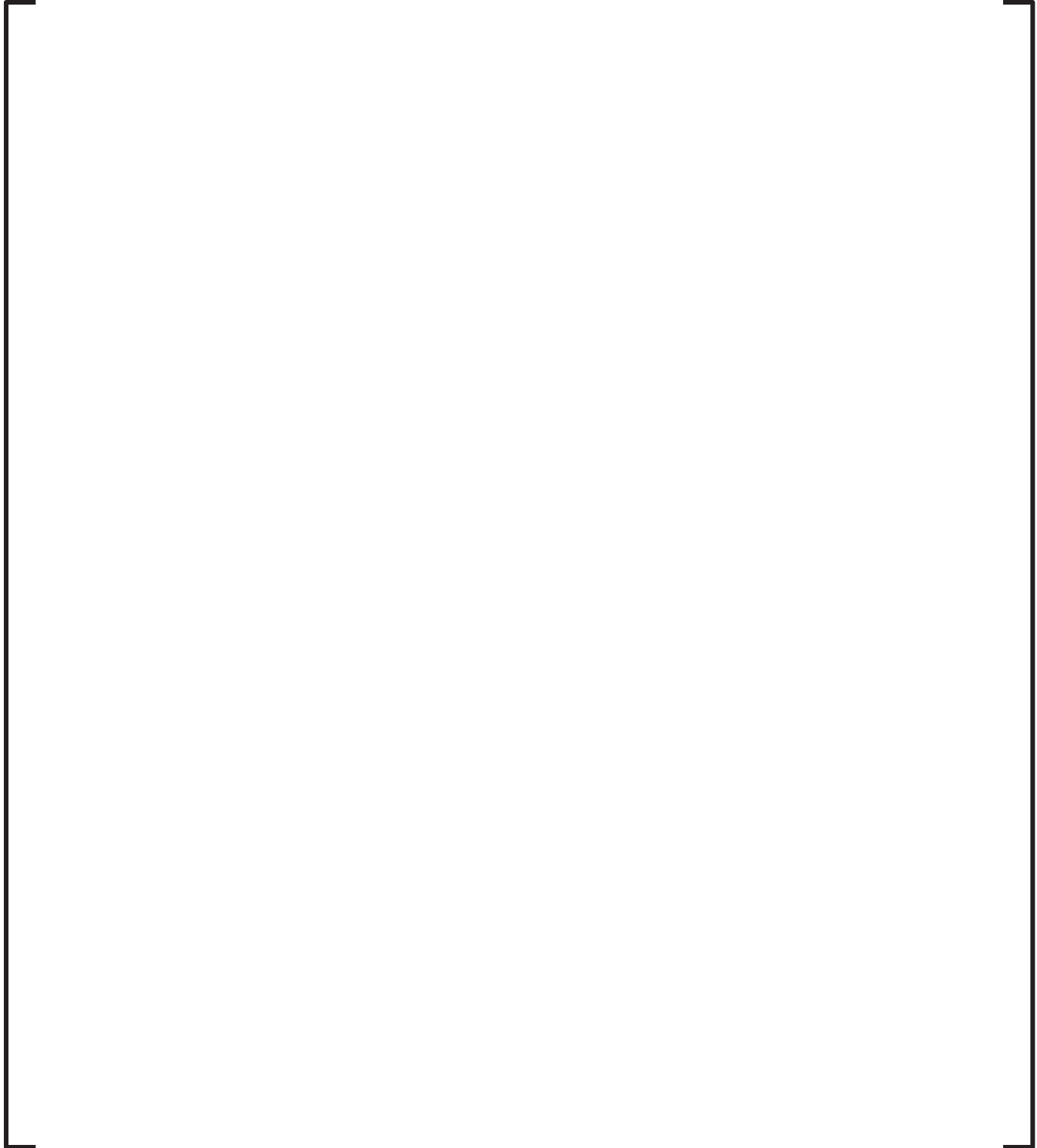


Figure D.27 [

] Enrichment Distribution

Figure D.28 [

] Enrichment Distribution



Figure D.29 [] Enrichment Distribution

ATTACHMENT 8a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3860P Revision 0

(Proprietary)

Mechanical Design Report for Browns Ferry ATRIUM 11 Fuel Assemblies

ATTACHMENT 8b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

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Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
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ANP-3860NP Revision 0

(Non Proprietary)

Mechanical Design Report for Browns Ferry ATRIUM 11 Fuel Assemblies



Mechanical Design Report for Browns Ferry ATRIUM 11 Fuel Assemblies

ANP-3860NP
Revision 0

Licensing Report

April 2021

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

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Nomenclature

Acronym	Definition
AFC	Advanced fuel channel
AOO	Anticipated operational occurrences
ARS	Acceleration response spectra
ASME	American Society of Mechanical Engineers
B&PV	Boiler and pressure vessel
BQ	Beta-quench
BWR	Boiling water reactor
ELC	Enhanced load chain
EOL	End of life
HALC	Harmonized advanced load chain
LTA	Lead test assembly
LOCA	Loss-of-coolant accident
LTP	Lower tie plate
MWd/kgU	Megawatt-days per kilogram of Uranium
NRC	U. S. Nuclear Regulatory Commission
PLFR	Part-length fuel rods
SRP	Standard review plan
UTP	Upper tie plate
Z4B	Proprietary Zircaloy BWR material similar to Zircaloy-4
Zry-4	Zircaloy-4
Zry-2	Zircaloy-2
3GFG	3rd Generation FUELGUARD

1.0 INTRODUCTION

This report documents the successful completion of all licensing analyses and related testing necessary to verify that the mechanical design criteria are met for the ATRIUM™ 11 Fuel Assemblies supplied by Framatome Inc. (Framatome) for insertion into Browns Ferry Units. This report also provides a description of the mechanical design and licensing methods. The scope of this report is limited to an evaluation of the mechanical design of the fuel assembly and fuel channel.

The ATRIUM 11 design is a Framatome advanced boiling water reactor (BWR) fuel design that builds on the history of proven ATRIUM family of fuel designs. The design uses an 11x11 fuel array, a [] fuel rod, a central water channel that displaces a 3x3 array of rods and is made from an advanced Zirconium alloy Z4B material, a modular lower tie plate with a 3rd generation FUELGUARD and nine ULTRAFLOW spacer grids [] .

The fuel assembly design was evaluated according to the Framatome BWR generic mechanical design criteria (Reference 1). The fuel channel design was evaluated to the criteria given in the fuel channel topical reports (References 2 and 3). The generic design criteria have been approved by the U.S. Nuclear Regulatory Commission (NRC) and the criteria are applicable to the subject fuel assembly and channel design. Mechanical analyses have been performed using NRC-approved design analysis methodology (References 1, 2, 3 and 4). The methodology permits maximum licensed assembly and fuel channel exposures of [] (Reference 4, Section 1.0).

The fuel assembly and fuel channel meet all mechanical compatibility requirements for use in Browns Ferry Units. This includes compatibility with both co-resident fuel and the reactor core internals.

2.0 DESIGN DESCRIPTION

This section provides a design description of the ATRIUM 11 fuel assembly and fuel channel. Reload-specific design information is available in the design package provided by Framatome for each reload delivery.

2.1 Overview

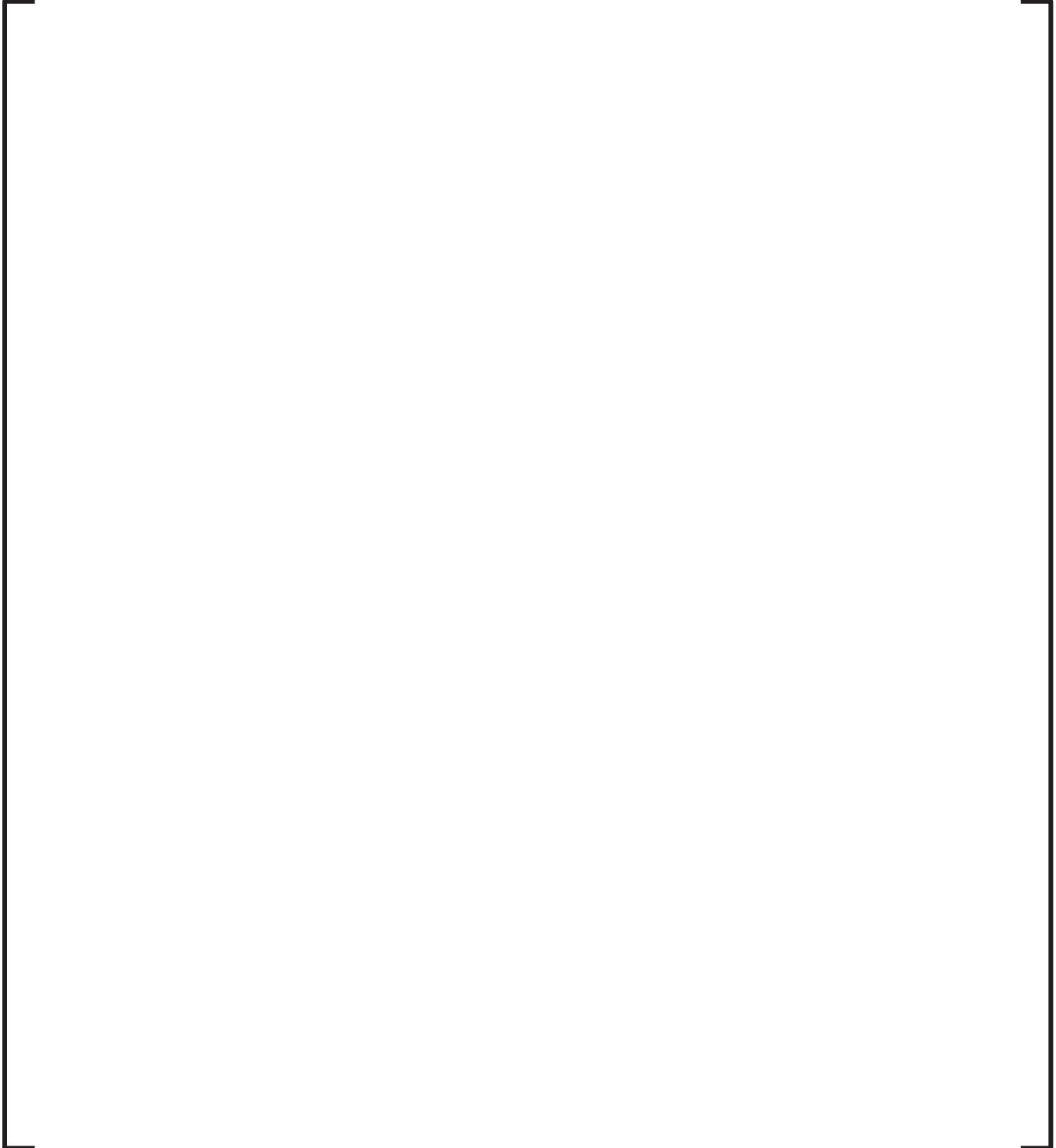
Browns Ferry has successfully operated for several cycles with reload quantities of ATRIUM-10 and ATRIUM 10XM fuel assemblies. Browns Ferry will operate with ATRIUM 11 fuel assemblies in reload quantities starting with Browns Ferry Unit 2 Cycle 23. The ATRIUM 11 bundle consists of an 11x11 fuel lattice with a square internal water channel that displaces a 3x3 array of rods.

The ATRIUM 11 incorporates key design features relative to previous ATRIUM designs as described in Reference 5.

Table 2-1 lists the key design parameters of the ATRIUM 11 fuel assembly.

2.1.1 Fuel Assembly

Figure 2-1 provides an illustration of the fuel assembly, and Table 2-1 lists the main fuel assembly attributes. The fuel assembly is accompanied by a fuel channel, as described later in this section.



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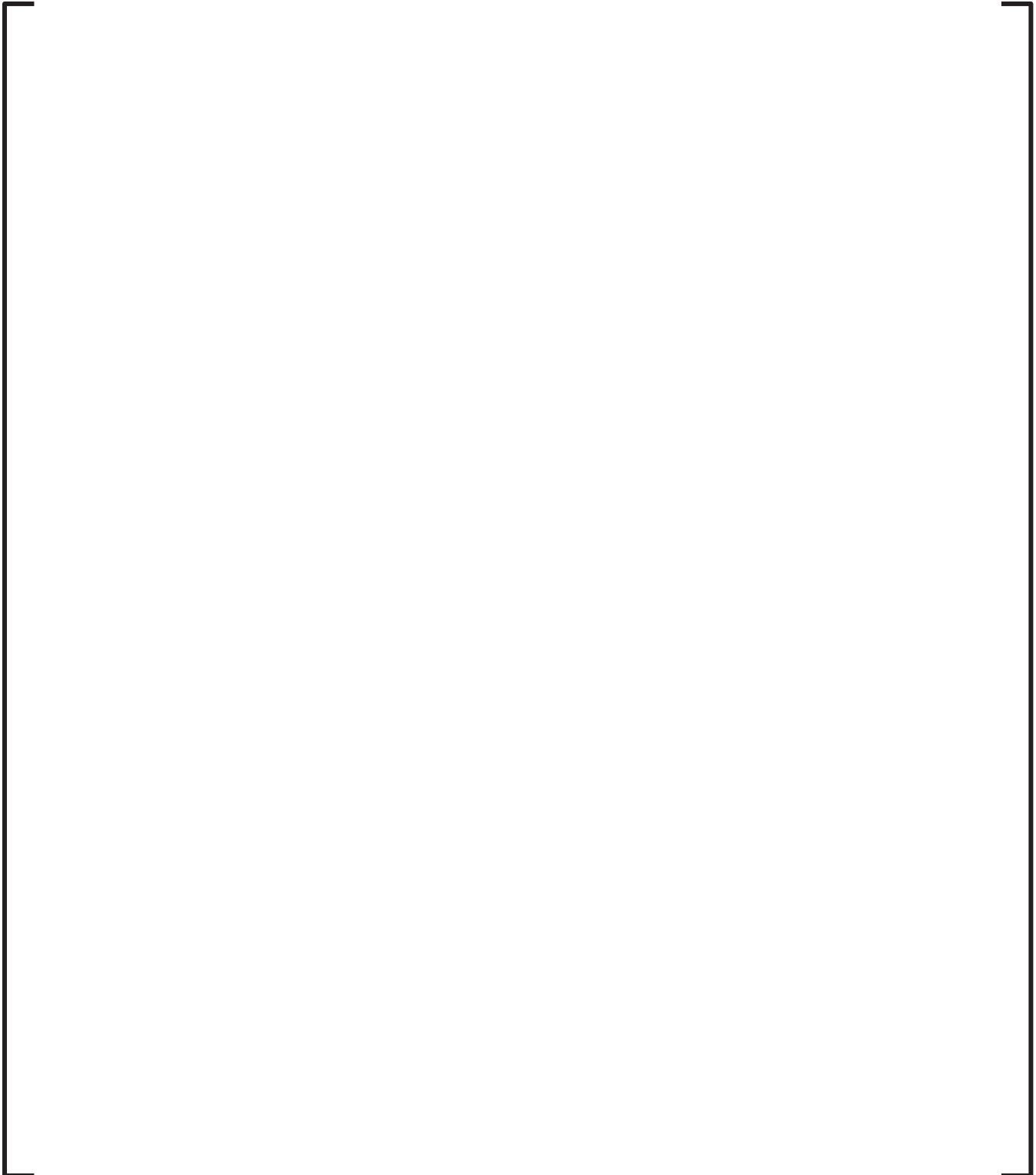
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2.1.2 Upper Tie Plate and Connecting Hardware

Figure 2-2 provides an illustration of the UTP and connecting hardware.



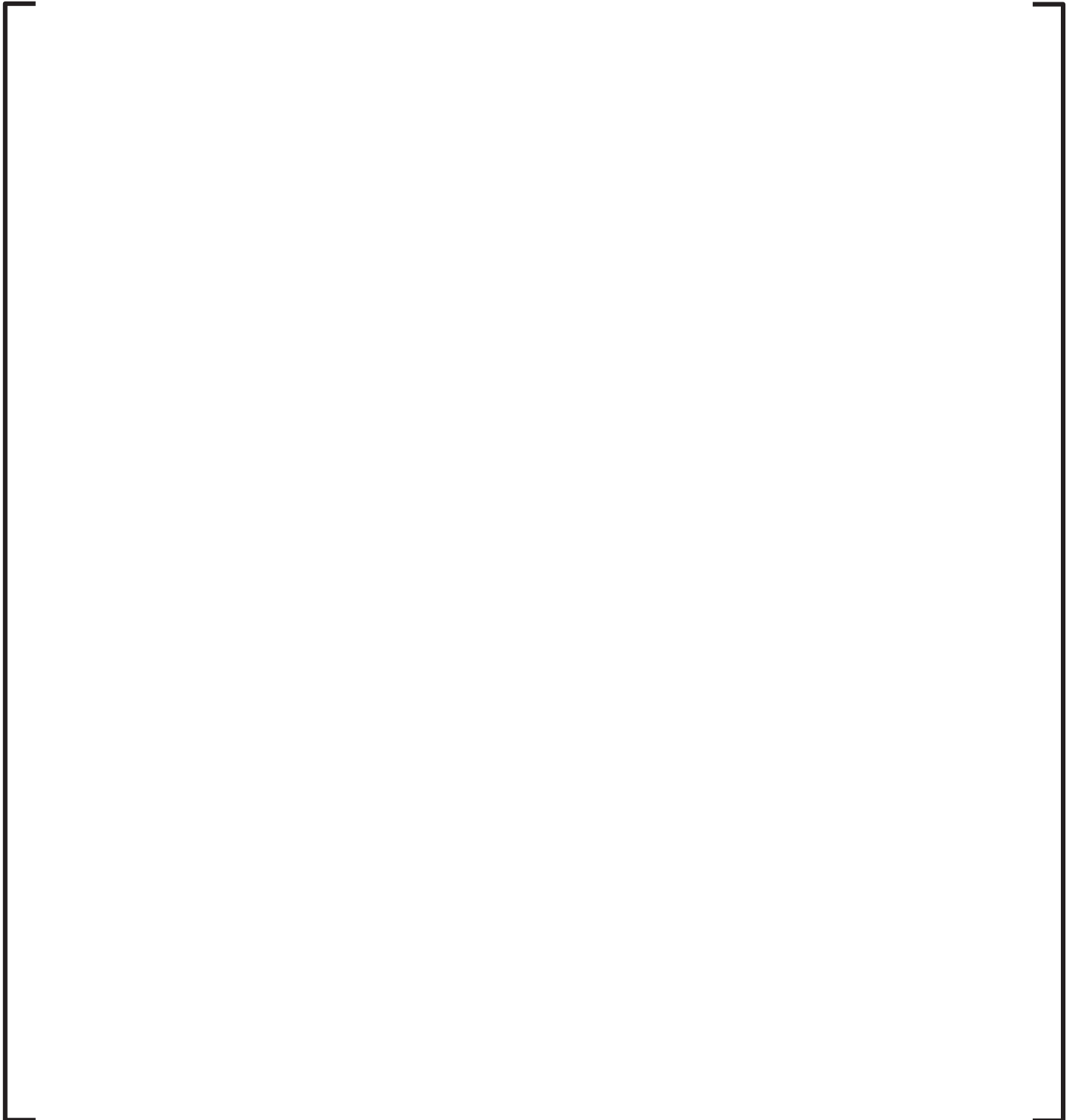
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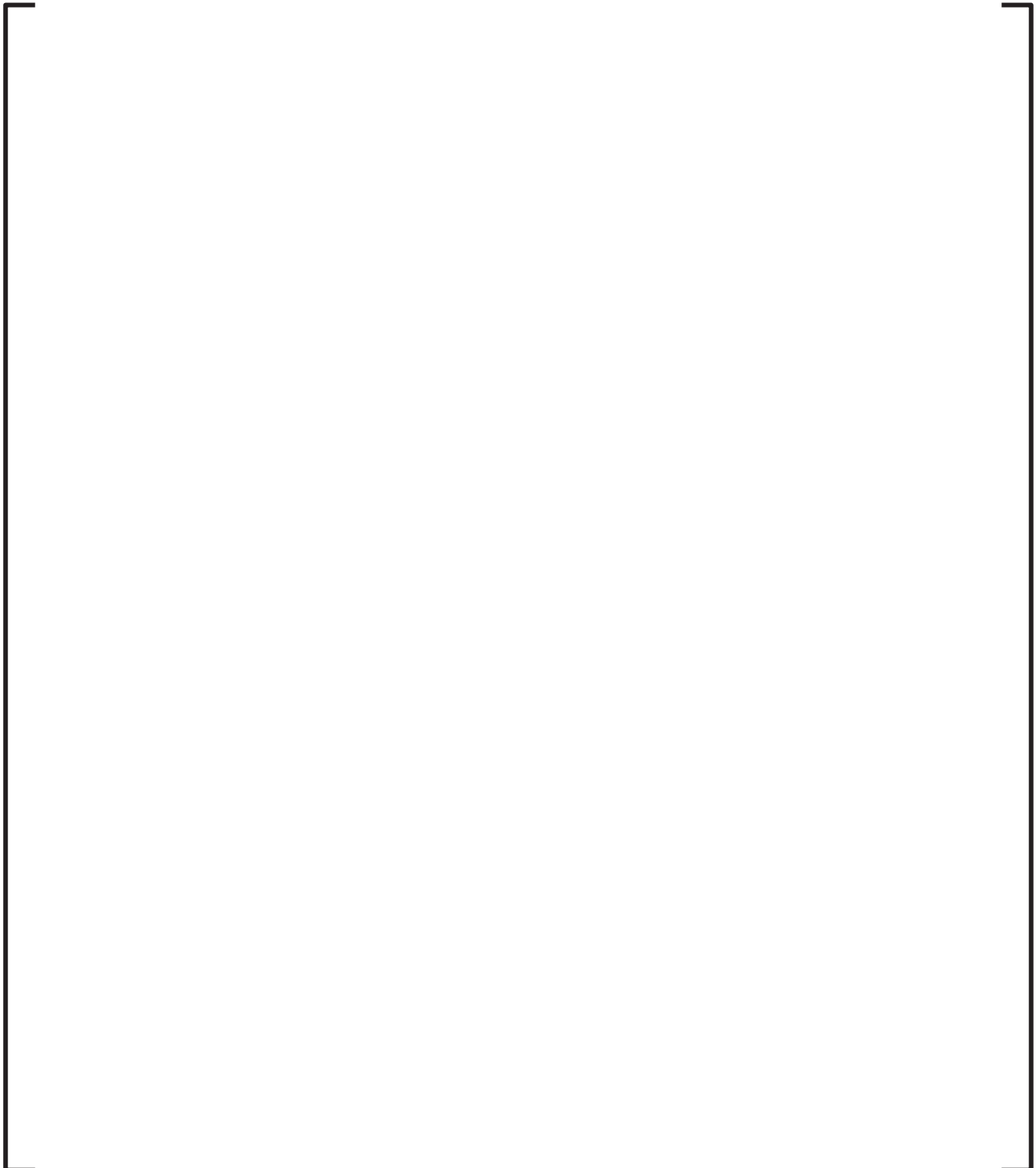
2.1.3 Water Channel

Figure 2-1 and Figure 2-2 provides an illustration of the water channel, and Table 2-1 lists the main water channel attributes.



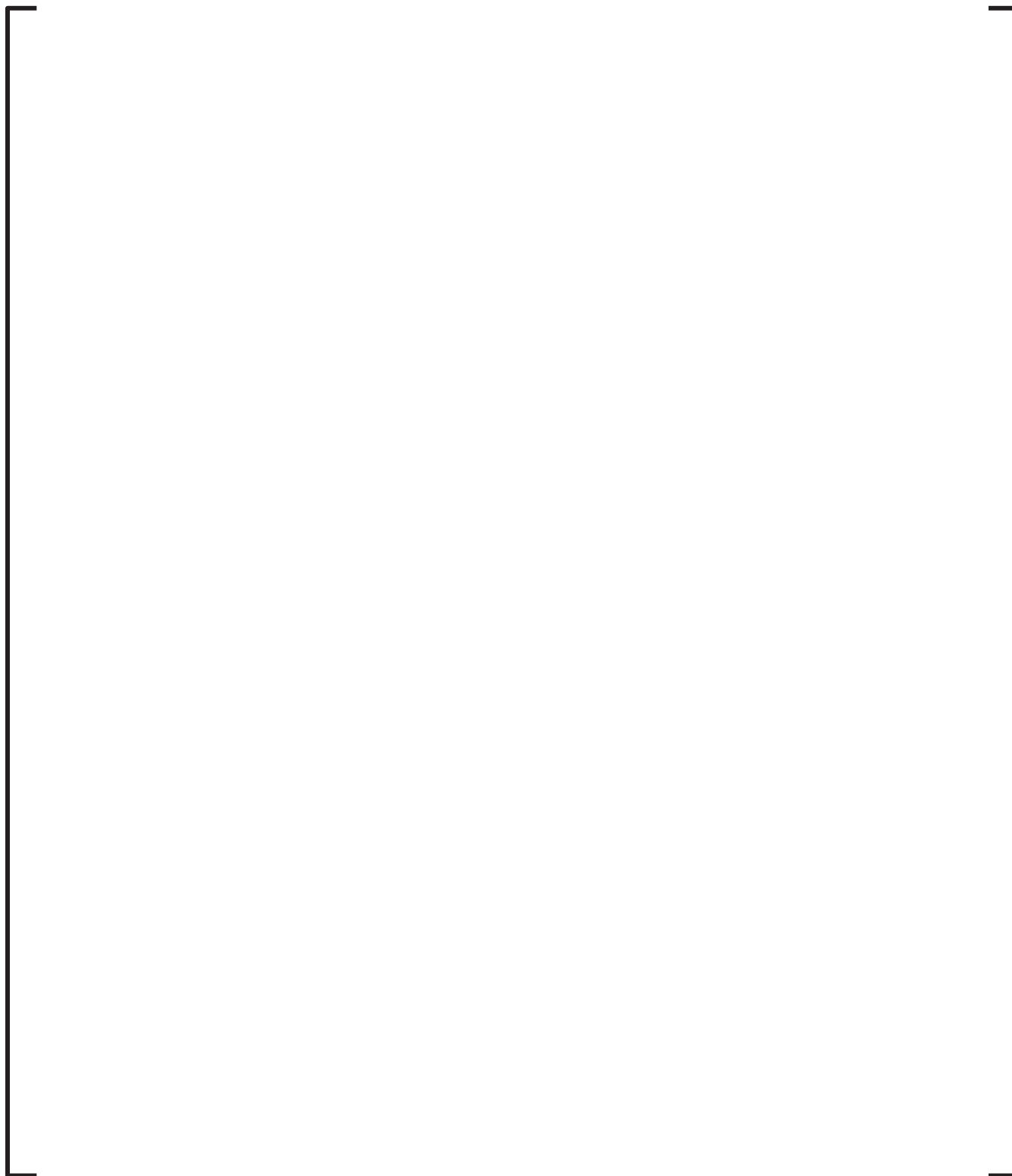
2.1.4 Spacer Grid

Figure 2-3 provides illustration of the spacer grid, and Table 2-1 lists the main spacer grid attributes.



2.1.5 Lower Tie Plate

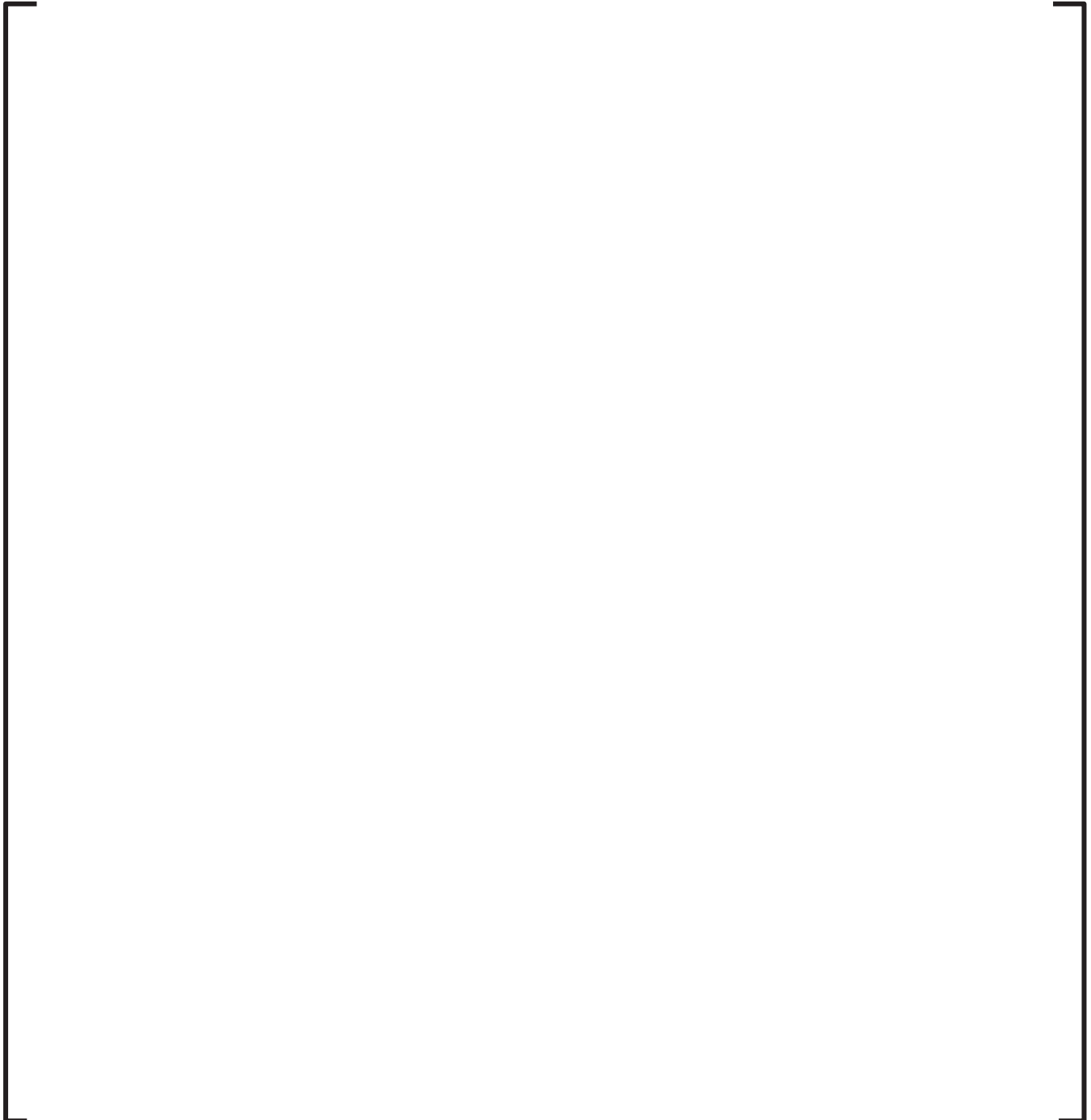
Figure 2-4 provides an illustration of the 3GFG FUELGUARD.





2.1.6 Fuel Rods

This mechanical design report documents the fuel structural analyses. The fuel rod thermal-mechanical report provides fuel rod design description detail. Figure 2-5 provides an illustration of the full-length and the two part-length fuel rods.



2.2 *Fuel Channel and Components*

Figure 2-6 provides an illustration of the fuel channel and components, and Table 2-2 lists the fuel channel component attributes.

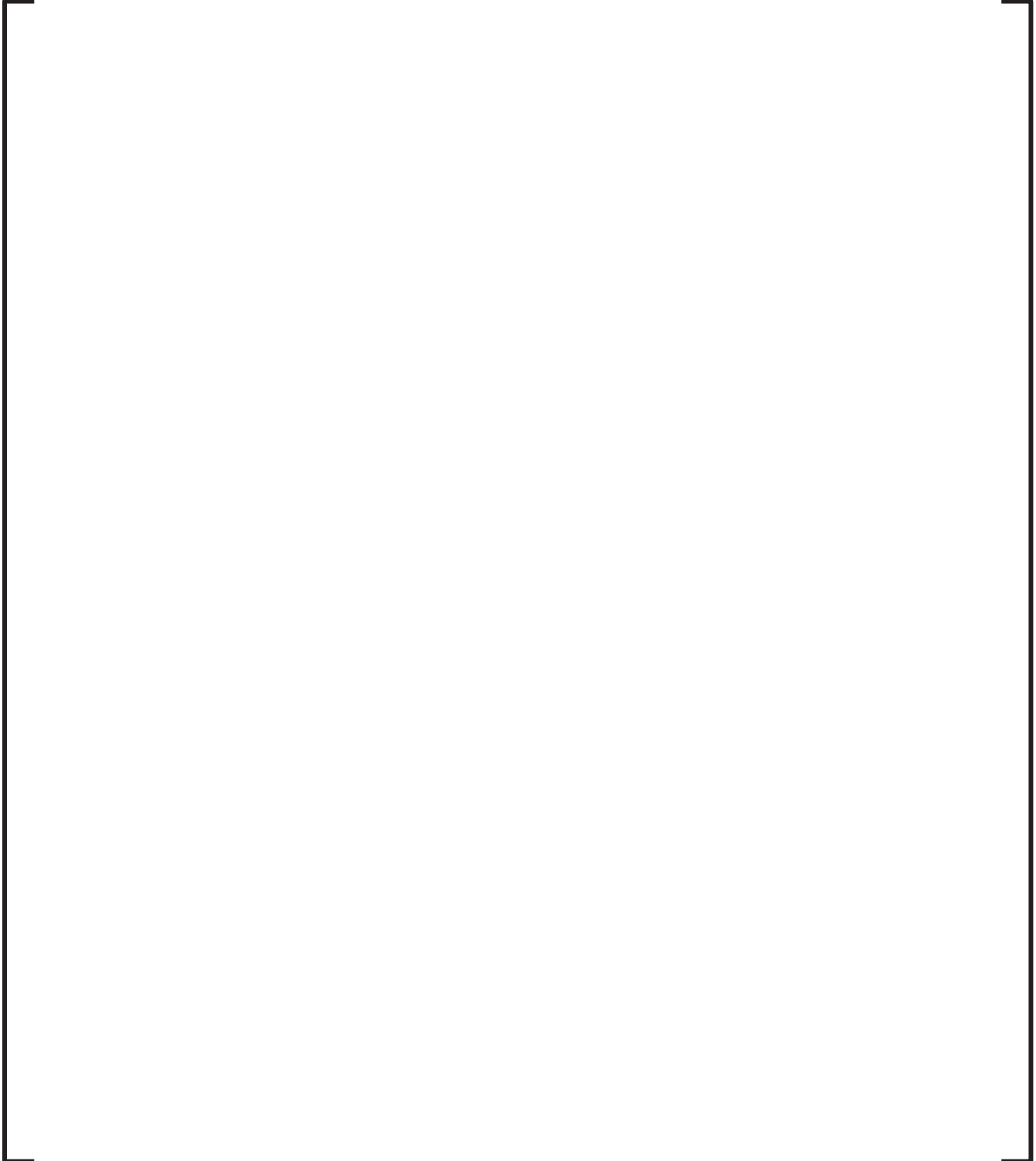




Table 2-1
Fuel Assembly and Component Description

Table 2-1
Fuel Assembly and Component Description
(Continued)

Table 2-2
Fuel Channel and Channel Spacer Assembly Description

3.0 FUEL DESIGN EVALUATION

This section provides a summary of the mechanical methodology and results from the structural design evaluations. Results from the mechanical design evaluation demonstrate that the design satisfies the mechanical criteria to the analyzed exposure limit. Sections 3.1 through 3.4 correspond to the fuel assembly criteria sections within Section 3.0 of Reference 1. Section 3.5 and Table 3-2 corresponds to the advanced fuel channel criteria sections within Table 1.1 and 1.2 of Reference 2.

3.1 *Objectives*

The objectives of designing fuel assemblies (systems) to specific criteria are to provide assurance that:

- The fuel assembly (system) shall not fail as a result of normal operation and anticipated operational occurrences (AOOs). The fuel assembly (system) dimensions shall be designed to remain within operational tolerances, and the functional capabilities of the fuel shall be established to either meet or exceed those assumed in the safety analysis.
- Fuel assembly (system) damage shall never prevent control rod insertion when it is required.
- The number of fuel rod failures shall be conservatively estimated for postulated accidents.
- Fuel coolability shall always be maintained.
- The mechanical design of fuel assemblies shall be compatible with co-resident fuel and the reactor core internals.
- Fuel assemblies shall be designed to withstand the loads from handling and shipping.

The first four objectives are those cited in the Standard Review Plan (SRP). The latter two objectives are to assure the structural integrity of the fuel and the compatibility with the existing reload fuel. To satisfy these objectives, the criteria are applied to the fuel rod and the fuel assembly (system) designs. Specific component criteria are also necessary to assure compliance. The criteria established to meet these objectives include those given in Chapter 4.2 of the SRP.

3.2 *Fuel Rod Evaluation*

The mechanical design report documents the fuel structural analyses only. The fuel rod evaluation will be documented in the fuel rod thermal-mechanical report. However, the fuel rod mechanical fracturing (Reference 1, Section 3.2.7) is evaluated in Section 3.4.4 *Structural Deformations*.

3.3 *Fuel System Evaluation*

The detailed fuel system design evaluation is performed to ensure the structural integrity of the design under normal operation, AOO, faulted conditions, handling operations, and shipping. The analysis methods are based on fundamental mechanical engineering techniques, often employing finite element analysis, prototype testing, and correlations based on in-reactor performance data. Summaries of the major assessment topics and associated testing are described in the sections that follow.

Prototype testing is an essential element of Framatome methodology for demonstrating compliance with structural design requirements. Results from design verification testing may directly demonstrate compliance with criteria or may be used as input to design analyses.

Testing performed to qualify the mechanical design or evaluate assembly characteristics includes:

- Fuel assembly axial load structural strength
- Fuel assembly fretting
- Fuel assembly static lateral deflection
- Fuel assembly lateral vibration
- Fuel assembly impact
- Spacer grid lateral impact strength
- Tie plate lateral load strength

3.3.1 Stress, Strain, or Loading Limits on Assembly Components

The structural integrity of the fuel assemblies is assured by setting design limits on stresses and deformations due to various handling, operational, AOOs, and accident or faulted loads.

Framatome uses Section III of the American Society of Mechanical Engineers (ASME) boiler and pressure vessel (B&PV) code as a guide to establish acceptable stress, deformation, and load limits for standard assembly components. These limits are applied to the design and evaluation of the UTP, LTP, spacer grids, springs, and load chain components, as applicable.

All significant loads experienced during normal operation, AOOs, and under faulted conditions are evaluated to confirm the structural integrity of the fuel assembly components. Outside of faulted conditions, most structural components are under the most limiting loading conditions during fuel handling. See Section 3.3.9 for a discussion of fuel handling loads and Section 3.4.4 for the structural evaluation of faulted conditions. Although normal operation and AOO loads are often not limiting for structural components, a stress evaluation may be performed to confirm the design margin and to establish a baseline for adding accident loads. The stress calculations use conventional, open-literature equations. A general-purpose, finite element stress analysis code, such as ANSYS, may be used to calculate component stresses.

3.3.2 Fatigue

Section addressed in the fuel rod thermal-mechanical report.

3.3.3 Fretting Wear

Fuel rod failures due to grid-to-rod fretting shall not occur. [

].

Fretting wear is evaluated by testing, as described in Section 3.3.3.1. The testing is conducted by [

]. The inspection measurements for wear are documented. The lack of significant wear demonstrates adequate rod restraint geometry at the contact locations. Also, the lack of significant wear at the spacer cell locations [] provides further assurance that no significant fretting will occur at higher exposure levels.

3.3.3.1 Fuel Assembly Fretting Test

A fretting test was conducted on a full-size test assembly to evaluate the ATRIUM 11 fuel rod support design. [

]. After the test, the assembly was inspected for signs of fretting wear. No significant wear was found on fuel rods in contact with spacer springs [

]. The results agree with past test results on BWR designs where no noticeable wear was found on the fuel rods or other interfacing components following exposure to coolant flow conditions.

3.3.4 Oxidation, Hydriding, and Crud Buildup

Section addressed in the fuel rod thermal-mechanical report.

3.3.5 Rod Bow

The predicted rod-to-rod gap closure due to bow is assessed by thermal hydraulics group for impact on thermal margins.

Differential expansion between the fuel rods and cage structure, and lateral thermal and flux gradients can lead to lateral creep bow of the rods in the spans between spacer grids. This lateral creep bow alters the pitch between the rods and may affect the peaking and local heat transfer. The Framatome design criterion for fuel rod bowing is [

].

Visual exams on ATRIUM 11 have not revealed any unusual fuel rod bow behavior for exposures up to [] based on the latest experience from Lead Test Assembly post-irradiation exams. This exposure is beyond the threshold where increasing rod bow had been observed on other designs. Therefore, the ATRIUM 11 fuel design has been shown to have minimal rod bow. A rod gap closure ratio curve is provided in Reference 4.

3.3.6 Axial Irradiation Growth

Reference 4 requires [

].

The fuel rod growth correlation is established from [

].

Assembly growth is established from ATRIUM 10x10 and 11x11 arrayed fuel assemblies with water channels made of Z4B material. It is based on the ATRIUM fuel assembly growth data only and excludes designs with load bearing tie rods as well as the European bundle-in-basket designs. [

].

The fuel rod and assembly growth approved correlations are described within Reference 4 along with the respective tolerance limits.

3.3.7 Rod Internal Pressure

Section addressed in the fuel rod thermal-mechanical report.

3.3.8 Assembly Lift-off

Fuel assembly lift-off is evaluated under both normal operating conditions (including AOOs) and under faulted conditions. The fuel shall not levitate under normal operating or AOO conditions. Under postulated accident conditions, the fuel shall not become disengaged from the fuel support. These criteria assure control blade insertion is not impaired.

For normal operating conditions, the net axial force acting on the fuel assembly is calculated by adding the loads from gravity, hydraulic resistance from coolant flow, difference in fluid flow entrance and exit momentum, and buoyancy. The calculated net force is confirmed to be in the downward direction, indicating no assembly lift-off. [

].

Mixed core conditions for assembly lift-off are considered on a cycle-specific basis, as determined by the plant operating conditions and other fuel types. Analyses to date indicate a large margin to assembly lift-off under normal operating conditions.

For faulted conditions, [

]. The fuel will not lift under normal or AOO

conditions, it will not become disengaged from the fuel support under faulted conditions, nor block insertion of the control blade in all operating conditions.

3.3.9 Fuel Assembly Handling

The fuel assembly shall withstand, without permanent deformation, all normal axial loads from shipping and fuel handling operations. Analyses or testing shall demonstrate that the fuel is capable of [] .

The fuel assembly structural components are assessed for axial fuel handling loads by analyses and testing. To demonstrate compliance with the criteria, the tests and analyses are performed by loading a test assembly or the individual components of the load chain to an axial tensile force greater than [] . An acceptable test and analysis demonstrates no yielding after loading.

Handling requirements for the fuel rod plenum spring are addressed in the fuel rod thermal-mechanical report.

3.3.9.1 Fuel Assembly Axial Load Tests

Each test is used in support of analytical or Finite Element Analysis to demonstrate that no significant permanent deformation occurs for loads [] .

Descriptions of tests:

3.3.10 Miscellaneous Components

3.3.10.1 Compression Spring Forces

The compression spring force shall support the weight of the upper tie plate and channel throughout the design life of the fuel. The ATRIUM 11 has a single large compression spring mounted on the central water channel. The compression spring serves the same function as previous ATRIUM family of fuel designs by providing support for the UTP and fuel channel. The spring force is calculated based on the installed deflection and specified spring force requirements to meet support criteria. Irradiation-induced relaxation is taken into account for EOL conditions. The minimum compression spring force at EOL is greater than the combined weight of the UTP assembly and fuel channel assembly. Since the compression spring design of the ATRIUM family of fuel assemblies load chain designs do not interact with the fuel rods, no consideration is required for fuel rod buckling loads.

3.3.10.2 LTP Seal Spring

The LTP seal spring shall limit the bypass coolant leakage rate between the LTP and fuel channel. The seal spring shall accommodate expected channel deformation while remaining in contact with the fuel channel. Also, the seal spring shall have adequate corrosion resistance and be able to withstand the operating stresses without yielding.

Flow testing is used to confirm acceptable bypass flow characteristics. The seal spring is designed with adequate deflection to accommodate the maximum expected channel bulge while maintaining acceptable bypass flow. [] is selected as the material because of its high strength at elevated temperature and its excellent corrosion resistance. Seal spring stresses are analyzed using a finite element method.

3.4 Fuel Coolability

For accidents in which severe fuel damage might occur, core coolability and the capability to insert control blades are essential. Chapter 4.2 of the SRP provides several specific areas important to fuel coolability, as discussed below.

3.4.1 Cladding Embrittlement

This evaluation is not part of the mechanical design analysis.

3.4.2 Violent Expulsion of Fuel

This evaluation is not part of the mechanical design analysis.

3.4.3 Fuel Ballooning

This evaluation is not part of the mechanical design analysis.

3.4.4 Structural Deformations

ATRIUM 11 structural component deformations or stresses from postulated accidents are limited according to requirements contained in the ASME B&PV Code, Section III, Division 1, Appendix F, and SRP Section 4.2, Appendix A.

The methodology for analyzing the fuel under the influence of accident loads is described in the Mechanical Designs for BWR Fuel Channels Topical Report (Reference 2) and is further discussed in Section 3.5.2. Evaluations performed for the fuel under accident conditions include

[] .

[

].

Dynamic properties of the ATRIUM 11 fuel assembly are provided to Browns Ferry in support of evaluations assessing the impact of the introduction of the ATRIUM 11 to the reactor pressure vessel, internal reactor components and other applicable evaluations.

3.4.4.1 Test Verifications

Fuel assemblies are tested with, and without, a fuel channel as described in Appendix C of Reference 2. Testing is performed to obtain the dynamic characteristics of the fuel assembly and spacer grids. The stiffness, natural frequencies and damping values derived from the tests are used as inputs for analytical models of the fuel assembly and fuel channel. In general, the testing and analyses have shown the dynamic response of ATRIUM 11 to be similar to ATRIUM-10 and ATRIUM 10XM fuel assemblies.

3.4.4.1.1 Fuel Assembly Static Lateral Deflection Test

A lateral deflection test is performed to determine the fuel assembly stiffness, both with and without a fuel channel. The stiffness is obtained by supporting the fuel assembly at the two ends in a vertical position, applying a side displacement at the central spacer location, and measuring the corresponding force.

3.4.4.1.2 Fuel Assembly Lateral Vibration Tests

The lateral vibration testing consists of both a free vibration test and a forced vibration test

[] .

The test setup for the free vibration test [

].

The forced vibration test [

].

3.4.4.1.3 Fuel Assembly Impact Tests

Impact testing was performed in a similar manner to the lateral deflection tests. The unchanneled assembly is supported in a vertical position with both ends fixed. The assembly is displaced a specified amount and then released. [

].

3.4.4.1.4 Spacer Grid Lateral Impact Strength Test

Spacer grid impact strength is determined by a [

].

The maximum force prior to the onset of buckling was determined from the tests. The results were adjusted to reactor operating temperature conditions to establish an allowable lateral load.

3.4.4.1.5 Tie Plate Strength Tests

In addition to the axial tensile tests described in Section 3.3.9.1, a lateral load test is performed on the UTP and LTP.

The UTP lateral load test was conducted on a test machine which applied [

] . This

provides a limiting lateral load for accident conditions.

To determine a limiting lateral load for accident conditions for the 3GFG LTP, a lateral load test was conducted by attaching the grid of the tie plate to a rigid vertical plate [

] .

The results were adjusted to reactor operating temperature conditions to establish an allowable lateral load per Reference 1, Section 3.3.1.

3.5 *Fuel Channel and Components*

The fuel channel assembly design criteria are summarized below, and evaluation results are summarized in Table 3-2. The analysis methods are described in detail in Reference 2.

3.5.1 Design Criteria for Normal Operation

Stress due to Pressure Differential. The stress limits during normal operation are obtained from the ASME B&PV Code, Section III, Division 1, Subsection NG for Service Level A. The calculated stress intensities are due to the differential pressure across the fuel channel wall. The pressure loading includes the normal operating pressure plus the increase during AOO. The unirradiated properties of the fuel channel material are used since the yield and ultimate tensile strength increase during irradiation (Reference 7). As an alternative to the elastic analysis stress intensity limits, a plastic analysis may be performed as permitted by paragraph NB-3228.3 of the ASME B&PV Code.

In the case of AOOs, the amount of bulging is limited to that value which will permit control blade movement. During normal operation, any significant permanent deformation due to yielding is precluded by restricting the maximum stresses at the inner and outer faces of the channel to be less than the yield strength.

Fatigue. Cyclic changes in power and flow during operation impose a duty loading on the fuel channel. The cyclic duty from pressure fluctuations is limited to less than the fatigue lifetime of the fuel channel. The fatigue life is based on the O'Donnell and Langer curve (Reference 6), which includes a factor of 2 on stress amplitude or a factor of 20 on the number of cycles, whichever is more conservative.

Oxidation and Hydriding. Oxidation reduces the material thickness and results in less load-carrying capacity. The fuel channels have thicker walls than other components (e.g., fuel rods), and the normal amounts of oxidation and hydrogen pickup are not limiting provided: the alloy composition and impurity limits are carefully selected; the heat treatments are also carefully chosen; and the plant water chemistry will be maintained in accordance with approved EPRI BWR Water Chemistry Guidelines. [

].

Long-Term Deformation. Changes to the geometry of the fuel channel occur due to creep deformation during the long term exposure in the reactor core environment. Overall deformation of the fuel channel occurs from a combination of bulging and bowing. Bulging of the side walls occurs because of the differential pressure across the wall. Lateral bowing of the channel is caused primarily from the neutron flux and thermal gradients. Too much deflection may prevent normal control blade maneuvers and it may increase control blade insertion time above the Technical Specification limits. The total channel deformation must not stop free movement of the control blade. [

].

3.5.2 Design Criteria for Accident Conditions

Fuel Channel Stresses, Load Limit, and Vertical Acceleration. The criteria are based on the ASME B&PV Code, Section III, Appendix F, for faulted conditions (Service Level D). Component support criteria for elastic system analysis are used as defined in paragraphs

F-1332.1 and F-1332.2. The unirradiated properties of the fuel channel material are used since the yield and ultimate tensile strength increase during irradiation (Reference 7). [

].

Vertical acceleration produces a membrane stress in the axial direction due to a postulated impact of the channeled fuel assembly impacting the fuel support after liftoff.

The amount of bulging remains limited to that value which will permit control blade insertion.

Channel Bending from Combined Horizontal Excitations. [

].

Fuel Channel Gusset Strength. [

].

Table 3-1
Results for ATRIUM 11 Fuel Assembly Criteria

Criteria Section	Description	Criteria	Results
<i>ANF-89-98(P)(A) (Reference 1) Associated Mechanical Design Criteria Sections</i>			
3.3	Fuel System Criteria		
3.3.1	Stress, strain and loading limits on assembly components	The ASME B&PV Code Section III is used to establish acceptable stress levels or load limits for assembly structural components. The design limits for accident conditions are derived from Appendix F of Section III.	[] .
3.3.3	Fretting wear	[] .	[] .
3.3.5	Rod bow	Protect thermal limits	[]
3.3.6	Axial irradiation growth Upper end cap clearance	Clearance always exists	[]
3.3.8	Assembly lift-off Normal operation (including AOOs)	No lift-off from fuel support	[]
	Postulated accident	No disengagement from fuel support	[] .

Table 3-1
Results for ATRIUM 11 Fuel Assembly Criteria
(Continued)

Criteria Section	Description	Criteria	Results
3.3	Fuel System Criteria (Continued)		
3.3.9	Fuel assembly handling	[	Verified by testing and Analyses to meet requirement
3.3.10	Miscellaneous components		
3.3.10.1	Compression spring forces	Support weight of UTP and fuel channel throughout design life	The design criteria are met
3.3.10.2	LTP seal spring	Accommodate fuel channel deformation, adequate corrosion, and withstand operating stresses	The design criteria are met
3.4	Fuel Coolability		
3.4.4	Structural deformations	Maintain coolable geometry and ability to insert control blades. SRP 4.2, App. A, and ASME Section III, App. F.	[
			]

Table 3-2
Results for ATRIUM 11 Advanced Fuel Channel Criteria

Criteria Section	Description	Criteria	Results
EMF-93-177(P)(A) (Reference 2) Associated Fuel Channel (FC) Criteria Sections			
FC 3.2	ATRIUM 11 Advanced Fuel Channel – Normal Operation		
FC 3.2.1	Stress due to pressure differential	The pressure load including AOO is limited to [] according to ASME B&PV Code, Section III. The pressure load is also limited such that [] .	The deformation during AOO remains within functional limits for normal control blade operation and the [] is met. There is no significant plastic deformation.
FC 3.2.2	Fatigue	Cumulative cyclic loading to be less than the design cyclic fatigue life for Zircaloy.	Expected number of cycles is less than allowable
FC 3.2.3	Oxidation and hydriding	Oxidation shall be accounted for in the stress and fatigue analyses	The maximum expected oxidation is low in relation to the wall thickness. Oxidation was accounted for in the stress and fatigue analyses.
FC 7.0	Long-term deformation (bulge creep and bow)	Bulge and bow shall not interfere with free movement of the control blade	Margin to a stuck control blade remains positive

Table 3-2
Results for ATRIUM 11 Advanced Fuel Channel Criteria
(Continued)

Criteria Section	Description	Criteria	Results
FC 3.3	ATRIUM 11 Advanced Fuel Channel – Accident Conditions		
FC 3.3.1	Fuel channel stresses and load limit and vertical accelerations	The pressure load is limited to [] . The pressure load is also limited such that [] .	The deformation during blowdown does not interfere with control blade insertion. This also satisfies the less restrictive [] .
FC 3.3.1 (continued)	Channel bending from combined horizontal excitations	Allowable bending moment based on ASME Code, Section III, Appendix F [] .	[] .
FC 3.3.2	Fuel channel gusset strength	Vertical load must be less than ASME allowable load rating based on testing.	[] .

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3. EMF-93-177P-A Revision 1, Supplement 1P-A, Revision 0, "Mechanical Design for BWR Fuel Channels Supplement 1: Advanced Methods for New Channel Designs," AREVA NP Inc., September 2013.
4. BAW-10247P-A Supplement 2P-A Revision 0, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors, Supplement 2: Mechanical Methods," Framatome Inc., August 2018.
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ATTACHMENT 9a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3866P Revision 0

(Proprietary)

**Browns Ferry ATRIUM 11 Fuel Rod Thermal-Mechanical Evaluation for Browns
Ferry LAR**

ATTACHMENT 9b

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(Non Proprietary)

**Browns Ferry ATRIUM 11 Fuel Rod Thermal-Mechanical Evaluation for Browns
Ferry LAR**



ATRIUM 11 Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry LAR

ANP-3866NP
Revision 0

Licensing Report

October 2020

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Nomenclature

Acronym	Definition
3GFG	3 rd generation FUELGUARD
AOO	anticipated operational occurrences
ASME	American Society of Mechanical Engineers
B&PV	Boiler and Pressure Vessel
BOL	beginning of life
BWR	boiling water reactor
CRWE	control rod withdrawal error
CUF	cumulative usage factor
EOL	end of life
EPU	extended power uprate
FDL	fuel design limit
ID	inside diameter
LAR	License Amendment Request
LHGR	linear heat generation rate
LTP	lower tie plate
MWd/kgU	megawatt days per kilogram of initial uranium
MELLLA+	maximum extended load line limit analysis plus
NRC	Nuclear Regulatory Commission, U. S.
OD	outside diameter
PCI	pellet-to-cladding-interaction
PLFR	part length fuel rod
ppm	parts per million
SRA	stress relieved annealed
S-N	stress amplitude versus number of cycles
UTL	upper tolerance limit

1.0 INTRODUCTION

This document reports the results of thermal-mechanical analyses for the performance of ATRIUM 11 fuel assemblies inserted into to an equilibrium cycle for the Browns Ferry units and demonstrates that the design criteria relevant to these limits are satisfied. This report is intended to support a License Amendment Request (LAR) for the approval to use the Framatome advanced analysis methods that will be deployed coincident with the implementation of the ATRIUM 11 fuel assembly design. These analyses assume the use of chromia additive in the enriched urania portions of the fuel and assume operation in the Maximum Extended Load Line Limit Plus (MELLLA+) operation domain at Extended Power Uprate (EPU) conditions. Both the design criteria and the analysis methodology have been approved by the U. S. NRC (NRC).

The analysis results are evaluated according to the generic fuel rod thermal and mechanical design criteria contained in ANF-89-98(P)(A) Revision 1 and Supplement 1 (Reference 1) along with design criteria provided in the RODEX4 fuel rod thermal-mechanical topical report (Reference 2)*. Approved methodology for the inclusion of chromia additive in the fuel pellets is also used (Reference 3).

The RODEX4 fuel rod thermal-mechanical analysis code is used to analyze the fuel rod for fuel centerline temperature, cladding strain, rod internal pressure, cladding collapse, cladding fatigue and external oxidation. The code and application methodology are described in the RODEX4 topical report (Reference 2). The cladding steady-state stress and plenum spring design methodology are summarized in Reference 1.

The following sections describe the fuel rod design, design criteria and methodology with reference to the source topical reports. Results from the analyses are summarized for comparison to the design criteria.

* (N.B., the cladding external oxidation limit from that topical report of [] was reduced to [] when the RODEX4 methodology was approved for application to the Browns Ferry units (Reference 4)).

2.0 SUMMARY AND CONCLUSIONS

Key results are compared against each design criterion in Table 3-2. Results are presented for the limiting cases. Additional RODEX4 results are given in Section 3.0.

The analyses support a maximum fuel rod discharge exposure of 62 MWd/kgU.

Fuel rod criteria applicable to the design are summarized in Section 3.0. Analyses show the criteria are satisfied when the fuel is operated at or below the LHGR (linear heat generation rate) limit (Fuel Design Limit – FDL) presented in Figure 2-1.

Table 2-1 Summary of Fuel Rod Design Evaluation Results (MELLLA+)

Criteria Section*	Description	Criteria	Result, Margin [†] or Comment
3.2	Fuel Rod Criteria		
3.2.1	Internal hydriding	[	]
(3.1.1)	Cladding collapse	[	]
(3.1.2)	Overheating of fuel pellets	No fuel melting margin to fuel melt > 0. °C	[]
3.2.5	Stress and strain limits		
(3.1.1) (3.1.2)	Pellet-cladding interaction	[	]
3.2.5.2	Cladding steady-state stresses	[	]
3.3	Fuel System Criteria		
(3.1.1)	Fatigue	[	]
(3.1.1) [‡]	Oxidation, hydriding, and crud buildup	[	]
(3.1.1) (3.1.2)	Rod internal pressure	[	]
3.3.9	Fuel rod plenum spring (fuel handling)	Plenum spring to [	]

* Numbers in the column refer to paragraph sections in the generic design criteria document, ANF-89-98(P)(A) Revision 1 and Supplement 1 (Reference 1). A number in parentheses is the paragraph section in the RODEX4 fuel rod topical report (Reference 2).

[†] Margin is defined as (limit – result).

[‡] The cladding external oxidation limit is restricted to [] by Reference 4.

[

Figure 2-1 LHGR Limit (Normal Operation)

]

3.0 FUEL ROD DESIGN EVALUATION

Summaries of the design criteria and methodology are provided in this section along with analysis results in comparison to criteria. Both the fuel rod criteria and fuel system criteria as directly related to the fuel rod analyses are covered.

The fuel rod analyses cover normal operating conditions and AOOs (anticipated operational occurrences). The fuel centerline temperature analysis (overheating of fuel) and cladding strain analysis take into account slow transients at rated operating conditions.

Other fuel rod-related topics on overheating of cladding, cladding rupture, fuel rod mechanical fracturing, rod bow, axial irradiation growth, cladding embrittlement, violent expulsion of fuel and fuel ballooning are evaluated as part of the respective fuel assembly structural analysis, thermal hydraulic analyses, or LOCA analyses and are reported elsewhere. The evaluation of fast transients and transients at off-rated conditions also are reported separately from this report.

3.1 *Fuel Rod Design*

The ATRIUM 11 fuel rod is conventional in design configuration and very similar to past designs such as the ATRIUM 10XM, ATRIUM-10 and ATRIUM-9 fuel rods.

[

] plenum spring on the upper end of the fuel column assists in maintaining a compact fuel column during shipment and initial reactor operation.

There are two Part-length Fuel Rod (PLFR) designs incorporated in the fuel assembly. The longer is [] long, while the shorter is [] long. [

].

[

]

As on previous ATRIUM fuel designs that incorporated the 3rd generation FUELGUARD (3GFG) Lower Tie Plate (LTP), the PLFR's have a [

]

Table 3-1 lists the main parameters for the fuel rod and components.

3.2 *RODEX4 and Statistical Methodology Summary*

RODEX4 evaluates the thermal-mechanical response of the fuel rod surrounded by coolant. The fuel rod model considers the fuel column, gap region, cladding, gas plena and the fill gas and released fission gases. The fuel rod is divided into axial and radial regions with conditions computed for each region. The operational conditions are controlled by the [

].

The heat conduction in the fuel and clad is [

].

Mechanical processes include [

].

As part of the methodology, fuel rod power histories are generated [

].

Since RODEX4 is a best-estimate code, uncertainties are taken into account by a [

]. Uncertainties taken

into account in the analysis are summarized as:

- Power measurement and operational uncertainties – [

].

- Manufacturing uncertainties – [

].

- Model uncertainties – [

].

[

].

3.3 ***Summary of Fuel Rod Design Evaluation***

Results from the analyses are listed in Table 3-2. Summaries of the methods and codes used in the evaluation are provided in the following paragraphs. The design criteria also are listed along with references to the sections of the design criteria topical reports (References 1 and 2).

The fuel rod thermal and mechanical design criteria are summarized as follows.

- **Internal Hydriding.** The fabrication limit [] to preclude cladding failure caused by internal sources of hydrogen (Section 3.2.1 of Reference 1).
- **Cladding Collapse.** Clad creep collapse shall be prevented. [] (Section 3.1.1 of Reference 2).
- **Overheating of Fuel Pellets.** The fuel pellet centerline temperature during anticipated transients shall remain below the melting temperature (Section 3.1.2 of Reference 2).
- **Stress and Strain Limits.** [] during normal operation and during anticipated transients (Sections 3.1.1 and 3.1.2 of Reference 2).

Fuel rod cladding steady-state stresses are restricted to satisfy limits derived from the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code (Section 3.2.5.2 of Reference 1).
- **Cladding Fatigue.** The fatigue cumulative usage factor for clad stresses during normal operation and design cyclic maneuvers shall be below [] (Section 3.1.1 of Reference 2).
- **Cladding Oxidation, Hydriding and Crud Buildup.** Section 3.1.1 of Reference 2 limits the maximum cladding oxidation to less than [] to prevent clad corrosion failure. The oxidation limit is further reduced to [] (Reference 4).
- **Rod Internal Pressure.** The rod internal pressure is limited [] to ensure that significant outward clad creep does not occur and unfavorable hydride reorientation on cooldown does not occur (Section 3.1.1 of Reference 2).
- **Plenum Spring Design (Fuel Handling).** The rod plenum spring must maintain a force against the fuel column stack [] (Section 3.3.9 of Reference 1).

Cladding collapse, overheating of fuel, cladding transient strain, cladding cyclic fatigue, cladding oxidation, and rod pressure are evaluated []. Cladding stress and the plenum spring are evaluated [].

3.3.1 Internal Hydriding

The absorption of hydrogen by the cladding can result in cladding failure due to reduced ductility and formation of hydride platelets. Careful moisture control during fuel fabrication reduces the potential for hydrogen absorption on the inside of the cladding. The fabrication limit [] is verified by quality control inspection during fuel manufacturing.

3.3.2 Cladding Collapse

Creep collapse of the cladding and the subsequent potential for fuel failure is avoided in the design by limiting the axial gap formation due to fuel densification subsequent to pellet-clad contact. The size of the axial gaps which may form due to densification following first pellet-clad contact shall be less than [].

The evaluation is performed using the RODEX4 code and methodology. RODEX4 takes into account the []

].

Table 3-2 lists the results for an equilibrium cycle operating in the MELLLA+ operating domain for EPU conditions.

3.3.3 Overheating of Fuel Pellets

Fuel failure from the overheating of the fuel pellets is not allowed. The centerline temperature of the fuel pellets must remain below melting during normal operation and AOOs. The melting point of the fuel includes adjustments for []. Framatome establishes an LHGR limit to protect against fuel centerline melting during steady-state operation and during AOOs.

Fuel centerline temperature is evaluated using the RODEX4 code and methodology for both normal operating conditions and AOOs.

Table 3-2 lists the results for an equilibrium cycle operating in the MELLLA+ operating domain for EPU conditions.

3.3.4 Stress and Strain Limits

3.3.4.1 Pellet/Cladding Interaction

Cladding strain caused by transient-induced deformations of the cladding is calculated using the RODEX4 code and methodology. [

]. The strain limit is 1%.

Table 3-2 lists the results for an equilibrium cycle operating in the MELLLA+ operating domain for EPU conditions.

3.3.4.2 Cladding Stress

Cladding stresses are calculated using solid mechanics elasticity solutions and finite element methods. The stresses are conservatively calculated for the individual loadings and are categorized as follows:

Category	Membrane	Bending
Primary	[	]
Secondary	[	]

Stresses are calculated at the cladding outer and inner diameter in the three principal directions for both beginning of life (BOL) and end of life (EOL) conditions. At EOL, the stresses due to mechanical bow and contact stress are decreased due to irradiation relaxation. The separate stress components are then combined, and the stress intensities for each category are compared to their respective limits.

The cladding-to-end cap weld stresses are evaluated for loadings from differential pressure, differential thermal expansion, rod weight, and plenum spring force.

The design limits are derived from the ASME (American Society of Mechanical Engineers) Boiler and Pressure Vessel (B&PV) Code Section III (Reference 5) and the minimum specified material properties.

Table 3-3 lists the results in comparison to the limits for Beginning-of-Life (BOL) Hot conditions and End-of-Life (EOL) at both Hot and Cold conditions.

3.3.5 Fuel Densification and Swelling

Fuel densification and swelling are limited by the design criteria for fuel temperature, cladding strain, cladding collapse, and rod internal pressure criteria. Although there are no explicit criteria for fuel densification and swelling, the effect of these phenomena are included in the RODEX4 code and methodology.

3.3.6 Fatigue

Fuel rod cladding fatigue is calculated using the RODEX4 code and methodology. [

]. The CUF (cumulative usage factor) is summed for each of the axial regions of the fuel rod using Miner's rule. The axial region with the highest CUF is used in the subsequent [

]. The maximum CUF for the cladding must remain below [] to satisfy the design criterion. Table 3-2 lists the results for an equilibrium cycle operating in the MELLLA+ operating domain for EPU conditions.

3.3.7 Oxidation, Hydriding, and Crud Buildup

Cladding external oxidation is calculated using the RODEX4 code and methodology. The corrosion model includes an enhancement factor that is derived from poolside measurement data to obtain a fit of the expected oxide thickness. An uncertainty value for the model enhancement factor also is determined from the data. The model uncertainty is included as part of the [].

[

].

In the event abnormal crud is observed at a plant, a specific analysis is required to address the higher crud level. An abnormal level of crud is defined by a formation that increases the calculated fuel average temperature by 25°C above the design basis calculation. The formation of crud is not calculated within RODEX4. Instead, an upper bound of expected crud based on plant observations is input by the use of the crud heat transfer coefficient. The corrosion model also takes into consideration the effect of the higher thermal resistance from the crud on the corrosion rate. A higher corrosion rate is therefore included as part of the abnormal crud evaluation. A similar specific analysis is required if an abnormal corrosion layer is observed instead of crud.

In the case of the Browns Ferry units, no additional crud is taken into account in the calculations because an abnormal crud or corrosion layer (beyond the design basis) has not been observed at the Browns Ferry units.

[

].

Currently, [

].

The oxide limit is evaluated such that greater than [

].

Table 3-2 lists the results for an equilibrium cycle operating in the MELLLA+ operating domain for EPU conditions.

3.3.8 Rod Internal Pressure

Fuel rod internal pressure is calculated using the RODEX4 code and methodology. The maximum rod pressure is calculated under steady-state conditions and also takes into account slow transients. Rod internal pressure is limited to [

]. The expected upper bound of rod pressure [] is calculated for comparison to the limit.

Table 3-2 lists the results for an equilibrium cycle operating in the MELLLA+ operating domain for EPU conditions.

3.3.9 Plenum Spring Design (Fuel Assembly Handling)

The plenum spring must maintain a force against the fuel column to prevent [

]. This is accomplished by designing and verifying the spring force in relation to the fuel column weight. The plenum spring is designed such that the [

].

Table 3-1 Key Fuel Rod Design Parameters, ATRIUM 11 for Browns Ferry LAR

[

]

* The theoretical density of enriched $\text{UO}_2\text{-Cr}$ is 10.94 g/cm^3 while that for $\text{UO}_2\text{-Gd}_2\text{O}_3$ and naturally enriched UO_2 is 10.96 g/cm^3 .

Table 3-1 Key Fuel Rod Design Parameters, ATRIUM 11 for Browns Ferry LAR (cont'd)

[

]

Table 3-2 RODEX4 Fuel Rod Results Equilibrium Cycle—MELLLA+*

[

]

* Note that the results are provided up to fuel assembly discharge.

† Margin is defined as (limit – result).

Table 3-3 Cladding and Cladding-End Cap Steady-State Stresses

Description, Stress Category	Criteria	Result		
		BOL Cold	BOL Hot	EOL Hot
Cladding stress				
P _m (primary membrane stress)	[	]		
P _m + P _b (primary membrane + bending)	[	]		
P + Q (primary + secondary)	[	]		
Cladding-End Cap stress				
P _m + P _b	[	]		

4.0 REFERENCES

1. ANF-89-98(P)(A) Revision 1 and Supplement 1, *Generic Mechanical Design Criteria for BWR Fuel Designs*, Advanced Nuclear Fuels Corporation, May 1995.
2. BAW-10247PA Revision 0, *Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors*, AREVA NP Inc., February 2008.
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4. Letter from Farideh E. Saba (NRC) to Joseph W. Shea (TVA), "BROWNS FERRY NUCLEAR PLANTS, UNITS 1, 2 AND 3 – ISSUANCE OF AMENDMENTS REGARDING TECHNICAL SPECIFICATION (TS) CHANGE TS-478 ADDITION OF ANALYTICAL METHODOLOGIES TO TS 5.6.5 AND REVISION OF TS 2.1.1.2 FOR UNIT 2 (TAC NOS. MF0878 AND MF0879), ML14108A334," dated July 31, 2014.
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6. O'Donnell, W.J., and B. F. Langer, "Fatigue Design Basis for Zircaloy Components," *Nuclear Science and Engineering*, Vol. 20, 1964.

ATTACHMENT 10a

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Units 1, 2, and 3**

Technical Specifications (TS) Change 535

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Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3859P Revision 0

(Proprietary)

Browns Ferry Thermal-Hydraulic Design Report for ATRIUM 11 Fuel Assemblies

ATTACHMENT 10b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3859NP Revision 0

(Non Proprietary)

Browns Ferry Thermal-Hydraulic Design Report for ATRIUM 11 Fuel Assemblies



Browns Ferry Thermal-Hydraulic Design Report for ATRIUM 11 Fuel Assemblies

ANP-3859NP
Revision 0

September 2020

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Nomenclature

Acronym	Definition
AOO	anticipated operational occurrences
ASME	American Society of Mechanical Engineers
BWR	boiling water reactor
BWROG	BWR Owners Group
CHF	critical heat flux
CPR	critical power ratio
CRDA	control rod drop accident
ECCS	emergency core cooling system
EPU	extended power uprate (defined as 120% OLTP, 3952 MWt)
LOCA	loss-of-coolant accident
LTP	lower tie plate
MAPLHGR	maximum average planar linear heat generation rate
MCPR	minimum critical power ratio
MWR	metal-water reaction
NRC	Nuclear Regulatory Commission, U.S.
OLMCPR	operating limit minimum critical power ratio
OLTP	original licensed thermal power (3293 MWt)
OPRM	oscillation power range monitor
PCT	peak cladding temperature
RPF	radial peaking factor
SER	safety evaluation report
SLMCPR	safety limit minimum critical power ratio
UO ₂	uranium dioxide
UTP	upper tie plate

1.0 INTRODUCTION

The results of Browns Ferry thermal-hydraulic analyses are presented to demonstrate that Framatome ATRIUM 11 fuel is hydraulically compatible with the previously loaded ATRIUM 10XM fuel design at extended power uprate (EPU) maximum extended load line limit analysis plus (MELLLA+) conditions. This report also provides the hydraulic characterization of the ATRIUM 11 and the coresident ATRIUM 10XM fuel designs for Browns Ferry.

The generic thermal-hydraulic design criteria applicable to the design have been reviewed and approved by the U.S. Nuclear Regulatory Commission (NRC) in the topical report ANF-89-98(P)(A) Revision 1 and Supplement 1 (Reference 1). In addition, thermal-hydraulic criteria applicable to the design have also been reviewed and approved by the NRC in the topical report XN-NF-80-19(P)(A) Volume 4 Revision 1 (Reference 2).

2.0 SUMMARY AND CONCLUSIONS

The thermal-hydraulic evaluations presented in this report are for the various, expected core configurations that include ATRIUM 11 and ATRIUM 10XM fuel designs at EPU MELLLA+ operation. These fuel designs have been determined to be hydraulically compatible at Browns Ferry for the entire range of the licensed EPU MELLLA+ power-to-flow operating map. Detailed calculation results supporting this conclusion are provided in Section 3.2 and Tables 3.2–3.10.

The ATRIUM 11 and the ATRIUM 10XM fuel assemblies are geometrically different, but hydraulically the two designs are compatible at EPU MELLLA+ operation. [

]

Core bypass flow is not significantly affected by any combination core loading of ATRIUM 11 and ATRIUM 10XM fuel for EPU MELLLA+ operation. Analyses at rated conditions show the core bypass flow varying between [] of rated flow. Analyses at rated power and the MELLLA+ region boundary of 85% flow show the core bypass flow varying between [].

Analyses demonstrate the design criteria discussed in Section 3.0 are satisfied for the Browns Ferry EPU MELLLA+ core configurations consisting of ATRIUM 11 and ATRIUM 10XM fuel combinations. These analyses were performed for expected EPU MELLLA+ core power distributions and core flow conditions encountered during operation.

3.0 THERMAL-HYDRAULIC DESIGN EVALUATION

Thermal-hydraulic analyses are performed to verify that design criteria are satisfied and to help establish thermal operating limits with acceptable margins of safety during normal reactor operation and anticipated operational occurrences (AOOs). The design criteria that are applicable to the Framatome fuel designs are described in Reference 1. To the extent possible, these analyses are performed on a generic fuel design basis. However, due to reactor and cycle operating differences, many of the analyses supporting these thermal-hydraulic operating limits are performed on a plant- and cycle-specific basis and are documented in plant- and cycle-specific reports (Reference 2).

The thermal-hydraulic design criteria are summarized below:

- **Hydraulic compatibility.** The hydraulic flow resistance of the reload fuel assemblies shall be sufficiently similar to the existing fuel in the reactor such that there is no significant impact on total core flow or the flow distribution among assemblies in the core. This criterion evaluation is addressed in Sections 3.1 and 3.2.
- **Thermal margin performance.** Fuel assembly geometry, including spacer design and rod-to-rod local power peaking, should minimize the likelihood of boiling transition during normal reactor operation as well as during AOOs. The fuel design should fall within the bounds of the applicable empirically based boiling transition correlation approved for Framatome reload fuel. Within other applicable mechanical, nuclear, and fuel performance constraints, the fuel design should achieve good thermal margin performance. The thermal-hydraulic design impact on steady-state thermal margin performance is addressed in Section 3.3. Additional thermal margin performance evaluations dependent on the cycle-specific design are addressed in the reload licensing report.
- **Fuel centerline temperature.** Fuel design and operation shall be such that fuel centerline melting is not projected for normal operation and AOOs. This criterion evaluation is addressed in the fuel rod thermal and mechanical design report.
- **Rod bow.** The anticipated magnitude of fuel rod bowing under irradiation shall be accounted for in establishing thermal margin requirements. This criterion is addressed in Section 3.4.

- **Bypass flow.** The bypass flow characteristics of the reload fuel assemblies shall not differ significantly from the existing fuel in order to provide adequate flow in the bypass region. This criterion evaluation is addressed in Section 3.5.
- **Stability.** Reactors fueled with new fuel designs must be stable in the approved power and flow operating region. The stability performance of new fuel designs will be equivalent to, or better than, existing (approved) Framatome fuel designs. This criterion evaluation is addressed in Section 3.6. Additional core stability evaluations dependent on the cycle-specific design are addressed in the reload licensing report.
- **Loss-of-coolant accident (LOCA) analysis.** LOCAs are analyzed in accordance with Appendix K modeling requirements using NRC-approved models. The criteria are defined in 10 CFR 50.46. LOCA analysis results are presented in the LOCA report.
- **Control rod drop accident (CRDA) analysis.** The results from the CRDA analysis must meet the criteria of Regulatory Guide 1.236.
- **ASME overpressurization analysis.** ASME pressure vessel code requirements must be satisfied. This criterion evaluation is addressed in the reload licensing report.
- **Seismic/LOCA liftoff.** Under accident conditions, the assembly must remain engaged in the fuel support. This criterion evaluation is addressed in the mechanical design report.

A summary of the thermal-hydraulic design evaluation is given in Table 3.1.

3.1 *Hydraulic Characterization*

The basic geometric parameters for ATRIUM 11 and ATRIUM 10XM fuel designs are summarized in Table 3.2. Component loss coefficients for the fuels mentioned are based on documented tests and are presented in Table 3.3. These loss coefficients include modifications to the test data reduction process [

] The bare rod, ULTRAFLOW spacer, UTP and LTP losses for
ATRIUM 11 and ATRIUM 10XM are based on tests performed at Framatome's Portable

Hydraulic Test Facility. [

]

The primary resistance for the leakage flow through the LTP flow holes is [

]

The resistances for the leakage paths are shown in Table 3.3.

3.2 *Hydraulic Compatibility*

The thermal-hydraulic analyses were performed in accordance with the Framatome thermal-hydraulic methodology for BWRs (Reference 2). The methodology and constitutive relationships used by Framatome for the calculation of pressure drop in BWR fuel assemblies are presented in Reference 3 and are implemented in the XCOBRA code. The XCOBRA code predicts steady-state thermal-hydraulic performance of the fuel assemblies of BWR cores at various operating conditions and power distributions. XCOBRA received NRC approval in Reference 4. The NRC reviewed the information provided in Reference 5 regarding inclusion of water rod models in XCOBRA and accepted the inclusion in Reference 6.

Hydraulic compatibility, as it relates to the relative performance of the ATRIUM 11 and coresident ATRIUM 10XM fuel designs, has been evaluated. Detailed analyses were performed for full cores of each fuel design presented herein. Analyses for mixed cores with ATRIUM 11 and ATRIUM 10XM fuel were also performed to demonstrate that the thermal-hydraulic design criteria are satisfied for transition core configurations under EPU MELLLA+ operation.

The hydraulic compatibility analysis is based on [

]

[

]

Table 3.4 summarizes the input conditions for the analyses. These conditions reflect four of the statepoints considered in the analyses: 100% power/100% flow, 100% power/85% flow, 77.6% power/55% flow and 54.3% power/37.3% flow. Table 3.4 also defines the core loadings for the transition core configurations. Input for other core configurations is similar in that core operating conditions remain the same and the same axial power distribution is used. Evaluations were made with the bottom-, middle-, and top-peaked axial power distributions presented in Figure 3.1. Results presented in Tables 3.5 - 3.10 and Figures 3.2 - 3.9 are for bottom peaked power distribution. Results for the middle-peaked and top-peaked axial power distributions show similar trends.

Table 3.5 – Table 3.6 provide a summary of calculated thermal-hydraulic results for the core configurations provided in Table 3.4. Tables 3.7 -3.10 provide a summary of results for all core configurations evaluated.

Core Loading 1 (Table 3.4) is a core consisting of approximately one third ATRIUM 11 fuel with the remainder ATRIUM 10XM fuel. This represents a core with a single reload of ATRIUM 11 fuel. The core average results and the differences between the fuel designs for both rated and off-rated statepoints are within the range considered hydraulically compatible. As shown in Table 3.5, [

] Differences in assembly flow

between the fuel designs as a function of assembly power level are shown in Figure 3.2 - Figure 3.5. Core pressure drop and core bypass flow fraction are also provided for *Core Loading 1* (Table 3.7-3.10). Based on the reported changes in pressure drop and

assembly flow caused by the first reload of ATRIUM 11, the ATRIUM 11 design is considered hydraulically compatible with the coresident ATRIUM 10XM design for EPU MELLLA+ operation since the thermal-hydraulic design criteria are satisfied.

Core Loading 2 (Table 3.4) is a core consisting of approximately two thirds ATRIUM 11 fuel with the remainder ATRIUM 10XM fuel. This represents a core with two reloads of ATRIUM 11 fuel. The core average results and the differences between the fuel designs for both rated and off-rated statepoints are within the range considered hydraulically compatible. As shown in Table 3.6, [

] Differences in assembly flow

between the fuel designs as a function of assembly power level are shown in Figure 3.6 - Figure 3.9. Core pressure drop and core bypass flow fraction are also provided for *Core Loading 2* (Table 3.7–3.10). Based on the reported changes in pressure drop and assembly flow caused by the second reload of ATRIUM 11, the ATRIUM 11 design is considered hydraulically compatible with the coresident ATRIUM 10XM design for EPU MELLLA+ operation since the thermal-hydraulic design criteria are satisfied.

3.3 ***Thermal Margin Performance***

Relative thermal margin analyses were performed in accordance with the thermal-hydraulic methodology for Framatome XCOBRA code. The calculation of the fuel assembly CPR (thermal margin performance) is established by means of an empirical correlation based on results of boiling transition test programs. The CPR methodology is the approach used by Framatome to determine the margin to thermal limits for BWRs.

CPR values for ATRIUM 11 fuel are calculated with the ACE/ATRIUM 11 critical power correlation (Reference 7) while the CPR values for ATRIUM 10XM fuel are calculated with the ACE/ATRIUM 10XM critical power correlation (Reference 8). Assembly design features are incorporated in the CPR calculation through the K-factor term in the ACE

correlations. The K-factors are based on the local power peaking for the nuclear design and on additive constants determined in accordance with approved procedures. The local peaking factors are a function of assembly void and exposure.

For the compatibility evaluation, steady-state analyses evaluated ATRIUM 11 and ATRIUM 10XM fuel assemblies with radial peaking factors (RPFs) between [

] Table 3.5 - Table 3.6 show representative CPRs of the ATRIUM 11 and ATRIUM 10XM fuel designs. Table 3.7 - Table 3.10 show similar comparisons of CPR and assembly flow for the various mixed core configurations evaluated. Analysis results indicate ATRIUM 11 fuel will not adversely affect the thermal margin performance of the coresident ATRIUM 10XM fuel.

3.4 *Rod Bow*

[

]

3.5 *Bypass Flow*

Total core bypass flow is defined as leakage flow through the LTP flow holes, channel seal, core support plate, and LTP-fuel support interface. Table 3.7 shows that total core bypass flow (excluding water rod flow) fraction at rated conditions changes from

[

] of rated core flow while transitioning through the core configurations

presented (bottom-peaked power shape). Table 3.8 shows that the total core bypass flow (excluding water rod flow) fraction at 100% power/85% flow changes from [

] of rated core flow during the transition from a full core of ATRIUM 10XM to a full core of ATRIUM 11 (bottom-peaked power shape). [

] In

summary, adequate bypass flow will be available with the introduction of the ATRIUM 11 fuel design and applicable design criteria are met.

3.6 *Stability*

Each new fuel design is analyzed to demonstrate that the stability performance is equivalent to or better than an existing Framatome fuel design. The stability performance is a function of the core power, core flow, core power distribution and, to a lesser extent, the fuel design. [

] A comparative stability analysis was performed with the NRC-approved STAIF code (Reference 9). The analysis shows that the ATRIUM 11 fuel design has decay ratios equivalent to or better than other Framatome fuel designs.

As stated above, the stability performance of a core is strongly dependent on the core power, core flow, and power distribution in the core. Therefore, core stability is evaluated on a cycle-specific basis and addressed in the reload licensing report.

**Table 3.1 Design Evaluation of Thermal and Hydraulic Criteria
for the ATRIUM 11 Fuel Assembly**

Criteria Section	Description	Criteria	Results or Disposition
3.0	Thermal and Hydraulic Criteria		
3.2	Hydraulic compatibility	Hydraulic flow resistance shall be sufficiently similar to existing fuel such that there is no significant impact on total core flow or flow distribution among assemblies.	Verified on a plant-specific basis. ATRIUM 11 demonstrated to be compatible with ATRIUM 10XM fuel. []
3.3	Thermal margin performance	Fuel design shall be within the limits of applicability of an approved CHF correlation.	ACE/ATRIUM 11 critical power correlation is applied to the ATRIUM 11 fuel. ACE/ATRIUM 10XM critical power correlation is applied to the ATRIUM 10XM fuel.
		< 0.1% of rods in boiling transition.	Verified on cycle-specific basis for Chapter 14 analyses.
---	Fuel centerline temperature	No centerline melting.	Plant- and fuel-specific analyses are performed. Addressed in the mechanical design report.
3.4	Rod bow	Rod bow must be accounted for in establishing thermal margins.	The lateral displacement of the fuel rods due to fuel rod bowing is not of sufficient magnitude to impact thermal margins. Verified on a cycle-specific basis.
3.5	Bypass flow	Bypass flow characteristics shall be similar among assemblies to provide adequate bypass flow.	Verified on a plant-specific basis. Analysis results demonstrate that adequate bypass flow is provided.

**Table 3.1 Design Evaluation of Thermal and Hydraulic Criteria
for the ATRIUM 11 Fuel Assembly (Continued)**

Criteria Section	Description	Criteria	Results or Disposition
3.0	Thermal and Hydraulic Criteria (Continued)		
3.6	Stability	New fuel designs are stable in the approved power and flow operating region, and stability performance will be equivalent to (or better than) existing (approved) Framatome fuel designs.	ATRIUM 11 channel and core decay ratios have been demonstrated to be equivalent to or better than other approved Framatome fuel designs. Core stability behavior is evaluated on a cycle-specific basis.
---	LOCA analysis	LOCA analyzed in accordance with Appendix K modeling requirements. Criteria defined in 10 CFR 50.46.	Plant- and fuel-specific analysis is performed with Appendix K LOCA models and verified with cycle-specific calculations.
---	CRDA analysis	Criteria defined in Regulatory Guide 1.236	Cycle-specific analysis is performed. Results must ensure that the number of effective fuel rod failures remains bounded by the licensing basis CRDA dose analysis.
---	ASME over-pressurization analysis	ASME pressure vessel core requirements shall be satisfied.	Cycle-specific analysis is performed.
---	Seismic/LOCA liftoff	Assembly remains engaged in fuel support.	Plant- and fuel-specific analyses are performed. Addressed in the mechanical design report.

**Table 3.2 Comparative Description of
Browns Ferry ATRIUM 11 and ATRIUM 10XM Fuel**

Fuel Parameter	ATRIUM 10XM	ATRIUM 11
Number of fuel rods		
Full-length fuel rods	79	92
PLFRs	12	
Short PLFRs		12
Long PLFRs		8
Fuel clad OD, in	0.4047	[]
Number of spacers	9*	9*
Active fuel length, ft		
Full-length fuel rods	12.500	12.500
PLFRs	6.25	
Short PLFRs		4.66
Long PLFRs		7.34
Hydraulic resistance characteristics	Table 3.3	Table 3.3
Number of water rods	1	1
Water rod OD, in	1.378 [†]	1.299 [†]

* The ATRIUM 10XM and ATRIUM 11 fuel designs have 9 spacers. For both fuel designs, the losses associated with the bottom spacer are combined with the orifice/LTP model, so that only 8 spacers are explicitly modeled for these two fuels.

[†] Square water channel outer width.

Table 3.3 Hydraulic Characterization Comparison Between Browns Ferry ATRIUM 10XM and ATRIUM 11 Fuel

**Table 3.4 Browns Ferry EPU MELLLA+
Thermal-Hydraulic Design Conditions**

Reactor Conditions	100%P / 100°F	100%P / 85°F	77.6%P / 55% F	54.3%P / 37.3°F
Core power level, MWt	3952	3952	3067	2146
Core exit pressure, psia	1060	1062	1038	987
Core inlet enthalpy, Btu/lbm	523.2	517.9	504.2	492.2
Total core coolant flow, Mlbm/hr	102.5	87.1	56.4	38.2
Axial power shape	Bottom-peaked (Figure 3.1)	Bottom-peaked (Figure 3.1)	Bottom-peaked (Figure 3.1)	Bottom-peaked (Figure 3.1)

Number of Assemblies	
Central Region	Peripheral Region
Core Loading 1 []	
Core Loading 2 []	

Table 3.5 Browns Ferry EPU MELLLA+ Core Loading 1 Thermal-Hydraulic Results

**Table 3.5 Browns Ferry EPU MELLLA+ Core Loading 1
Thermal-Hydraulic Results (*continued*)**

**Table 3.7 Browns Ferry Thermal-Hydraulic Results
at 100% Power / 100% Flow Conditions**

**Table 3.8 Browns Ferry Thermal-Hydraulic Results
at 100% Power / 85% Flow Conditions**

**Table 3.9 Browns Ferry Thermal-Hydraulic Results
at 77.6% Power / 55% Core Flow Conditions**

**Table 3.10 Browns Ferry Thermal-Hydraulic Results
at 54.3% Power / 37.3% Flow Conditions**

Figure 3.1 Axial Power Shapes



**Figure 3.2 Core Loading 1:
Hydraulic Demand Curves 100% Power / 100% Flow**



**Figure 3.3 Core Loading 1:
Hydraulic Demand Curves 100% Power / 85% Flow**



**Figure 3.4 Core Loading 1:
Hydraulic Demand Curves 77.6% Power / 55% Flow**



**Figure 3.5 Core Loading 1:
Hydraulic Demand Curves 54.3% Power / 37.3% Flow**



**Figure 3.6 Core Loading 2:
Hydraulic Demand Curves 100% Power / 100% Flow**



**Figure 3.7 Core Loading 2:
Hydraulic Demand Curves 100% Power / 85% Flow**



**Figure 3.8 Core Loading 2:
Hydraulic Demand Curves 77.6% Power / 55% Flow**



**Figure 3.9 Core Loading 2:
Hydraulic Demand Curves 54.3% Power / 37.3% Flow**



4.0 REFERENCES

1. ANF-89-98(P)(A) Revision 1 and Supplement 1, *Generic Mechanical Design Criteria for BWR Fuel Designs*, Advanced Nuclear Fuels Corporation, May 1995.
2. XN-NF-80-19(P)(A) Volume 4 Revision 1, *Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads*, Exxon Nuclear Company, June 1986.
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4. XN-NF-80-19(P)(A) Volume 3 Revision 2, *Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description*, Exxon Nuclear Company, January 1987.
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7. ANP-10335P-A Revision 0, *ACE/ATRIUM 11 Critical Power Correlation*, Framatome, May 2018.
8. ANP-10298P-A Revision 1, *ACE/ATRIUM 10XM Critical Power Correlation*, AREVA Inc., March 2014.
9. EMF-CC-074(P)(A) Volume 1, *STAIF – A Computer Program for BWR Stability Analysis in the Frequency Domain*; and Volume 2, *STAIF – A Computer Program for BWR Stability Analysis in the Frequency Domain – Code Qualification Report*, Siemens Power Corporation, July 1994.

ATTACHMENT 11a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3908P Revision 3

(Proprietary)

Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel

ATTACHMENT 11b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3908NP Revision 3

(Non Proprietary)

Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel



Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel

ANP-3908NP
Revision 3

July 2021

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0414-12-F04 (Rev. 004, 04/27/2020)

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	Table 3-1 and Table 3-2	Reinstated Table 3-1 and Table 3-2 information consistent with Revision 1 of this document, added proprietary brackets to proprietary information within the tables

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Nomenclature

Acronym	Definition
3GFG	Third Generation FUELGUARD
ACE	Framatome's advanced critical power correlation [
	]
AFC	Advanced Fuel Channel
AOO	Anticipated Operational Occurrences
ASME	American Society of Mechanical Engineers
ATWS	anticipated transient without scram
BOC	beginning of cycle
BWR	boiling water reactor
CDA	confirmation density algorithm
CFD	computational fluid dynamics
CFR	Code of Federal Regulations
CHF	critical heat flux
CPR	critical power ratio
CRDA	control rod drop accident
EOC	end of cycle
EPU	extended power uprate
FWCF	feedwater controller failure
HPCI	High Pressure Coolant Injection
IHPS	Inadvertant HPCI startup
KATHY	Karlstein thermal hydraulic test facility
LHGR	linear heat generation rate
LOFH	loss of feedwater heating
LOCA	loss of coolant accident
LTP	lower Tie Plate
LTR	licensing topical report
LUC	Lead use channel
LUT	look up table
MAPLHGR	maximum average planar linear heat generation rate
MCPR	minimum critical power ratio

Acronym	Definition
NRC	Nuclear Regulatory Commission, U. S.
OLMCPR	operating limit minimum critical power ratio
PCMI	pellet clad mechanical interaction
PHTF	Portable Hydraulic Test Facility
PLFR	part length fuel rod
RAI	request for additional information
RHR	residual heat removal
RSAR	reload safety analysis report
SLC	standby liquid control
SLMCPR	safety limit minimum critical power ratio
SER	safety evaluation report
UTP	Upper Tie Plate
Z4B	Zircolay BWR material similar to Zircaloy-4
Zry-4	Zircaloy-4

1.0 INTRODUCTION

This document reviews the Framatome approved licensing methodologies to demonstrate that they are applicable to licensing and operation of the Browns Ferry Nuclear Plant with ATRIUM 11 in the extended power uprate (EPU) operating domain with a representative power/flow operating map in Figure 1-1. Application of the new methods added for ATRIUM 11 (ACE ATRIUM 11, RODEX-4 for Chromia doped fuel, AURORA-B AOO, CRDA* and LOCA) for EPU applications are addressed in this document or in plant specific applications of the new methodologies. Application of Framatome methods to ATWS-I and the application of Framatome BEO-III stability methods with CDA are not addressed here and are discussed in separate reports, ANP-3906P and ANP-3907P respectively. These methodologies have all been approved for application to mixed core loadings as discussed in Appendix A including the ATRIUM 10XM and ATRIUM 11 fuel.

The [] applied for CRDA startup range evaluation in AURORA-B CRDA and the use of a modified Framatome hydrogen uptake model are the only plant specific applications addressed in this report.

This document applies to all three Browns Ferry units since all Browns Ferry BWR/4s have only minor differences. The most significant difference between the units is the core loadings and corresponding core designs. The impact of the differences in core designs between units and cycles is addressed in the cycle specific reload report for each unit.

* For the Browns Ferry ATRIUM 11 plant-specific application of CRDA, [] has been applied for the startup range evaluations.

For the introduction of ATRIUM 11 at EPU conditions a review of the RAI's received from previous license applications was used to identify anything that needed to be addressed. Most of the issues identified in previous license applications have been addressed by the NRC approved methodologies that are being used for the licensing of ATRIUM 11 fuel in Browns Ferry.

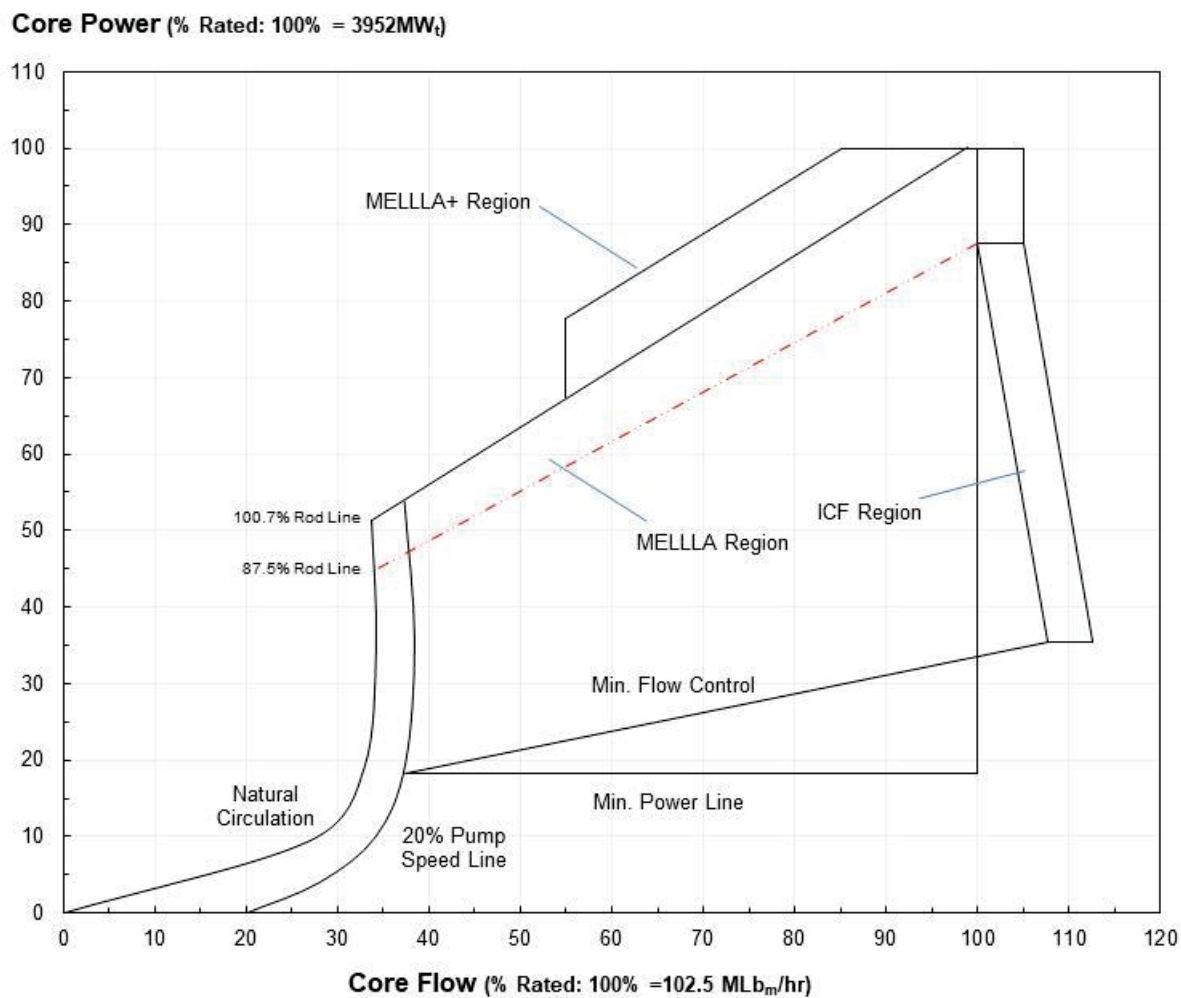


Figure 1-1
Browns Ferry Power Flow Operating Map

2.0 OVERVIEW

The introduction of ATRIUM 11 fuel coincides with the application of a new modern suite of methodologies (References 1 through 9) that also address a number of industry concerns. This is the third application of the entire suite of new and upgraded methodologies. Browns Ferry currently operates with ATRIUM 10XM fuel and is transitioning to ATRIUM 11. The design characteristics of the ATRIUM 10XM and ATRIUM 11 are explicitly accounted for in all of the models for operation with EPU and extended flow domains. The differences in fuel design characteristics between the ATRIUM 10XM and ATRIUM 11 are discussed in Section 3.0.

The first step in determining the applicability of current licensing methods to Browns Ferry operating conditions was a review of Framatome BWR topical reports listed in Table 2-1 and the Browns Ferry facility operating license conditions to identify SER restrictions. This review identified that there are no SER restrictions on core power level or core flow for the Framatome topical reports up to and including EPU/extended flow window. The review also indicated that the [

]. This is discussed in the Thermal Hydraulics section.

Based on the fundamental characteristics of the fuel designs, each of the major analysis domains thermal-mechanics, thermal-hydraulics, mechanics, core neutronics, transient analysis, LOCA and stability are assessed to determine any challenges to application.

Table 2-1 Framatome Licensing Topical Reports

Document Number	Document Title
XN-NF-79-56(P)(A) Revision 1 and Supplement 1(P)(A)	"Gadolinia Fuel Properties for LWR Fuel Safety Evaluation," Exxon Nuclear Company, November 1981
XN-NF-85-67(P)(A) Revision 1	"Generic Mechanical Design for Exxon Nuclear Jet Pump BWR Reload Fuel," Exxon Nuclear Company, July 1986
XN-NF-85-92(P)(A)	"Exxon Nuclear Uranium Dioxide/Gadolinia Irradiation Examination and Thermal Conductivity Results," Exxon Nuclear Company, November 1986
ANF-89-98(P)(A) Revision 1 and Supplement 1	"Generic Mechanical Design Criteria for BWR Fuel Designs," Advanced Nuclear Fuels Corporation, May 1995
ANF-90-82(P)(A) Revision 1	"Application of ANF Design Methodology for Fuel Assembly Reconstitution," Advanced Nuclear Fuels Corporation, May 1995
EMF-93-177(P)(A) Revision 1	"Mechanical Design for BWR Fuel Channels," Framatome ANP, August 2005
EMF-93-177P-A Revision 1 Supplement 1P-A Revision 0	"Mechanical Design for BWR Fuel Channels Supplement 1: Advanced Methods for New Channel Designs," AREVA Inc., September 2013
EMF-93-177 Revision 1 Supplement 2P-A Revision 1	"Mechanical Design for BWR Fuel Channels: Z4B Material," Framatome Inc., June 2019
BAW-10247PA Revision 0	"Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors," AREVA NP, February 2008
BAW-10247PA Revision 0 Supplement 1P-A, Revision 0	"Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 1: Qualification of RODEX4 for Recrystallized Zircaloy-2 Cladding", April 2017
BAW-10247P-A, Supplement 2P-A, Revision 0	"Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods", Framatome Inc., August 2018
ANP-10340P-A Revision 0	"Incorporation of Chromium-Doped Fuel in AREVA Approved Methods", Framatome Inc., May 2018

Table 2-1 Framatome Licensing Topical Reports *(Continued)*

Document Number	Document Title
XN-NF-80-19(P)(A) Volume 1 and Supplements 1 and 2	"Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis," Exxon Nuclear Company, March 1983
XN-NF-80-19(P)(A) Volume 4 Revision 1	"Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads," Exxon Nuclear Company, June 1986
EMF-2158(P)(A) Revision 0	"Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2," Siemens Power Corporation, October 1999
XN-NF-79-59(P)(A)	"Methodology for Calculation of Pressure Drop in BWR Fuel Assemblies," Exxon Nuclear Company, November 1983
XN-NF-80-19(P)(A) Volume 3 Revision 2	"Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description," Exxon Nuclear Company, January 1987
ANP-10298P-A Revision 1	"ACE/ATRIUM 10XM Critical Power Correlation," AREVA, March 2014
ANP-10335P-A Revision 0	"ACE/ATRIUM 11 Critical Power Correlation", Framatome Inc., May 2018
ANP-10307PA Revision 0	"AREVA MCPR Safety Limit Methodology for Boiling Water Reactors," AREVA NP, June 2011
ANF-1358(P)(A) Revision 3	"The Loss of Feedwater Heating Transient in Boiling Water Reactors," Framatome ANP, September 2005
ANP-10300P-A Revision 1	"AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios" Framatome Inc., January 2018
ANP-10332P-A Revision 0	"AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios" Framatome Inc., March 2019
ANP-10333P-A Revision 0	"AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident Scenarios", Framatome Inc., March 2018

3.0 ATRIUM 11 FUEL ASSEMBLY DESIGN

The ATRIUM 11 fuel assembly design consists of a lower tie plate (LTP) and upper tie plate (UTP), 112 fuel rods, 9 spacer grids, a central water channel, and miscellaneous assembly hardware.

The fuel design utilizes a square internal water channel which occupies nine (3x3) lattice positions. The upper and lower ends of the water channel are attached to connecting hardware which provides a load chain between the upper and lower tie plates.

The 11x11 rod array is comprised of 92 full length fuel rods, 8 long part length fuel rods (PLFR) and 12 short PLFRs. The PLFRs are captured in the LTP grid to prevent axial movement.

The fuel rod pitch is slightly larger in the upper section of the assembly relative to the fuel rod pitch in the lower section of the assembly. The array of fuel rods remain orthogonal throughout the assembly.

The nine ULTRAFLOW™ spacers are fabricated from Alloy 718 material and utilize integrated spring and dimple elements. Eight spacers are axially distributed over the heated length, while a ninth spacer is located just above the LTP to restrain the lower ends of the fuel rods.

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Details of the fuel design characteristics are presented in Table 3-1 and Table 3-2 along with the equivalent values for the ATRIUM 10XM fuel design which is currently used and licensed in the Browns Ferry units.

Table 3-1 Fuel Assembly and Component Description

Characteristic	ATRIUM 10XM	ATRIUM 11
Fuel Bundle		
Fuel rod array	10x10	11X11
Number of non-fueled elements	1 square water channel displaces a 3x3 array	1 square water channel displaces a 3x3 array
Number of fueled rods Full-length / Part-length	79 / 12	92 / 8 long / 12 short
Debris filter style	3GFG	3GFG
Fuel Rod		
Cladding material	Zry-2	Zry-2
Liner material	Fe-enhanced zirconium liner	Non Liner
Cladding heat treatment	stress-relief annealed	stress-relief annealed
Spacer Grid		
Variant name: ULTRAFLOW	AH62	AH 75/3 (Bottom []) AH 76/3 (Middle []) AH 77/3 (Top [])
Material	Alloy 718	Alloy 718

Table 3-2 Fuel Channel and Fastener Description

Characteristic	ATRIUM 10XM	ATRIUM 11
Advanced Fuel Channel		
Material	Zry-4, Z4B(LUC)	Z4B
Channel Fastener (ATRIUM 10XM) / Channel Spacer Assembly (ATRIUM 11)		

4.0 THERMAL-MECHANICAL LIMITS METHODOLOGY

The LHGR limit is established to support plant operation while satisfying the fuel thermal-mechanical design criteria. The methodology for performing the fuel rod evaluation is described in References 3 through 5. The extension of these methods to fuel incorporating chromia is described in Reference 6. Fuel rod design criteria evaluated by the methodology are contained in References 3 and 10.

Fuel rod power histories are generated as part of the methodology for equilibrium cycle conditions as well as cycle-specific operation. These power histories include the effect of channel bow as described in Reference 3. The uncertainties of the important physical phenomenon are taken into account in the categories of operating power uncertainties, code model parameter uncertainties, and fuel manufacturing tolerances. In addition, adjustments are made to the power history inputs for possible differences in planned versus actual operation. Upper limits on the analysis results are obtained for comparison to the design limits for fuel melt, cladding strain, rod internal pressure and other characteristics as described by the design criteria.

Since the power history inputs, which include LHGR, fast neutron flux, reactor coolant pressure and reactor coolant temperature, are used as input to the analysis, the results explicitly account for conditions representative of the ATRIUM 11 operation. The resulting LHGR limit is used to monitor the fuel so it is maintained within the same maximum allowable steady-state power envelope as analyzed.

5.0 THERMAL HYDRAULICS

5.1 *ATRIUM 11 Void Fraction*

The [] void-quality correlation has been qualified by Framatome against both the FRIGG void measurements, ATRIUM-10 and ATRIUM 10XM measurements. The standard deviation for the FRIGG tests was shown to be [] while the standard deviation for the ATRIUM-10 and ATRIUM 10XM tests was found to be [] respectively. []

[] the use of the [] correlation for ATRIUM 11 is justified.

The ATRIUM 11 [] void fraction measurements. S-RELAP5 was assessed against previous measurements based upon fundamental hydraulic characteristics. The Marviken assembly of FRIGG had a 2-sigma error of [] in void prediction. The ATRIUM-10 has a 2-sigma error of [] for void. []; therefore, the use of a 2-sigma error of [] is justified for the ATRIUM 11.

5.2 *ACE/ATRIUM 11 Critical Power Ratio Correlation*

The critical power ratio (CPR) correlation used in MICROBURN-B2, SAFLIM3D, S-RELAP5, RAMONA5-FA, and X-COBRA is based on the ACE/ATRIUM 11 critical power correlation described in Reference 7. As with all Framatome correlations, the range of applicability is enforced in Framatome methods through automated bounds checking and corrective actions. The ATRIUM 11 bounds checking process is similar to the ATRIUM 10XM as provided in Table 5-1. The ACE CPR correlation uses K-factor values to account for rod local peaking, rod location and bundle geometry effects.

The K-factor parameter is described in detail in Section 6.10 of Reference 7.

The ranges of applicability of the ACE/ATRIUM 11 and ACE/ATRIUM 10XM are compared in Table 5-2.

5.3 *Loss Coefficients*

Wall friction and component loss coefficients were determined for Browns Ferry based on single-phase testing of a prototypic ATRIUM 11 fuel assembly in the Portable Hydraulic Test Facility (PHTF). Prototypical fuel rods, spacer grids, flow channel, upper tie plate and lower tie plate were used in the testing. A description of the PHTF facility and an overview of the process for determining the component loss coefficients are described in Reference 11.

The ATRIUM 11 PHTF tests form the basis for the single phase loss coefficients currently used for design and licensing analyses supporting U.S. BWRs. The PHTF is used by Framatome to obtain single phase loss coefficients for the spacers. The friction factor correlation is a Reynolds dependent function based on the Moody friction model and the measured surface roughness. The pressure drops across the spacers are measured in the PHTF for each new design. [

]

The wall friction and component loss coefficients determined from the PHTF and utilized in the validation of the MICROBURN-B2 pressure drop model for the ATRIUM 11 fuel design are provided in Table 5-3.

PHTF data was reduced to determine single phase losses for the spacers in the [

] of the bundle. The values have been selected because they are representative of the hydraulic characteristics of actual ATRIUM 11 fuel assemblies loaded into the reactor.

The modeling of the two-phase spacer pressure drop multiplier for the ATRIUM 11 fuel design has been confirmed with two-phase pressure drop measurements taken in the KATHY facility.

Figure 5-1 shows measured versus the MICROBURN-B2 predicted two phase pressure drop for a range of conditions. This figure confirms the applicability of the thermal-hydraulic models to predict pressure drop for the ATRIUM 11 design.

**Table 5-3 Hydraulic Characteristics
of ATRIUM 11 Fuel Assemblies**

* Loss coefficients are referenced to the adjacent assembly bare rod flow area.

† [

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**Figure 5-1 Measured versus Predicted (MICROBURN-B2) Bundle
Pressure Drop**

6.0 TRANSIENTS AND ACCIDENTS

6.1 *Void Calculation Uncertainties*

The Framatome analyses methods and the correlations used are applicable for all Framatome designs in EPU conditions. The approach for addressing bias and uncertainties in the void calculation remains unchanged and is applicable for Browns Ferry operation with the ATRIUM 11 fuel design.

The OLMCPR is determined based on the safety limit MCPR (SLMCPR) methodology and the transient analysis (Δ CPR) methodology. Void prediction uncertainty is not a direct input to either of these methodologies; however, the impact of void prediction uncertainty is inherently incorporated in both methodologies as discussed below.

The SLMCPR methodology explicitly considers important uncertainties in the Monte Carlo calculation performed to determine the number of rods in boiling transition. One of the uncertainties considered in the SLMCPR methodology is the bundle power uncertainty. This uncertainty is determined through comparison of calculated to measured core power distributions. Any miscalculation of void conditions will increase the error between the calculated and measured power distributions and be reflected in the bundle power uncertainty. Therefore, void prediction uncertainty is an inherent component of the bundle power uncertainty used in the SLMCPR methodology.

The transient analyses methodology utilizes a [

]

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Section 3.5.2.7 documented the NRC's review of this response as such:

However, the NRC staff does not agree with AREVA's third response. [

]

The result of this conclusion was Limitation and Condition 12 of AURORA-B AOO which requires plant-specific approval for any changes made to the transient coolant mixing.

This section is intended to provide the description of the method used to determine [

].

6.3.1 Transient Mixing Determination

For Browns Ferry, the mixing is evaluated using [

]

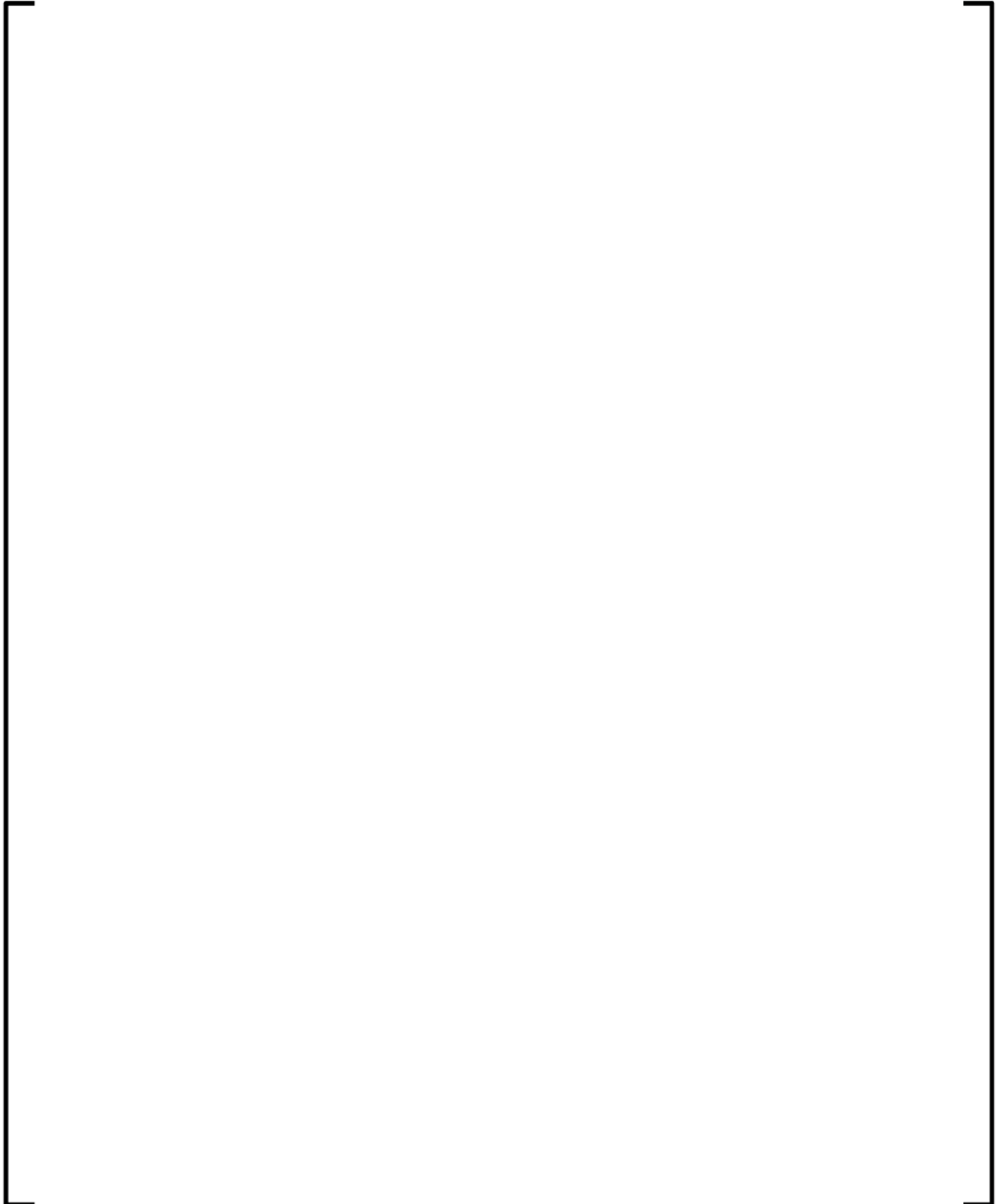
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[

]



Figure 6-1 [

]

6.3.2 Implementation in AURORA-B AOO Licensing

Once the amount of mixing has been determined, the AURORA-B licensing model will be constructed. In order to ensure a conservative estimation of mixing is used, [

]

6.4 *Control Rod Drop Accident*

[

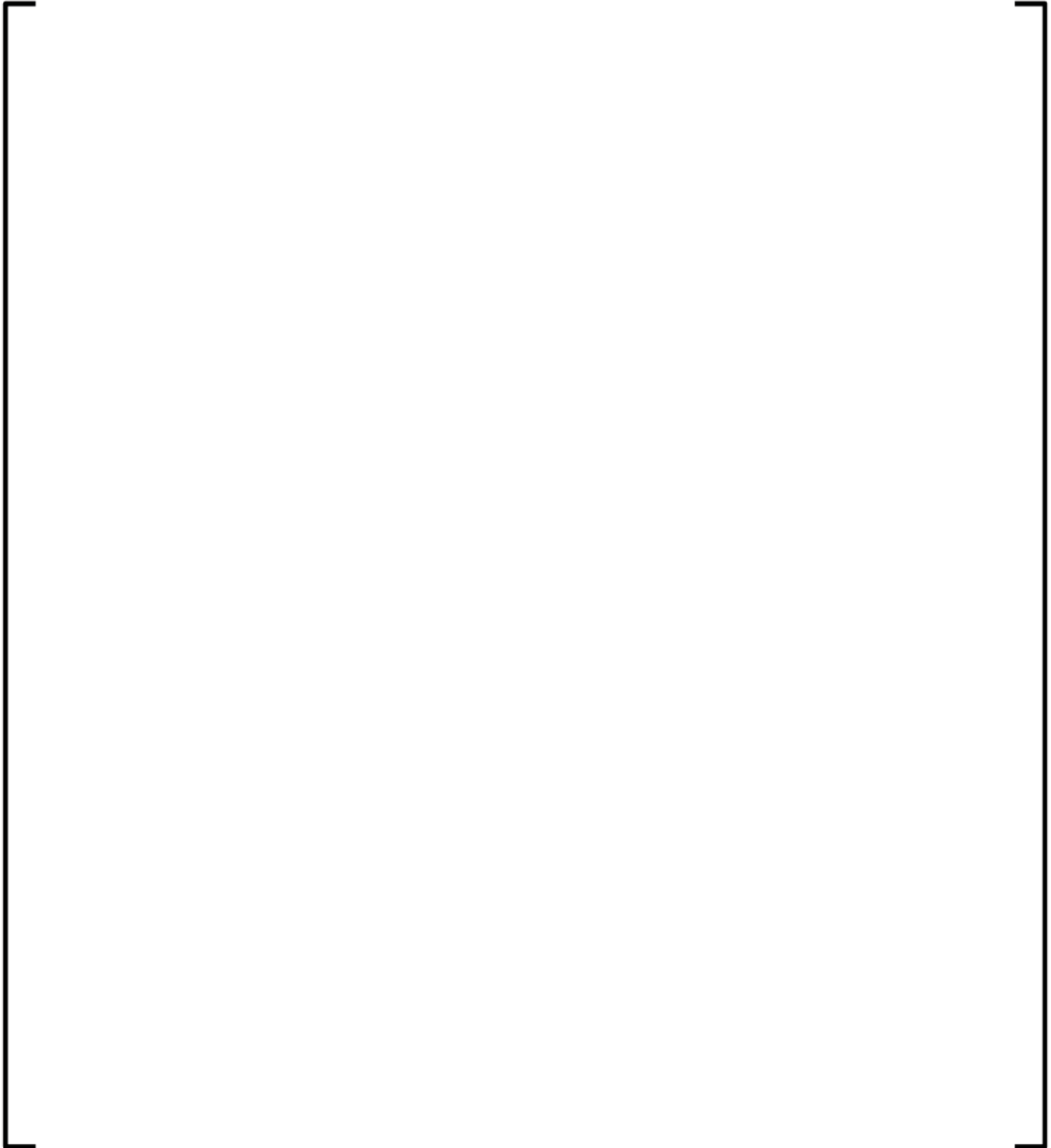
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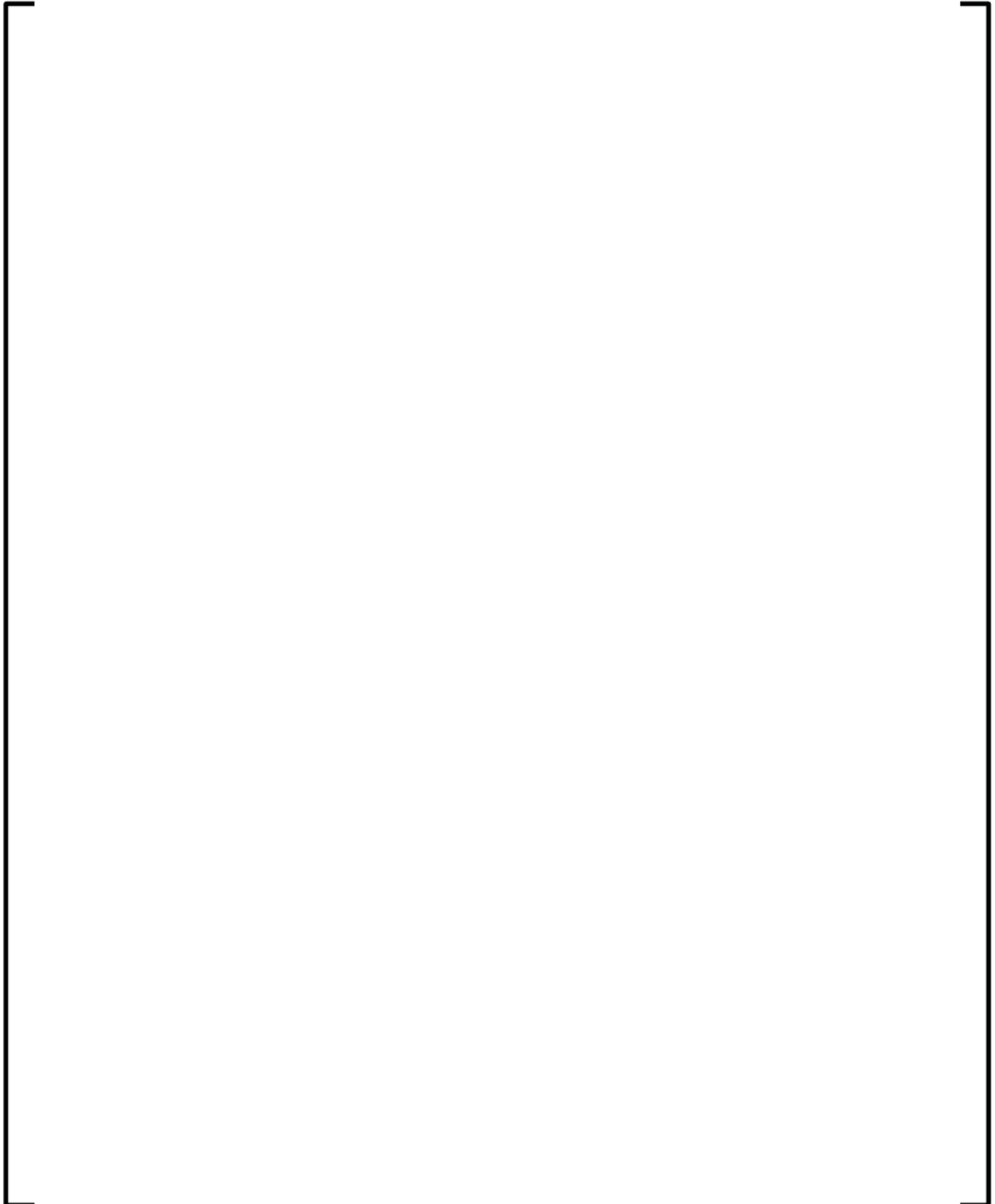
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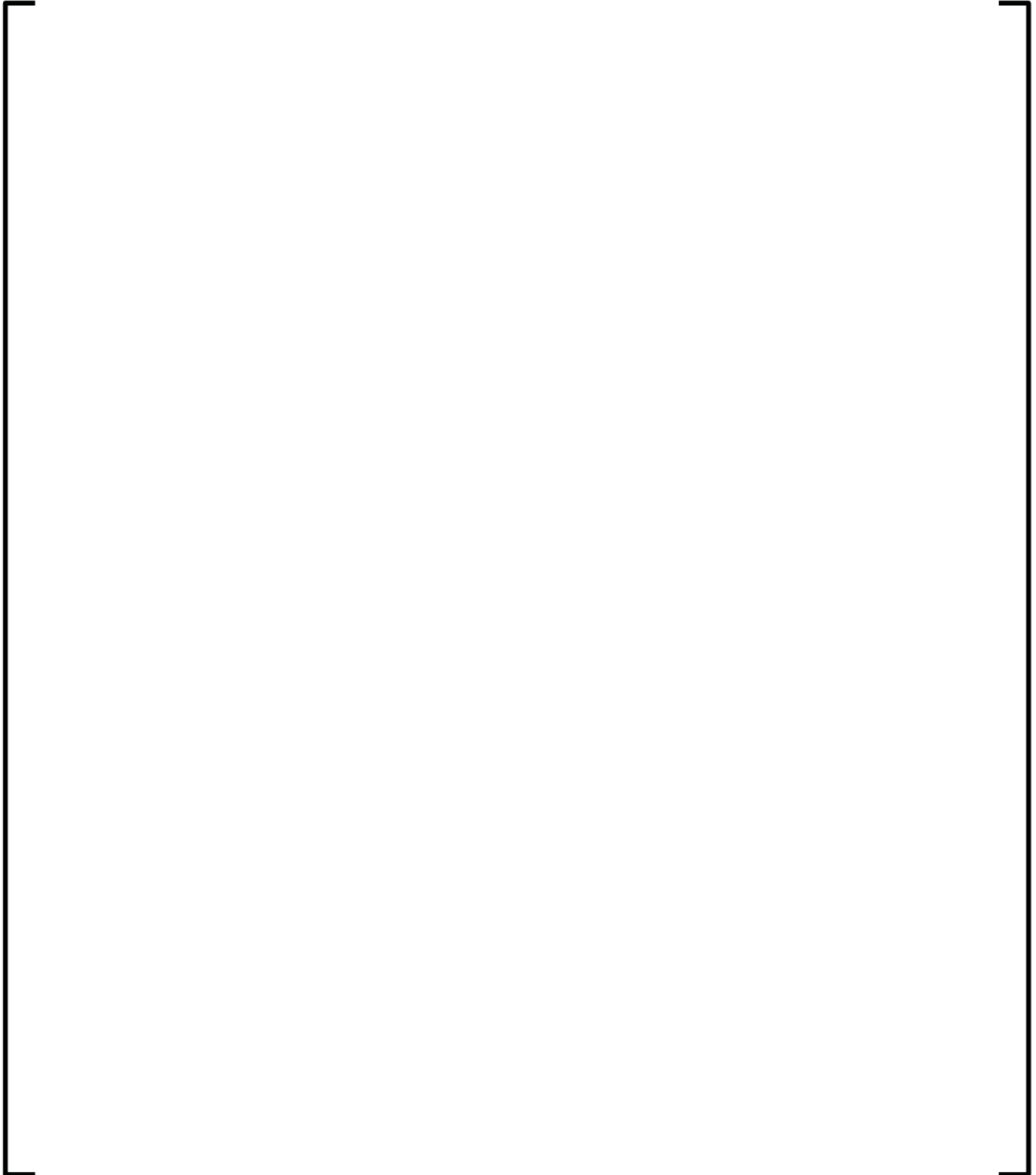




Figure 6-2 Total Enthalpy Rise with CHF Multipliers



Figure 6-3 **[**

]



Figure 6-4 [

]

6.5 *Loss of Coolant Accident*

The approved AURORA-B LOCA methodology, Reference 9, has been approved to be applicable to BWR/3 to BWR/6 with conditions extending up to EPU with extended flow windows. In addition, Limitation and Condition 27 of Reference 9 addresses the application of the methodology to [

].

6.6 *AURORA-B AOO Time Step Size*

Section 6.8.2 of ANP-10300P-A, Reference 1, provides a discussion of a time step size sensitivity study using the AURORA-B AOO methodology. The conclusion of this section states:

[

]

This conclusion was based off of a set of sensitivity studies which [

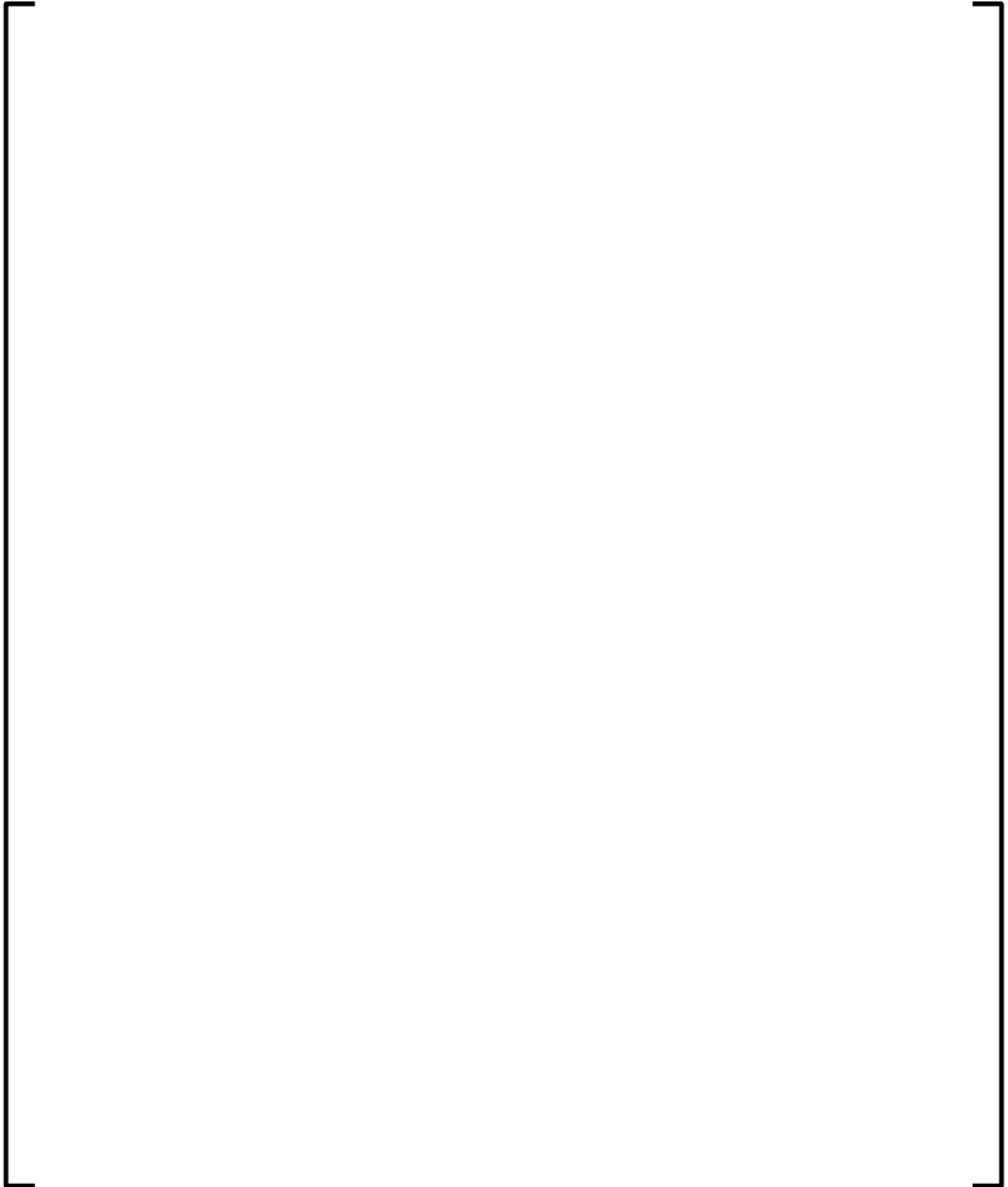
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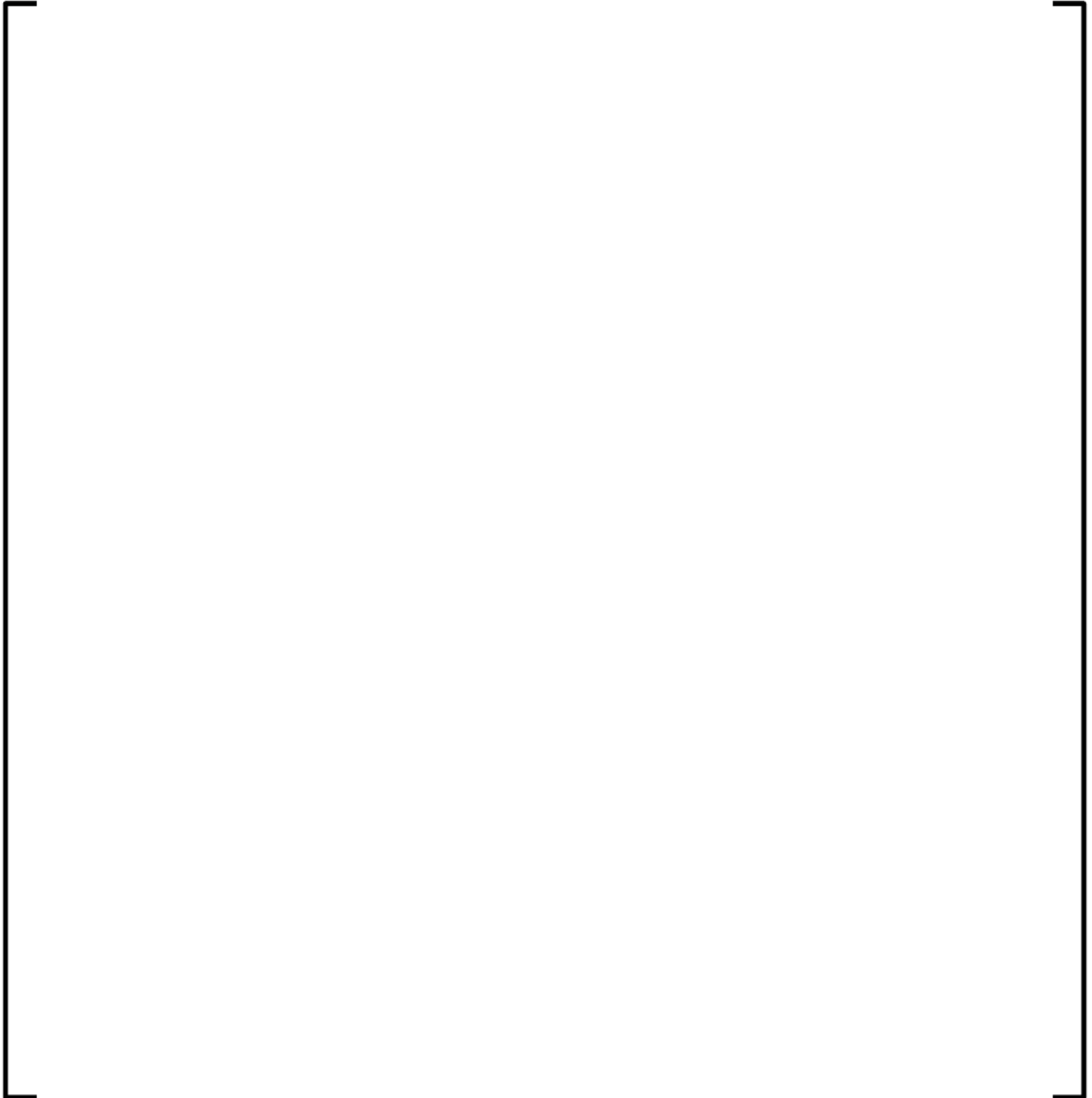


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7.0 ATWS

7.1 ATWS General

The AURORA-B methodology is used for the ATWS overpressurization analysis. The ACE/ATRIUM 11 critical power correlation pressure limit is not a factor in the analysis.

Dryout might occur in the limiting (high power) channels of the core during the ATWS event. For the ATWS overpressurization analysis, ignoring dryout for the hot channels is conservative in that it maximizes the heat transferred to the coolant and results in a higher calculated pressure.

The ATWS event is not limiting relative to acceptance criteria identified in 10 CFR 50.46. The core remains covered and adequately cooled during the event. Following the initial power increase during the pressurization phase, the core returns to natural circulation conditions after the recirculation pumps trip and fuel cladding temperatures are maintained at acceptable low levels. The ATWS event is significantly less limiting than the loss of coolant accident relative to 10 CFR 50.46 acceptance criteria.

7.2 Void Prediction

Framatome performs cycle-specific ATWS analyses of the short-term reactor vessel peak pressure using the AURORA-B methodology. The ATWS peak pressure calculation is a core-wide pressurization event that is sensitive to similar phenomenon as other pressurization transients. Bundle design is included in the development of input for the coupled neutronic and thermal-hydraulic S-RELAP5 core model. Important inputs to the S-RELAP5 system model are biased in a conservative direction.

The Framatome transient analysis methodology utilizes a non-parametric uncertainty analysis which includes the uncertainties in individual phenomena. The methodology

[

]

[

] As demonstrated in Section 5.1 the void prediction is robust for past and present designs including the ATRIUM 11.

The reference ATWS analysis evaluation presented in the topical report (Reference 1) of the core active density response, which is closely related to the void response, showed minimal changes in the peak vessel pressure. A study was also performed for the ASME overpressure event (FWCF) with similar results.

7.3 *ATWS Containment Heatup*

Fuel design differences may impact the power and pressure excursion experienced during the ATWS event. This in turn may impact the amount of steam discharged to the suppression pool and containment.



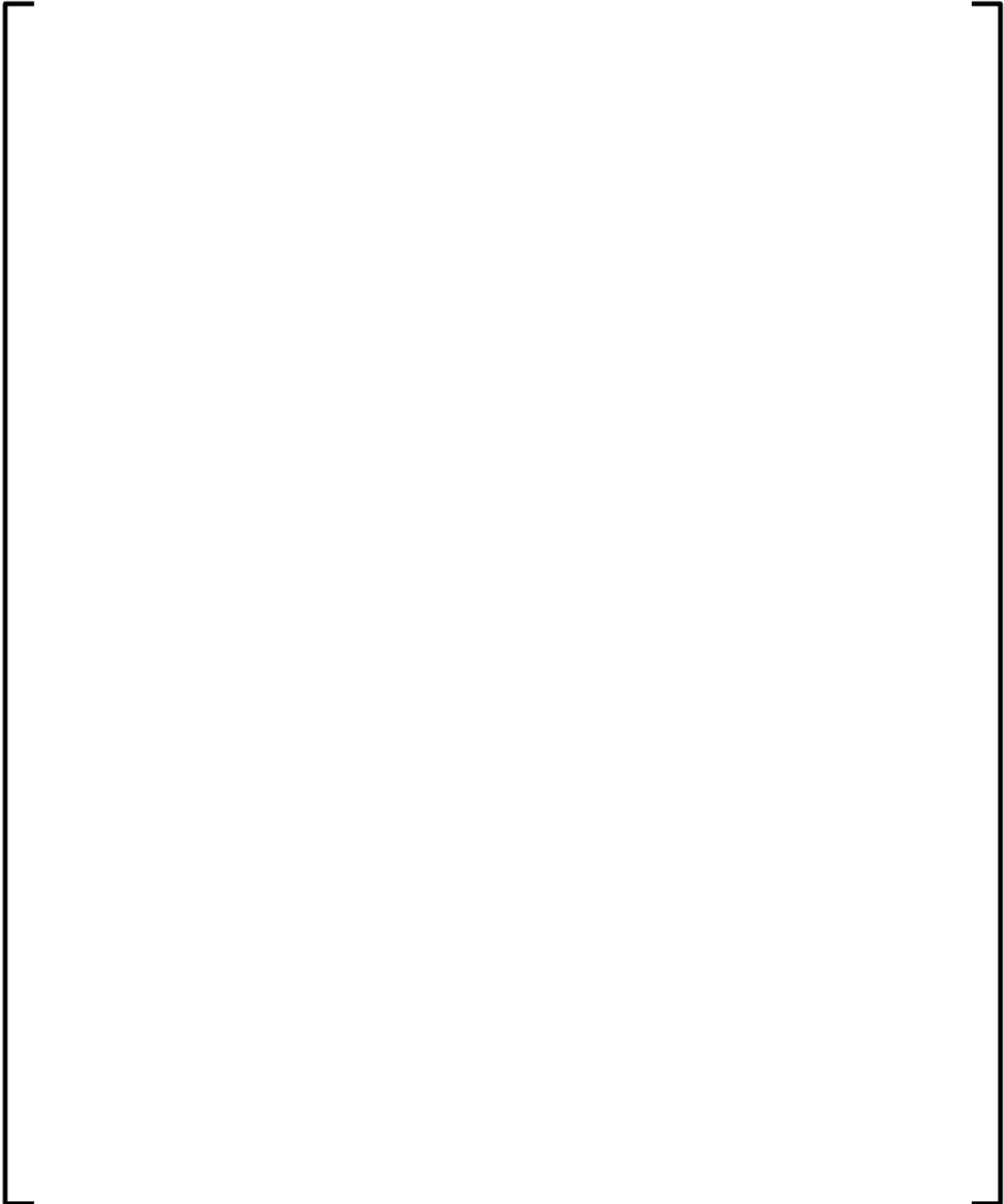
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Table 7-1 [

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Table 7-2 [

]

* Boron worth is quoted as a positive value since it refers to the boron defect. The ppm boron used is 720 at 68 F. The calculation uses the equivalent boron at 365.8 F, used in Browns Ferry SLCS calculations.

8.0 NEUTRONICS

From the neutronics perspective, the ATRIUM 11 fuel design differs from the ATRIUM 10XM fuel design primarily in the fuel rod diameter and pitch and position and number of the part length rods. The CASMO-4 code is designed to model a wide range of fuel rod diameters and pitches. The neutronic models have already been demonstrated to accurately model the vacant positions and this continues to be true for the ATRIUM 11 fuel design.

8.1 *Shutdown Margin*

The part length rod in the corner of the assembly improves the shutdown margin performance of the fuel design because of the flux trap that is created in the cold condition with the vacant rod position of all four assemblies in a control cell being in close proximity. The heterogeneous solution of CASMO-4 accurately models the vacant rod position and the associated reactivity. No change in predicted hot operating or cold critical eigenvalue is anticipated with the ATRIUM 11 fuel design.

8.2 *Monitoring*

The part length rod in the corner of the assembly has an impact on the corner flux that influences the detector response. The heterogeneous solution of CASMO-4 accurately calculates this corner flux depression. This characterization is used directly in the MICROBURN-B2 determination of the predicted detector response. For the Browns Ferry analyses the plena have been explicitly modeled with the heterogeneous CASMO-4 model, thus providing the most accurate model available.

8.3 *Bypass modeling*

The bypass behavior of the ATRIUM 11 fuel design is identical to the ATRIUM 10XM fuel design, thus there is no difference in the modeling. Any differences in bypass heat deposition are treated explicitly.

Cycle-specific validation that the allowable bypass voiding at the LPRM D level has been met will continue to be performed. This validation will be documented in the corresponding Reload Safety Analysis Report for that cycle.

8.4 *Vessel fluence*

Comparisons of ATRIUM 11 and ATRIUM 10XM peripheral fast fluence were performed using the equilibrium fuel cycle designs of References 19 and 20, respectively. The results of this comparison as summarized in Figure 8-1 and Figure 8-2 show that the peripheral fluence of the ATRIUM 11 equilibrium core design remains bounded by the previous ATRIUM 10XM equilibrium design. This is a reasonable result due to the lower batch fraction of the ATRIUM 11 equilibrium cycle design. The lower batch fraction results in higher burnup and lower power for the assemblies loaded on the periphery of the core.

The results also include core-wide comparisons between the two equilibrium cycles. As illustrated in Figure 8-2 the ATRIUM 11 core wide results are not bound by the previous ATRIUM 10XM results. This is also consistent with the lower batch fraction since the interior assemblies operate at a higher overall power to compensate for the lower power on the periphery. The more bottom peaked distribution for ATRIUM 11 is also consistent with expectations for this fuel design. However, it is also noted that even with the overall increases in the central portion of the core, the upper and lower nodes have essentially the same accumulated fluence minimizing any impact to lower or upper core components.

Based upon the above discussion, the implementation of ATRIUM 11 fuel will not have an adverse impact on the existing vessel fluence evaluation or to the lower and upper core components.

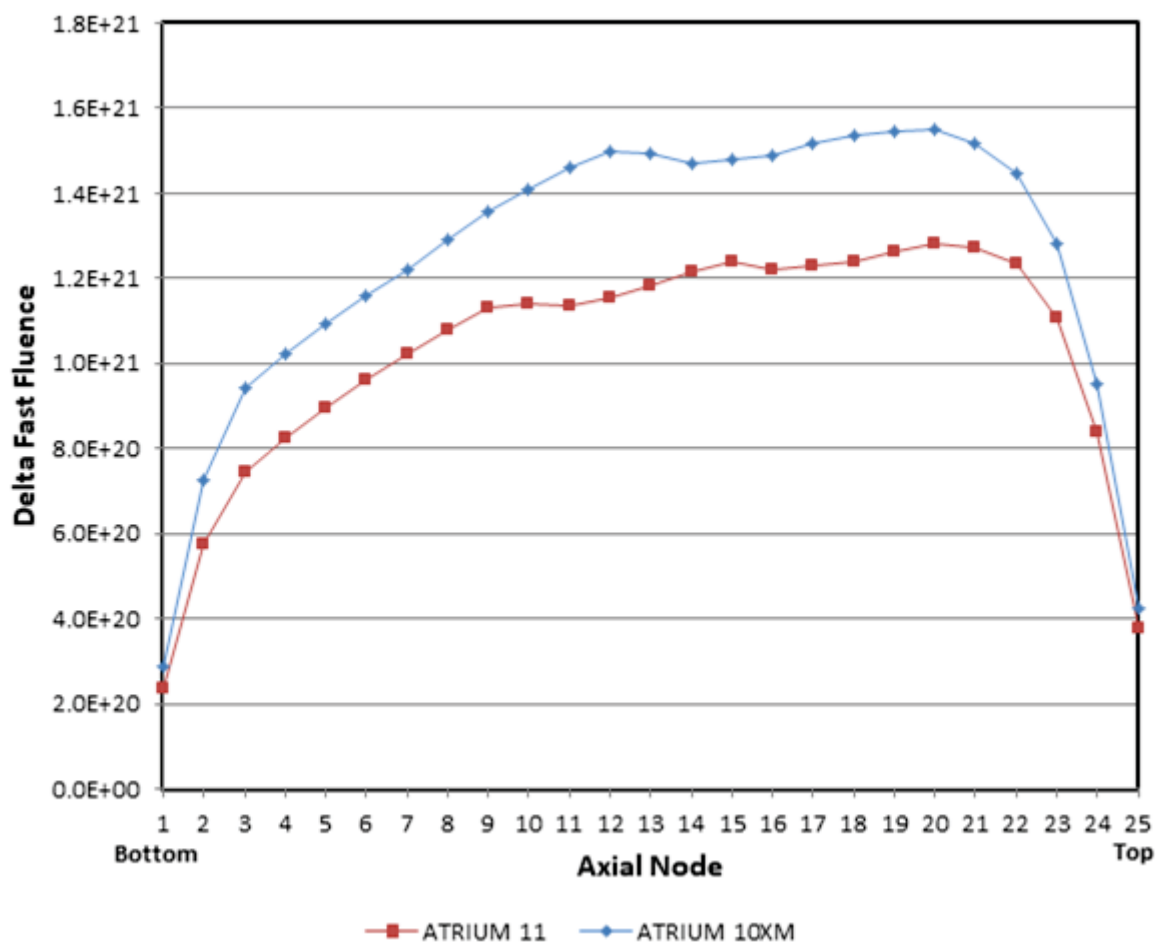


Figure 8-1 Comparison of Peripheral Assembly Planar Average Fluence Accumulation for Equilibrium Cycles of ATRIUM 10XM and ATRIUM 11

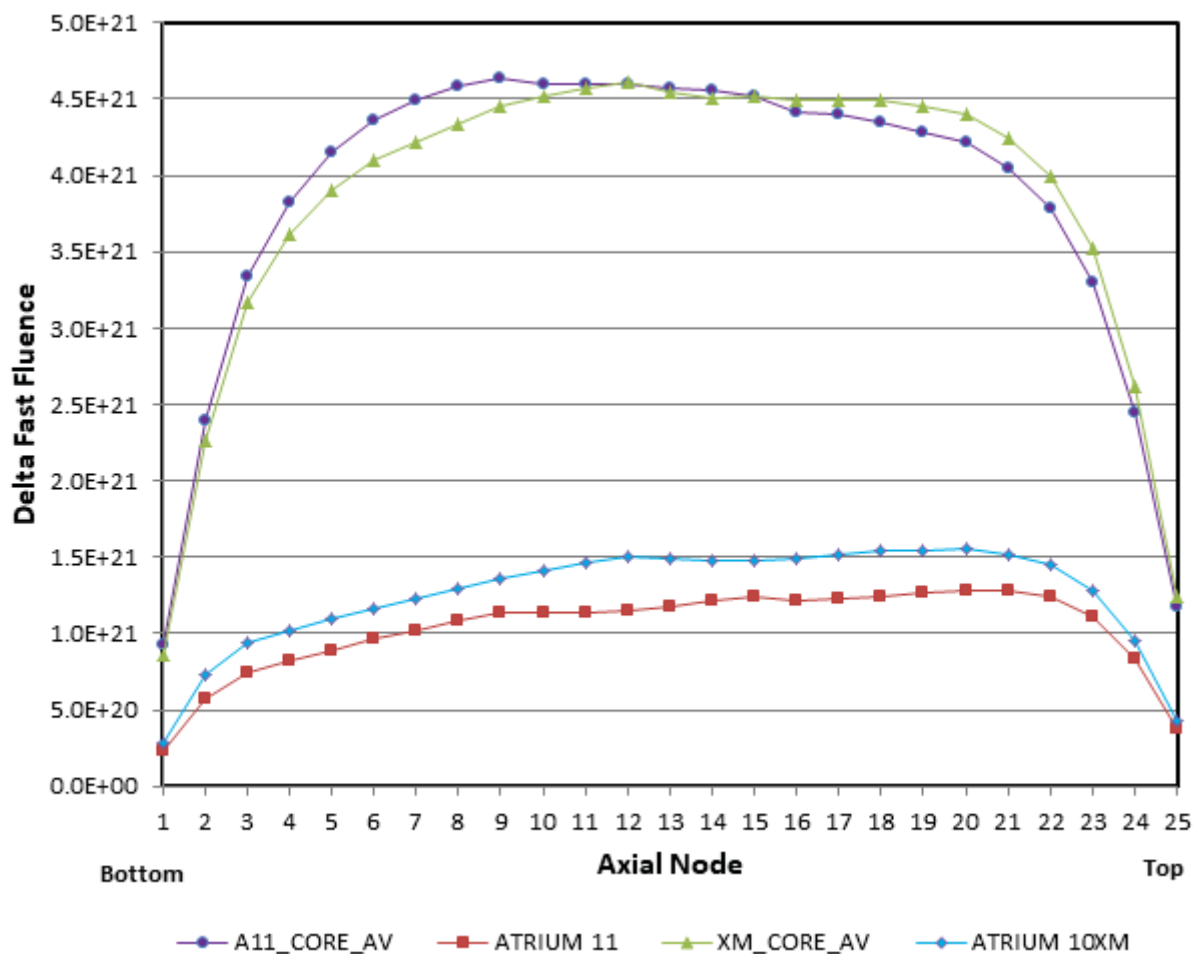


Figure 8-2 Comparison of Core and Peripheral Assembly Planar Average Fluence Accumulation for Equilibrium Cycles of ATRIUM 10XM and ATRIUM 11

9.0 REFERENCES

1. ANP-10300P-A Revision 1, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios," Framatome Inc., January 2018.
2. ANP-10333P-A Revision 0, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA) ," Framatome Inc., March 2018
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7. ANP-10335P-A Revision 0, "ACE/ATRIUM 11 Critical Power Correlation," Framatome Inc., May 2018.
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APPENDIX A APPLICATION OF FRAMATOME METHODOLOGY FOR MIXED CORES

A.1. DISCUSSION

Framatome has considerable experience analyzing fuel design transition cycles and has methodology and procedures to analyze mixed cores composed of multiple fuel types. For each core design, analyses are performed to confirm that all design and licensing criteria are satisfied. The analyses performed explicitly include each fuel type in the core. The analyses consider the cycle-specific core loading and use input data appropriate for each fuel type in the core. The mixed core analyses are performed using generically approved methodology in a manner consistent with NRC approval of the methodology. Based on results from the analyses, operating limits are established for each fuel type present in the core. During operation, each fuel type is monitored against the appropriate operating limits.

Thermal hydraulic characteristics are determined for each fuel type that will be present in the core. The thermal hydraulic characteristics used in core design, safety analysis, and core monitoring are developed on a consistent basis for both Framatome fuel and other vendor co-resident fuel to minimize variability due to methods. For Browns Ferry operation, the entire core will be composed of Framatome fuel designs.

For core design and nuclear safety analyses, the neutronic cross-section data is developed for each fuel type in the core using CASMO-4. MICROBURN-B2 is used to design the core and provide input to safety analyses (core neutronic characteristics, power distributions, etc.). Each fuel assembly is explicitly modeled in MICROBURN-B2 using cross-section data from CASMO-4 and geometric data appropriate for the fuel design.

Fuel assembly thermal-mechanical limits for all fuel are verified and monitored for each mixed core designed by Framatome. Framatome performs design and licensing

analyses to demonstrate that the core design meets steady-state limits and that transient limits are not exceeded during anticipated operational occurrences.

The critical power ratio (CPR) is evaluated for each fuel type in the core using calculated local fluid conditions and an appropriate critical power correlation. Fuel type specific correlation coefficients for Framatome fuel are based on data from the Framatome critical power test facility. The ACE/ATRIUM 10XM critical power correlation will be used for monitoring ATRIUM 10XM fuel present during the transition to operation with ATRIUM 11 at Browns Ferry. The CPR correlation used for the ATRIUM 11 fuel is the ACE/ATRIUM 11 critical power correlation described in Reference 7. The ACE CPR correlation uses K-factor values to account for rod local peaking, rod location and bundle geometry effects.

In the safety limit MCPR analysis each fuel type present in the core is explicitly modeled using appropriate geometric data, thermal hydraulic characteristics, and power distribution information (from CASMO-4 and MICROBURN-B2 analyses). CPR is evaluated for each assembly using fuel type specific correlation coefficients. Plant and fuel type specific uncertainties are considered in the statistical analysis performed to determine the safety limit MCPR. The safety limit MCPR analysis is performed each cycle and uses the cycle specific core configuration.

An operating limit MCPR is established for each fuel type in the core. For fast transients the AURORA-B code (Reference 1) is used to determine the overall system and hot channel response. The core nuclear characteristics used in AURORA-B are obtained from MICROBURN-B2 and reflect the actual core loading pattern. Critical power performance is evaluated using local fluid conditions and fuel type specific CPR correlation coefficients. The transient CPR response is used to establish an operating limit MCPR for each fuel type.

For transient events that are sufficiently slow such that the heat transfer remains in phase with changes in neutron flux during the transient, evaluations are performed with

steady state codes such as MICROBURN-B2 in accordance with NRC approval. Such slow transients are modeled by performing a series of steady state solutions with appropriate boundary conditions using the cycle specific design core loading plan. Each fuel assembly type in the core is explicitly modeled. The change in CPR between the initial and final condition after the transient is determined, and if the CPR change is more severe than those determined from fast transient analyses, the slow transient result is used to determine the MCPR operating limit.

MAPLHGR operating limits are established and monitored for each fuel type in the core to ensure that 10 CFR 50.46 acceptance criteria are met during a postulated LOCA. The S-RELAP5 code is used to determine the overall system and hot channel response during a postulated LOCA. While system analyses are typically performed on an equilibrium core basis, the thermal hydraulic characteristics of all fuel assemblies in the core are considered to ensure the LOCA analysis results are applicable to mixed core configurations.

The core monitoring system will monitor each fuel assembly in the core. Each assembly is modeled with geometric, thermal hydraulic, neutronic, and CPR correlation input data appropriate for the specific fuel type. Each assembly in the core will be monitored relative to thermal limits that have been explicitly developed for each fuel type.

In summary, Framatome methodology is used consistent with NRC approval to perform design and licensing analyses for mixed cores. The cycle design and licensing analyses explicitly consider each fuel type in mixed core configurations. Limits are established for each fuel type and operation within these limits is verified by the monitoring system during operation.

ATTACHMENT 12a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3905P Revision 1

(Proprietary)

Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel

ATTACHMENT 12b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

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Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel



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ANP-3905NP
Revision 1

July 2021

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1.	Page 2-1	Updated peak cladding temperature, local oxidation and hydrogen generation results to address Framatome CR-2021-1448
2.	Page 6-1 and 6-2	Updated limiting break information
3.	Page 6-3	Updated break spectrum results
4.	Page 6-4	Updated event timing information
5.	Figures 6.1-6.15	Updated figures
6.	Page 7-2	Updated limiting break information
7.	Page 7-3	Updated peak cladding temperature and break size results
8.	Pages 9-1 through 9-3	Updated peak cladding temperature results, break size information, and metal water reaction results
9.	Page 9-4	Updated figure
10.	Page 10-1	Updated limiting break information
11.	Page A-6	Updated disposition for Limitation and Condition 17

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Nomenclature

ADS	automatic depressurization system
ADSVOOS	ADS valve out-of-service
BWR	boiling-water reactor
CFR	Code of Federal Regulations
CHF	critical heat flux
CMWR	core average metal-water reaction
DC	direct current
DEG	double-ended guillotine
DG	diesel generator
ECCS	emergency core cooling system
FHOOS	feedwater heaters out-of-service
HPCI	high-pressure coolant injection
ICF	increased core flow
ID	inside diameter
LHGR	linear heat generation rate
LOCA	loss-of-coolant accident
LPCI	low-pressure coolant injection
LPCS	low-pressure core spray
MAPLHGR	maximum average planar linear heat generation rate
MCPR	minimum critical power ratio
MELLLA+	maximum extended load line limit analysis plus
MSIV	main stream isolation valve
MWR	metal-water reaction
NSSS	nuclear steam supply system
NRC	Nuclear Regulatory Commission, U.S.
OD	outside diameter
PCT	peak cladding temperature

Nomenclature (continued)

RCIC	reactor core isolation cooling
RDIV	recirculation discharge isolation valve
RWCU	reactor water cleanup
SE	Safety Evaluation
SF-ADS	single failure of ADS
SF-ADS IL	single failure of ADS, initiation logic
SF-ADS SV	single failure of ADS, single valve
SF-BATT	single failure of battery (DC) power
SF-BATT BA	single failure of battery (DC) power, board A
SF-BATT BB	single failure of battery (DC) power, board B
SF-BATT BC	single failure of battery (DC) power, board C
SF-DGEN	single failure of a diesel generator
SF-HPCI	single failure of the HPCI system
SF-LOCA	single failure of opposite unit false LOCA signal
SF-LPCI	single failure of a LPCI valve
SLO	single-loop operation
TLO	two-loop operation

1.0 Introduction

The results of a loss-of-coolant accident (LOCA) break spectrum and emergency core cooling system (LOCA-ECCS) analyses for Browns Ferry Units 1, 2, and 3 are documented in this report. The purpose of the break spectrum analysis is to identify the break characteristics that result in the highest calculated peak cladding temperature (PCT) [] during a postulated LOCA. The results provide the maximum average planar linear heat generation rate (MAPLHGR) limit for ATRIUM™ 11 fuel as a function of exposure for normal (two-loop) operation.

Variation in the following LOCA parameters is examined:

- Break location
- Break type (double-ended guillotine (DEG) or split)
- Break size
- Limiting ECCS single failure
- Axial power shape (top- or mid-peaked)
- Initial statepoint
- Fuel rod type

The analyses documented in this report are performed with LOCA Evaluation Models developed by Framatome*, and approved for reactor licensing analyses by the U.S. Nuclear Regulatory Commission (NRC). The models and computer codes used by Framatome for LOCA analyses are collectively referred to as the AURORA-B LOCA Evaluation Model (References 1 – 3). The calculations described in this report are performed in conformance with 10 CFR 50 Appendix K requirements and satisfy the event acceptance criteria identified in 10 CFR 50.46.

Key model characteristics included in the report analyses are shown below. Other initial conditions used in the analyses are described in Section 4.0.

- Operation in the MELLLA+ domain of Figure 1.1 is supported. [

]

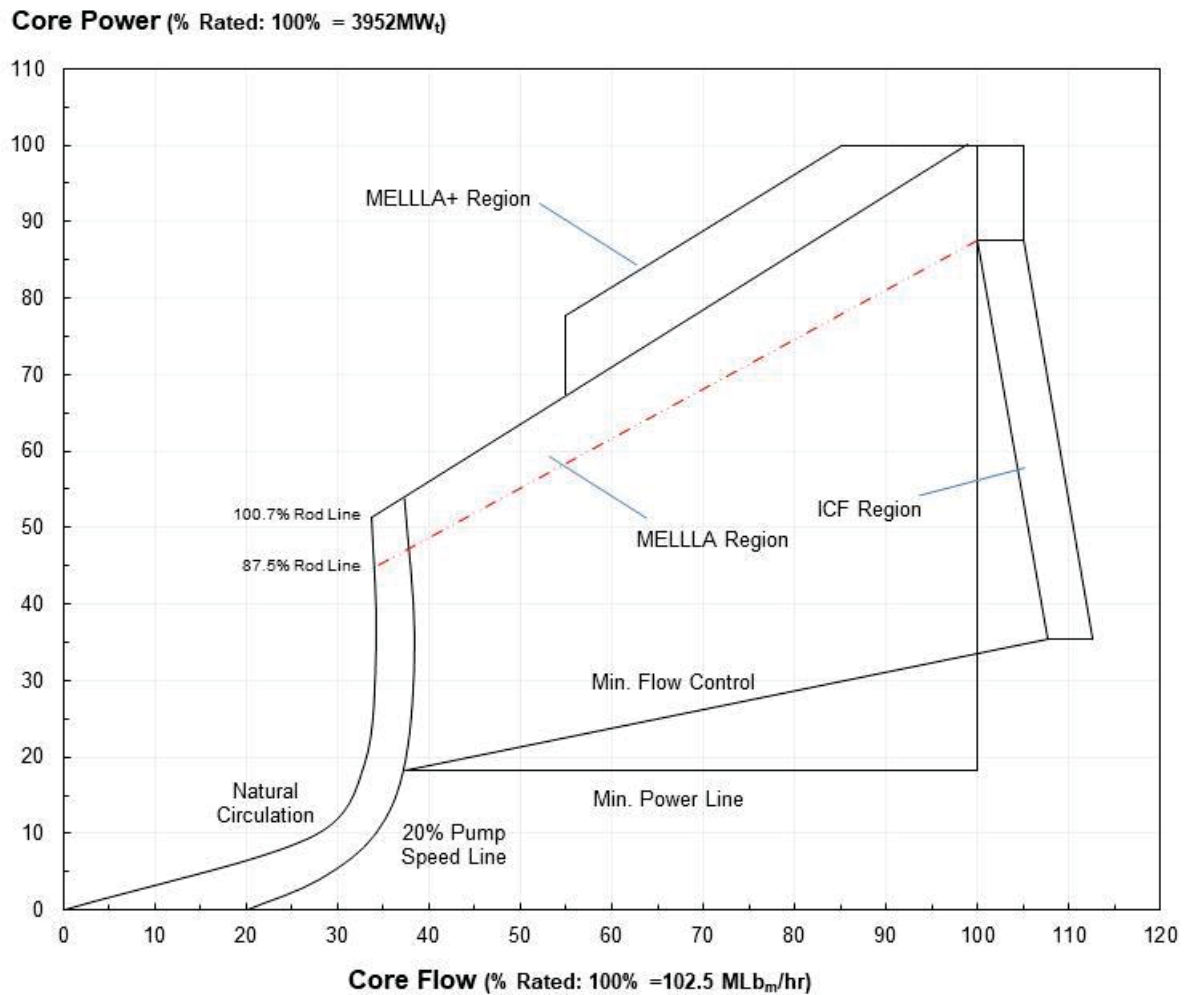
* Framatome Inc. formerly known as AREVA Inc.

- [
-]
- [
 -]
 - The core is composed entirely of ATRIUM 11 fuel.
 - A 2.0% increase in initial core power to address the maximum uncertainty in monitoring reactor power, as per NRC requirements, is included.
 - [] were assumed to be at the MAPLHGR limit shown in Figure 2.1.
 - []

The limiting break characteristics from the break spectrum study are used in analyses to determine the MAPLHGR limit and [] versus exposure. Even though the limiting break will not change with exposure, the value of PCT calculated for any given set of break characteristics is dependent on exposure and the corresponding MAPLHGR and [].

Single-loop operation (SLO) results are discussed in Section 7.0. Long term coolability is addressed in Section 8.0.

**Figure 1.1 Browns Ferry MELLLA+ Power
/ Flow Map**



2.0 Summary of Results

The LOCA analysis results presented in this report are applicable to Browns Ferry Units 1, 2, and 3. A more detailed discussion of results is provided in Sections 6.0 – 7.0.

The PCT and metal-water reaction (MWR) results, from the ATRIUM 11 fuel exposure-dependent analysis presented in Section 9.0, are presented below.

Parameter	ATRIUM 11*
Peak cladding temperature (°F)	1898 []
Local cladding oxidation (max %)	8.27 []
Total hydrogen generated (% of total hydrogen possible)	< 0.73

The MAPLHGR limit was determined by applying the AURORA-B LOCA Evaluation Model for the analysis of the limiting LOCA event. The exposure-dependent MAPLHGR limit for ATRIUM 11 fuel is shown in Figure 2.1. Exposure dependent results with the [] are presented in Section 9.0. The results of these calculations confirm that the LOCA acceptance criteria in the Code of Federal Regulations (10 CFR 50.46) are met for operation at or below these limits.

The LOCA analysis results (i.e., the limiting break characteristics and exposure analysis) presented in this report are applicable for a full core of ATRIUM 11 fuel as well as transition cores containing ATRIUM 11 fuel. []

* []

[

]

The SLO LOCA analyses support operation with an ATRIUM 11 multiplier of 0.85 applied to the normal two-loop operation MAPLHGR limit. [

]

The long-term coolability evaluation confirms that the ECCS capacity is sufficient to maintain adequate cooling in an ATRIUM 11 core for an extended period after a LOCA.

Available ADS valves are presented in Tables 5.1 and 5.2. No additional valves are assumed to be out-of-service (ADSVOOS). All analyses also support the [

]

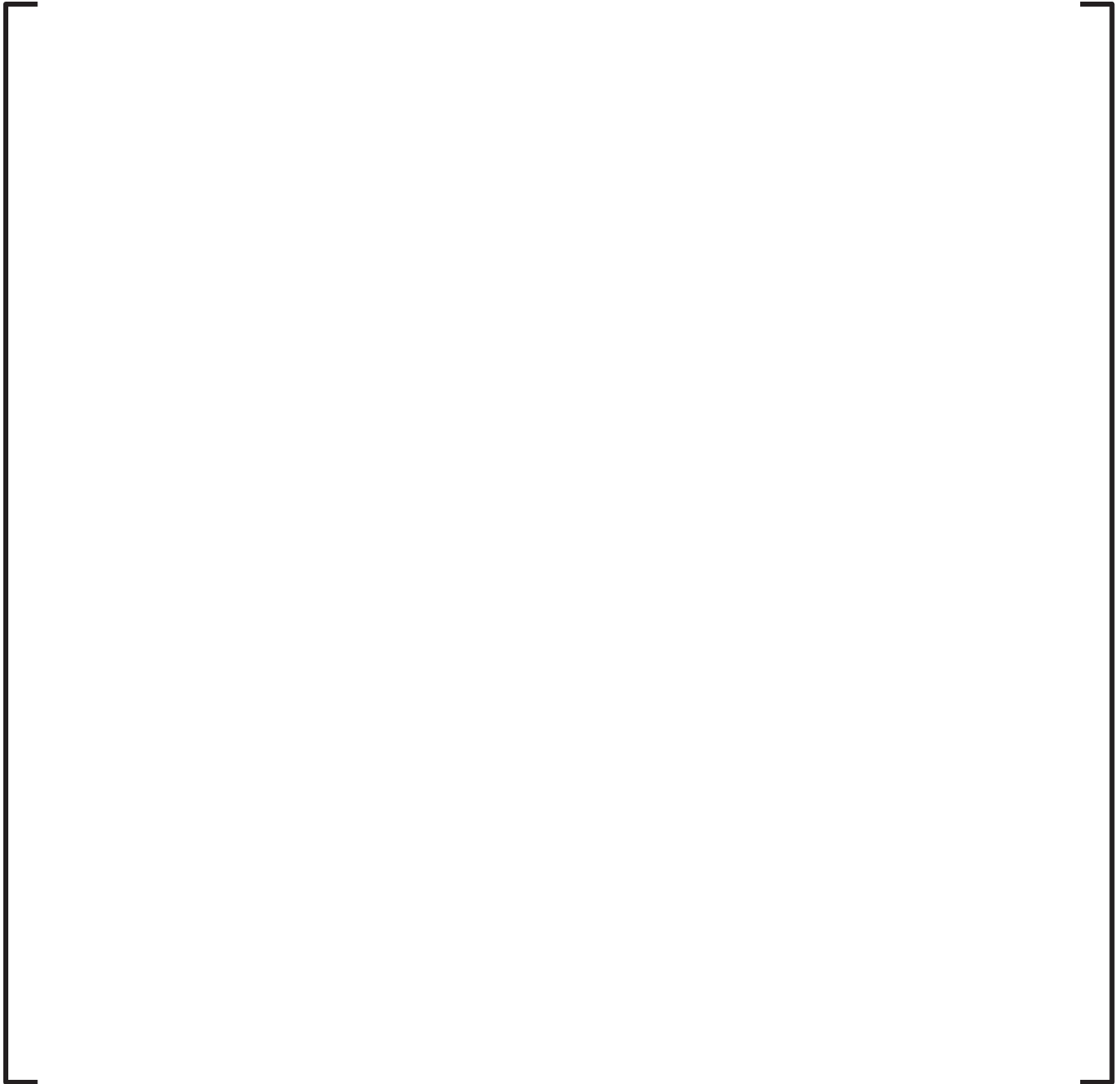
All analyses were [

]

Therefore, this LOCA analysis supports FHOOS operation.

The analysis supports operation in the MELLLA+ domain of the Browns Ferry power/flow map shown in Figure 1.1.

**Figure 2.1 MAPLHGR Limit
for ATRIUM 11 Fuel**





3.0 LOCA Description

3.1 *Accident Description*

The LOCA is described in the Code of Federal Regulations 10 CFR 50.46 as a hypothetical accident that results in a loss of reactor coolant from breaks in reactor coolant pressure boundary piping up to and including a break equivalent in size to a double-ended rupture of the largest pipe in the reactor coolant system. There is not a specifically identified cause that results in the pipe break. However, for the purpose of identifying a design basis accident, the pipe break is postulated to occur inside the primary containment before the first isolation valve.

For a boiling water reactor (BWR), a LOCA may occur over a wide spectrum of break locations and sizes. Responses to the break vary significantly over the break spectrum. The largest possible break is a double-ended rupture of a recirculation pipe; however, this is not necessarily the most severe challenge to the ECCS. A double-ended rupture of a main steam line causes the most rapid primary system depressurization, but because of other phenomena, steam line breaks are seldom limiting with respect to the event acceptance criteria (10 CFR 50.46). Because of these complexities, an analysis covering the full range of break sizes and locations is performed to identify the limiting break characteristics.

Regardless of the initiating break characteristics, the event response is conveniently separated into three phases: the blowdown phase, the refill phase, and the reflood phase. The relative duration of each phase is strongly dependent upon the break size and location. [

]

During the blowdown phase of a LOCA, there is a net loss of coolant inventory, an increase in fuel cladding temperature due to core flow degradation, and for the larger breaks, the core becomes fully or partially uncovered. There is a rapid decrease in pressure during the blowdown phase. During the early phase of the depressurization,

the exiting coolant provides core cooling. Consistent with the discussion presented in Reference 1, [

]

In the refill phase of a LOCA, the ECCS is functioning and there is a net increase of coolant inventory. During this phase the core sprays provide core cooling and, along with low-pressure and high-pressure coolant injection (LPCI and HPCI), supply liquid to refill the lower portion of the reactor vessel. In general, the core heat transfer to the coolant is less than the fuel decay heat rate and the fuel cladding temperature continues to increase during the refill phase.

In the reflood phase, the coolant inventory has increased to the point where the mixture level re-enters the core region. During the core reflood phase, cooling is provided above the mixture level by entrained reflood liquid and below the mixture level by pool boiling. Sufficient coolant eventually reaches the core hot node and the fuel cladding temperature decreases. [

]

3.2 Acceptance Criteria

A LOCA is a potentially limiting event that may place constraints on fuel design, local power peaking, and in some cases, acceptable core power level. During a LOCA, the normal transfer of heat from the fuel to the coolant is disrupted. As the liquid inventory in the reactor decreases, the decay heat and stored energy of the fuel cause a heatup of the undercooled fuel assembly. In order to limit the amount of heat that can contribute to the heatup of the fuel assembly during a LOCA, an operating limit on the MAPLHGR is applied to each fuel assembly in the core.

The Code of Federal Regulations prescribes specific acceptance criteria (10 CFR 50.46) for a LOCA event as well as specific requirements and acceptable features for Evaluation Models (10 CFR 50 Appendix K). The conformance of the AURORA-B LOCA Evaluation Models to Appendix K is described in Reference 1. The ECCS must be designed such that the plant response to a LOCA meets the following acceptance criteria specified in 10 CFR 50.46:

- The calculated maximum fuel element cladding temperature shall not exceed 2200°F.
- The calculated local oxidation of the cladding shall nowhere exceed 0.17 times the local cladding thickness.
- The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all of the metal in the cladding cylinders surrounding the fuel, except the cladding surrounding the plenum volume, were to react.
- Calculated changes in core geometry shall be such that the core remains amenable to cooling.
- After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.

These criteria are commonly referred to as the PCT criterion, the local oxidation criterion, the hydrogen generation criterion, the coolable geometry criterion, and the long-term cooling criterion. A MAPLHGR limit is established for each fuel type to ensure that these criteria are met.

LOCA results are provided in Section 6.0 to identify the LOCA events which produce the highest PCT [] LOCA analysis results demonstrating that the PCT, local oxidation, and hydrogen generation (core wide oxidation) criteria are met are provided in Section 9.0. Compliance with these three criteria ensures that a coolable geometry is maintained. Long-term coolability criterion is discussed in Section 8.0.

4.0 LOCA Analysis Description

The Evaluation Model used for the break spectrum analysis is the AURORA-B LOCA analysis methodology described in Reference 1. The AURORA-B LOCA methodology employs two major computer codes to evaluate the system and fuel response during all phases of a LOCA. These are the S-RELAP5 and RODEX4 computer codes. A

[

] of the LOCA to determine the PCT and maximum local
clad oxidation for []

A complete analysis starts with the specification of fuel parameters using RODEX4 (Reference 3). RODEX4 is used to determine the [

] The initial stored energy used in S-RELAP5 is
[]

4.1 Break Spectrum Analysis

S-RELAP5 is used to calculate the thermal-hydraulic response during all phases of the LOCA using a [

] The reactor vessel
nodalization is shown in Figure 4.1 and the core nodalization is shown in Figure 4.2 consistent with those in the topical report approved by the NRC (Reference 1). The reactor core is modeled with heat generation rates determined from reactor kinetics equations with reactivity feedback and decay heat as required by Appendix K of 10 CFR 50. The clad swelling and rupture models from NUREG-0630 (Reference 2) have been incorporated into S-RELAP5.

The S-RELAP5 model is executed over a range of break locations, break sizes, break types, initial statepoints, axial shapes and assumed single-failures to determine the break that yields the highest PCT [

]

4.2 Exposure Analysis

The [

] from beginning-of-life to end-of-life [] increments to determine an exposure-dependent MAPLHGR limit and [

] Figures of merit including PCT, local cladding oxidation, and core-wide metal-water reaction are evaluated over the range of exposures to confirm the acceptability of the LOCA analysis with respect to 10 CFR 50.46 criteria. [

]

4.3 Plant Parameters

The LOCA analysis is performed using the plant parameters provided by the utility. Table 4.1 provides a summary of reactor initial conditions used in the break spectrum analysis. Table 4.2 lists selected reactor system parameters.

The LOCA analysis is performed for a full core of ATRIUM 11 fuel. Some of the key fuel parameters used in the analysis are summarized in Table 4.3.

4.4 *ECCS Parameters*

The ECCS configuration is shown in Figure 4.3. Table 4.4 – Table 4.7 provide the important ECCS characteristics assumed in the analysis. The ECCS is modeled as time-dependent junctions connected to the appropriate reactor locations: LPCS injects into the upper plenum, HPCI injects into the upper downcomer, and LPCI injects into the recirculation lines.

The flow through each ECCS valve is determined based on system pressure and valve position. Flow versus pressure for a fully open valve is obtained by linearly interpolating the pump capacity data provided in Table 4.4 – Table 4.6. No credit for ECCS flow is assumed until the ECCS injection valves open and the ECCS pumps reach rated speed.

The ADS valves are modeled as a junction connecting the reactor steam line to the suppression pool. The flow through the ADS valves is calculated based on pressure and valve flow characteristics. The valve flow characteristics are determined such that the calculated flow is equal to the rated capacity at the reference pressure shown in Table 4.7.

In the Framatome LOCA analysis model, ECCS initiation is assumed to occur when the water level drops to the applicable level setpoint. No credit is assumed for the start of HPCI, LPCS, or LPCI due to high drywell pressure. [

]

The recirculation discharge isolation valve (RDIV) parameters are shown in Table 4.8.

Table 4.1 Initial Conditions*

Reactor power (% of rated)	102	102	[	]
[				
Reactor power (MWt)	4031	4031	[	]
[				
[				
Steam flow rate (Mlb/hr)	16.7	16.7	[	]
Steam dome pressure (psia)	1051	1051	[	]
[				
[				
[				
[				
Rod average power distributions	Figure 4.4	Figure 4.5	Figure 4.6	Figure 4.7

* [

† []

]

**Table 4.2 Reactor System
Parameters**

Parameter	Value
Vessel ID (in)	251
Number of fuel assemblies	764
Recirculation suction pipe area (ft ²)	3.507
1.0 DEG suction break area (ft ²)	7.013
Recirculation discharge pipe area (ft ²)	3.507
1.0 DEG discharge break area (ft ²)	7.013

**Table 4.3 ATRIUM 11 Fuel Assembly
Parameters**

* Does not include additional inner channel milling near the top of the channel.

**Table 4.4 High-Pressure Coolant Injection
Parameters**

Parameter	Value
Coolant temperature (°F)	120
<i>Initiating Signals and Setpoints</i>	
Water level*	L2 (448 in)
High drywell pressure (psig)	Not credited
<i>Time Delays</i>	
Time for HPCI pump to reach rated speed and injection valve wide open (sec)	35
<i>Delivered Coolant Flow Rate Versus Pressure</i>	
Vessel to Torus ΔP (psid)	Flow Rate (gpm)
0	0
150	5000
1120	5000
1174	3600

* Relative to vessel zero.

**Table 4.5 Low-Pressure Coolant Injection
Parameters**

Parameter	Value	
Reactor pressure permissive for opening valves (psia)	350	
Coolant temperature (°F)	120	
<i>Initiating Signals and Setpoints</i>		
Water level*	L1 (372.5 in)	
High drywell pressure (psig)	Not credited	
<i>Time Delays</i>		
Time for LPCI pumps to reach ADS permissive (maximum) (sec) [†]	32 [‡]	
Time for LPCI pumps to reach rated speed (maximum) (sec) [†]	44	
LPCI injection valve stroke time (sec)	40	
<i>Delivered Coolant Flow Rate Versus Pressure</i>		
Vessel to Drywell ΔP (psid)	Flow Rate for 2 Pumps Injecting Into 1 Recirculation Loop (gpm)	Flow Rate for 4 Pumps Injecting Into 2 Recirculation Loops (gpm)
0	17,240	34,480
20	16,540	33,080 [§]
319.5	0	0

* Relative to vessel zero.

[†] Includes 13-second delay for diesel generator start. 2-second signal processing delay for water level trip L1 is assumed in parallel with diesel generator delay.[‡] Analyses assume the longer delay time from LPCS (40 sec) for ADS ready permissive. Refer to Table 4.6.[§] Conservative value. Modeling limitations require the more conservative value of either the specified 4 pumps into 2 loops flow or twice the specified 2 pumps into 1 loop flow be used.

**Table 4.6 Low-Pressure Core Spray
Parameters**

Parameter	Value	
Reactor pressure permissive for opening valves (psia)	350	
Coolant temperature (°F)	120	
<i>Initiating Signals and Setpoints</i>		
Water level*	L1 (372.5 in)	
High drywell pressure (psig)	Not credited	
<i>Time Delays</i>		
Time for LPCS pumps to reach ADS permissive (maximum) (sec) [†]	40	
Time for LPCS pumps to reach rated speed (maximum) (sec) [†]	43	
LPCS injection valve stroke time (sec)	33	
<i>Delivered Coolant Flow Rate Versus Pressure[‡]</i>		
Vessel to Drywell ΔP (psid)	Flow Rate for 2 Pumps Into 1 Sparger (gpm)	Flow Rate for 4 Pumps Into 2 Spargers (gpm)
0	6,785	13,570
105	5,285	10,570
200	3,685	7,370
289	0	0

* Relative to vessel zero.

† Includes 13-second delay for diesel generator start. 2-second signal processing delay for water level trip L1 is assumed in parallel with diesel generator delay.

‡ Flow rates have been reduced to account for leakages associated with the Lower Sectional Hardware mod as discussed in GE Safety Communication SC 10-05. This further reduction applies only to the configuration at Unit 3 and can be conservatively applied to Units 1 and 2.

**Table 4.7 Automatic Depressurization
System Parameters**

Parameter	Value
Number of valves installed	6
Number of valves available	6
Minimum flow capacity of available valves (Mlbm/hr at psig)	4.8 at 1125
<i>Initiating Signals and Setpoints</i>	
Water level [*]	L1 (372.5 in)
<i>Time Delays</i>	
Delay time (from ADS initiating signal to time valves are open (sec) [†]	120

* Relative to vessel zero.

† ADS time initiation occurs after L1 setpoint trip. ADS valves are opened after the timer has elapsed and LPCS or LPCI pumps reach the ADS ready permissive. Analyses assume the longer delay from LPCS for ADS ready permissive (see Table 4.6).

**Table 4.8 Recirculation Discharge
Isolation Valve Parameters**

Parameter	Value
Reactor pressure permissive for closing valves – analytical (psia)	215
RDIV stroke time after pressure permissive (sec)	36

Figure 4.1 S-RELAP5 Vessel Model

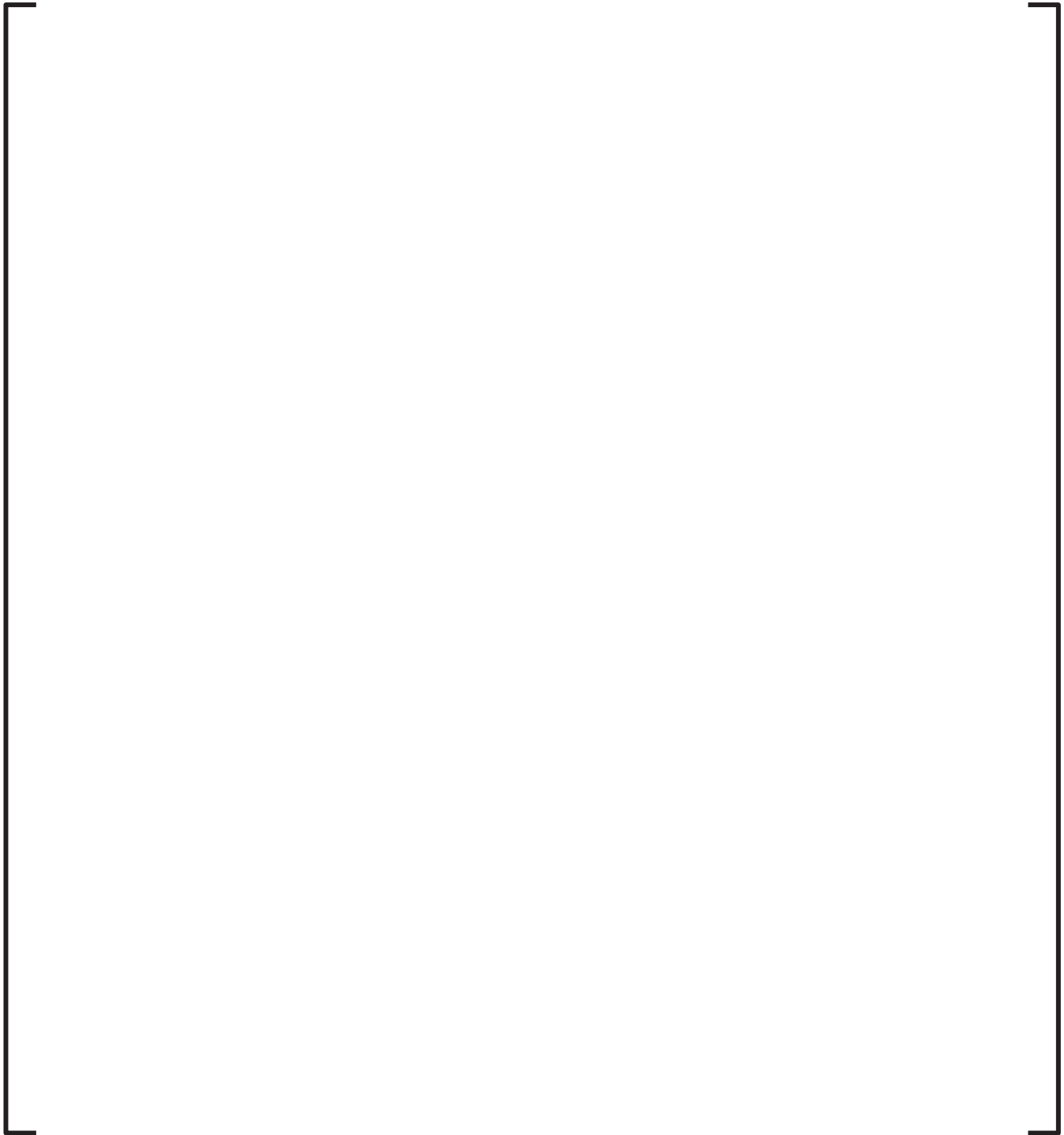


Figure 4.2 S-RELAP5 Core Model

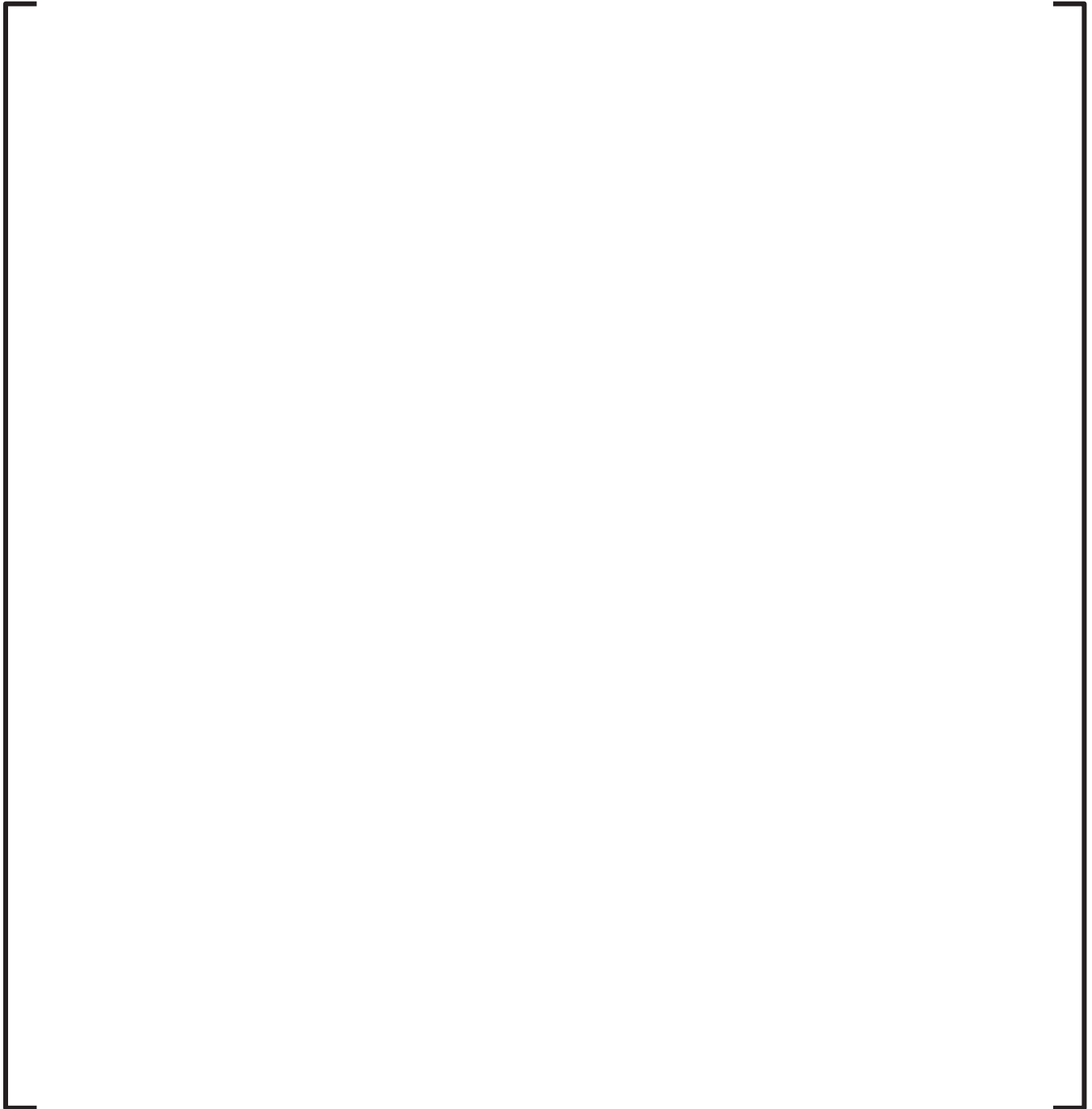


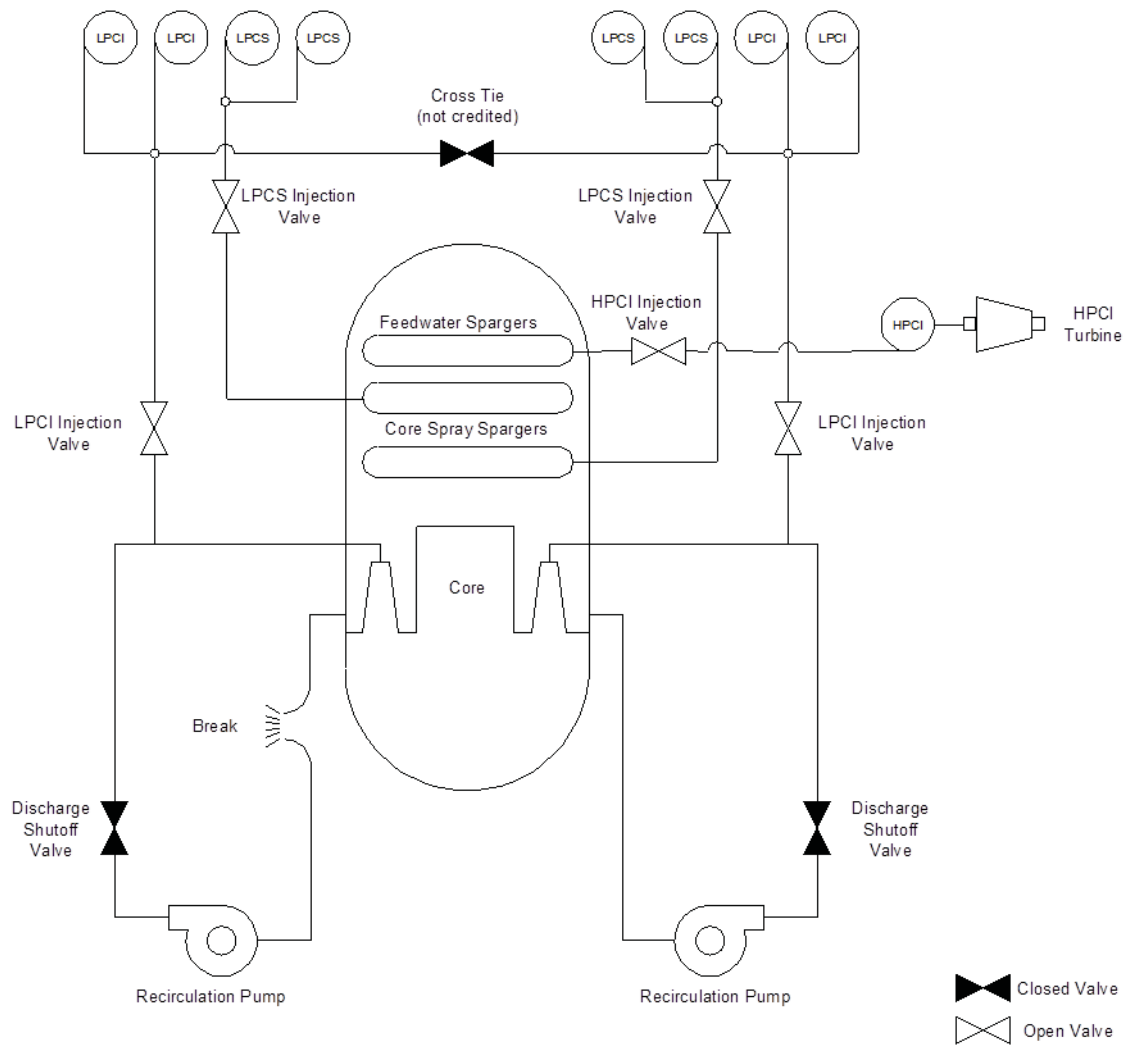
Figure 4.3 ECCS Schematic

**Figure 4.4 Rod Average Power Distributions
for 102%P and []
Mid- and Top-Peaked**



**Figure 4.5 Rod Average Power Distributions
for 102%P and []
Mid- and Top-Peaked**



**Figure 4.6 Rod Average Power Distributions
for []
Mid- and Top-Peaked**



**Figure 4.7 Rod Average Power Distributions
for []
Mid- and Top-Peaked**



5.0 Break Spectrum Analysis Description

The objective of the LOCA break spectrum analyses is to ensure that the operating conditions, break location, break type, break size, and ECCS single failure that produce the maximum PCT [] are identified. The LOCA response scenario varies considerably over the spectrum of break locations. Potential break locations have been separated into two groups: recirculation line breaks and non-recirculation line breaks. The basis for the break locations and potentially limiting single failures analyzed in this report is described in the following sections.

5.1 *Limiting Single Failure*

Regulatory requirements specify that the LOCA analysis consider availability of offsite power supplies and that only safety grade systems and components are available. In addition, regulatory requirements also specify that the most limiting single failure of ECCS equipment must be assumed in the LOCA analysis. The term "most limiting" refers to the ECCS equipment failure that produces the greatest challenge to event acceptance criteria. The limiting single failure can be a common power supply, an injection valve, a system pump, or system initiation logic. The most limiting single failure may vary with break size and location. The equipment identified that may produce a limiting single failure (SF) is shown below:

- Backup battery power (SF-BATT)
 - Board A (SF-BATT|BA)
 - Board B (SF-BATT|BB)
 - Board C (SF-BATT|BC)
- Opposite unit false LOCA signal (SF-LOCA)
- Low pressure coolant injection (SF-LPCI)
- Diesel generator (SF-DGEN)
- High-pressure coolant injection system (SF-HPCI)
- Automatic depressurization system (SF-ADS)
 - Failure of initiation logic (SF-ADS|IL)
 - Failure of single ADS valve (SF-ADS|SV)

The single failures and the available ECCS for each failure assumed in these analyses are summarized in Table 5.1 for recirculation line breaks and in Table 5.2 for non-recirculation line breaks. Other potential failures are not specifically considered because they result in as much or more ECCS capacity.

5.2 *Recirculation Line Breaks*

The response during a recirculation line LOCA is dependent on break size. The rate of reactor vessel depressurization decreases as the break size decreases. The high-pressure ECCS and ADS will assist in reducing the reactor vessel pressure to the pressure where the LPCI and LPCS flows start. For large breaks, rated LPCS and LPCI flow is generally reached before or shortly after the time when the ADS valves open so the ADS system is not required to mitigate the LOCA. ADS operation is an important emergency system for small breaks where it assists in depressurizing the reactor system faster, and thereby reduces the time required to reach rated LPCS and LPCI flow. The availability of ADS for each single failure is presented in Table 5.1, which shows a single failure of the battery for board A or board B results in the least amount of ECCS capacity and is therefore limiting. It should be noted that SF-LOCA and SF-DGEN are identical.

The two largest flow resistances in the recirculation piping are the recirculation pump and the jet pump nozzle. For breaks in the discharge piping, there is a major flow resistance in both flow paths from the reactor vessel to the break. For breaks in the suction piping, both major flow resistances are in the flow path from the vessel to the pump side of the break. As a result, pump suction side breaks experience a more rapid blowdown, which tends to make the event more severe (if ECCS capacity is equal). For suction side breaks, the recirculation discharge isolation valve on the broken loop closes which allows the LPCI flow to fill the discharge piping and supply flow to the lower plenum and core. For discharge side breaks, the LPCI flow in the broken loop is assumed to exit the system through the break resulting in a decrease in available LPCI

flow to the core, thereby increasing the severity of the event. Both suction and discharge recirculation pipe breaks are considered in the break spectrum analysis.

Two break types (geometries) are considered for the recirculation line break. The two types are the double-ended guillotine (DEG) break and the split break.

For a DEG break, the piping is assumed to be completely severed resulting in two independent flow paths to the containment. The DEG break is modeled by setting the break area (at both ends of the pipe) equal to the full pipe cross-sectional area and varying the discharge coefficient between 1.0 and 0.4. The range of discharge coefficients is used to cover uncertainty in the actual geometry at the break.

[

] The most limiting DEG break is determined by varying the discharge coefficient.

A split type break is assumed to be a longitudinal opening or hole in the piping that results in a single break flow path to the containment. Appendix K of 10 CFR 50 defines the cross-sectional area of the piping as the maximum split break area required for analysis.

Break types, break sizes, and single failures are analyzed for both suction and discharge recirculation line breaks.

Section 6.0 provides a description and results summary for breaks in the recirculation line.

5.3 *Non-Recirculation Line Breaks*

In addition to breaks in the recirculation line, breaks in other reactor coolant system piping must be considered in the LOCA break spectrum analysis. Although the recirculation line large breaks result in the largest coolant inventory loss, they do not necessarily result in the most severe challenge to event acceptance criteria. The

double-ended rupture of a main steam line is expected to result in the fastest depressurization of the reactor vessel. Special consideration is required when the postulated break occurs in ECCS piping. Although ECCS piping breaks are small relative to a recirculation pipe DEG break, they disable an ECCS system and therefore, increase the postulated break severity. Table 5.2 summarizes the available ECCS components of the potentially limiting single failures. The following sections address potential LOCAs due to breaks in non-recirculation line piping.

Non-recirculation line breaks outside containment are inherently less challenging to fuel limits than breaks inside containment. For breaks outside containment, isolation or check valve closure will terminate break flow prior to the loss of significant liquid inventory and the core will remain covered. If high-pressure coolant inventory makeup cannot be reestablished, ADS actuation may become necessary. [

] Although analyses of breaks outside containment may be required to address non-fuel related regulatory requirements, these breaks are not limiting relative to fuel acceptance criteria such as PCT.

5.3.1 Main Steam Line Breaks

A steam line break [

] The break results in high steam flow out of the broken line and into the containment. Prior to MSIV closure, a steam line break also results in high steam flow in the intact steam lines as they feed the break via the steam line manifold. A steam line break inside containment results in a rapid depressurization of the reactor vessel. Initially the break flow will be high quality steam; however, the rapid depressurization produces a water level swell that results in liquid discharge at the break. For steam line

breaks, the largest break size is most limiting because it results in the most level swell and liquid loss out of the break.

[

]

5.3.2 Feedwater Line Breaks

[

]

A feedwater line break also removes HPCI availability because the injection line is connected to the feedwater line. However, the available ECCS remains bounded as shown in Table 5.2.

5.3.3 HPCI Line Breaks

The HPCI injection line is connected to the feedwater line outside containment.

[

]

The HPCI steam supply line is connected to the main steam line inside containment.

[

]

5.3.4 LPCS Line Breaks

A break in the LPCS line is expected to have many characteristics similar to [

] However, some characteristics of the LPCS line break

are unique and are not addressed in other LOCA analyses. Two important differences from other LOCA analyses are that the break flow will exit from the region inside the core shroud and the break will disable one LPCS system. The LPCS line break is assumed to occur just outside the reactor vessel. [

]

5.3.5 LPCI Line Breaks

The LPCI injection lines are connected to the larger recirculation discharge lines. A break in a LPCI line would result in the partial or full loss of LPCI injection. [

]

5.3.6 RCIC Line Breaks

The RCIC discharges to the feedwater line; [

]

The steam supply to the RCIC turbine comes from the main steam line from the reactor vessel; [

]

5.3.7 RWCU Line Breaks

The reactor water cleanup (RWCU) extraction line is connected to a recirculation suction line with an additional connection to the vessel bottom head. [

]

The RWCU return line is connected to the feedwater line; [

]

5.3.8 Shutdown Cooling Line Breaks

The shutdown cooling suction piping is connected to a recirculation suction line and the shutdown cooling return line is connected to a recirculation discharge line. [

]

5.3.9 Instrument Line Breaks

[

]

**Table 5.1 Available ECCS for
Recirculation Line Break LOCAs**

Assumed Failure	Systems* † Remaining		Disposition
	Recirculation [‡] Suction Break	Recirculation Discharge Break	
SF-BATT BA	6 ADS, 1 LPCS, 2 LPCI	6 ADS, 1 LPCS	Analyze
SF-BATT BB	4 ADS, HPCI, 1 LPCS, 2 LPCI	4 ADS, HPCI, 1 LPCS	Analyze
SF-BATT BC [§]	4 ADS, HPCI, 1 LPCS, 3 LPCI	4 ADS, HPCI, 1 LPCS, 1 LPCI	Bounded by SF-BATT BB
SF-LOCA	6 ADS, HPCI, 1 LPCS, 2 LPCI	6 ADS, HPCI, 1 LPCS	Bounded by SF-BATT BA and SF-BATT BB
SF-LPCI	6 ADS, HPCI, 2 LPCS, 2 LPCI	6 ADS, HPCI, 2 LPCS	Bounded by SF-BATT BA and SF-BATT BB
SF-DGEN	6 ADS, HPCI 1 LPCS, 2 LPCI	6 ADS, HPCI, 1 LPCS	Bounded by SF-BATT BA and SF-BATT BB
SF-HPCI	6 ADS, 2 LPCS, 4 LPCI	6 ADS, 2 LPCS, 2 LPCI	Bounded by SF-BATT BA
SF-ADS IL	4 ADS, HPCI, 2 LPCS, 4 LPCI	4 ADS, HPCI, 2 LPCS, 2 LPCI	Bounded by SF-BATT BB
SF-ADS SV	5 ADS, HPCI, 2 LPCS, 4 LPCI	5 ADS, HPCI, 2 LPCS, 2 LPCI	Bounded by SF-BATT BB

* Each LPCS means operation of two core spray pumps in a system. It is assumed that both pumps in a system must operate to take credit for core spray cooling or inventory makeup. Furthermore, 2 LPCI refers to two LPCI pumps into one loop, 3 LPCI refers to two LPCI pumps into one loop and one LPCI pump into one loop. 4 LPCI refers to four LPCI pumps into two loops, two per loop.

† 4 ADS, 5 ADS, and 6 ADS means the number of ADS valves available for automatic activation.

‡ Systems remaining, as identified in this table for recirculation suction line breaks, are applicable to other non-ECCS line breaks. For a LOCA from an ECCS line break, the systems remaining are those listed for recirculation suction breaks, less the ECCS in which the break is assumed.

§ Unit 3 systems remaining. Conservative for Units 1 and 2.

**Table 5.2 Available ECCS for
Non-Recirculation Line Break LOCAs**

Non-Recirculation Line Break	Assumed Failure	Available ECCS*	Disposition
HPCI [†] Feedwater line [†] Steam line [†]	SF-BATT BA	6 ADS, 1 LPCS, 2 LPCI	Bounded by SF-BATT BB
	SF-BATT BB	4 ADS, 1 LPCS, 2 LPCI	Bounded by SF-BATT BA LPCS break
	SF-BATT BC	4 ADS, 1 LPCS, 3 LPCI	Bounded by SF-BATT BB
	SF-LOCA	6 ADS, 1 LPCS, 2 LPCI	Bounded by SF-BATT BB
	SF-LPCI	6 ADS, 2 LPCS, 2 LPCI	Bounded by SF-BATT BB
	SF-DGEN	6 ADS, 1 LPCS, 2 LPCI	Bounded by SF-BATT BB
	SF-HPCI	6 ADS, 2 LPCS, 4 LPCI	Bounded by SF-BATT BB
	SF-ADS IL	4 ADS, 2 LPCS, 4 LPCI	Bounded by SF-BATT BB
	SF-ADS SV	5 ADS, 2 LPCS, 4 LPCI	Bounded by SF-BATT BB
LPCS	SF-BATT BA	6 ADS, 2 LPCI	Analyze
	SF-BATT BB	4 ADS, HPCI, 2 LPCI	Analyze
	SF-BATT BC	4 ADS, HPCI, 3 LPCI	Bounded by SF-BATT BB
	SF-LOCA	6 ADS, HPCI, 2 LPCI	Bounded by SF-BATT BA and SF-BATT BB
	SF-LPCI	6 ADS, HPCI, 1 LPCS, 2 LPCI	Bounded by SF-BATT BA and SF-BATT BB
	SF-DGEN	6 ADS, HPCI, 2 LPCI	Bounded by SF-BATT BA and SF-BATT BB
	SF-HPCI	6 ADS, 1 LPCS, 4 LPCI	Bounded by SF-BATT BA
	SF-ADS IL	4 ADS, HPCI, 1 LPCS, 4 LPCI	Bounded by SF-BATT BB
	SF-ADS SV	5 ADS, HPCI, 1 LPCS, 4 LPCI	Bounded by SF-BATT BB

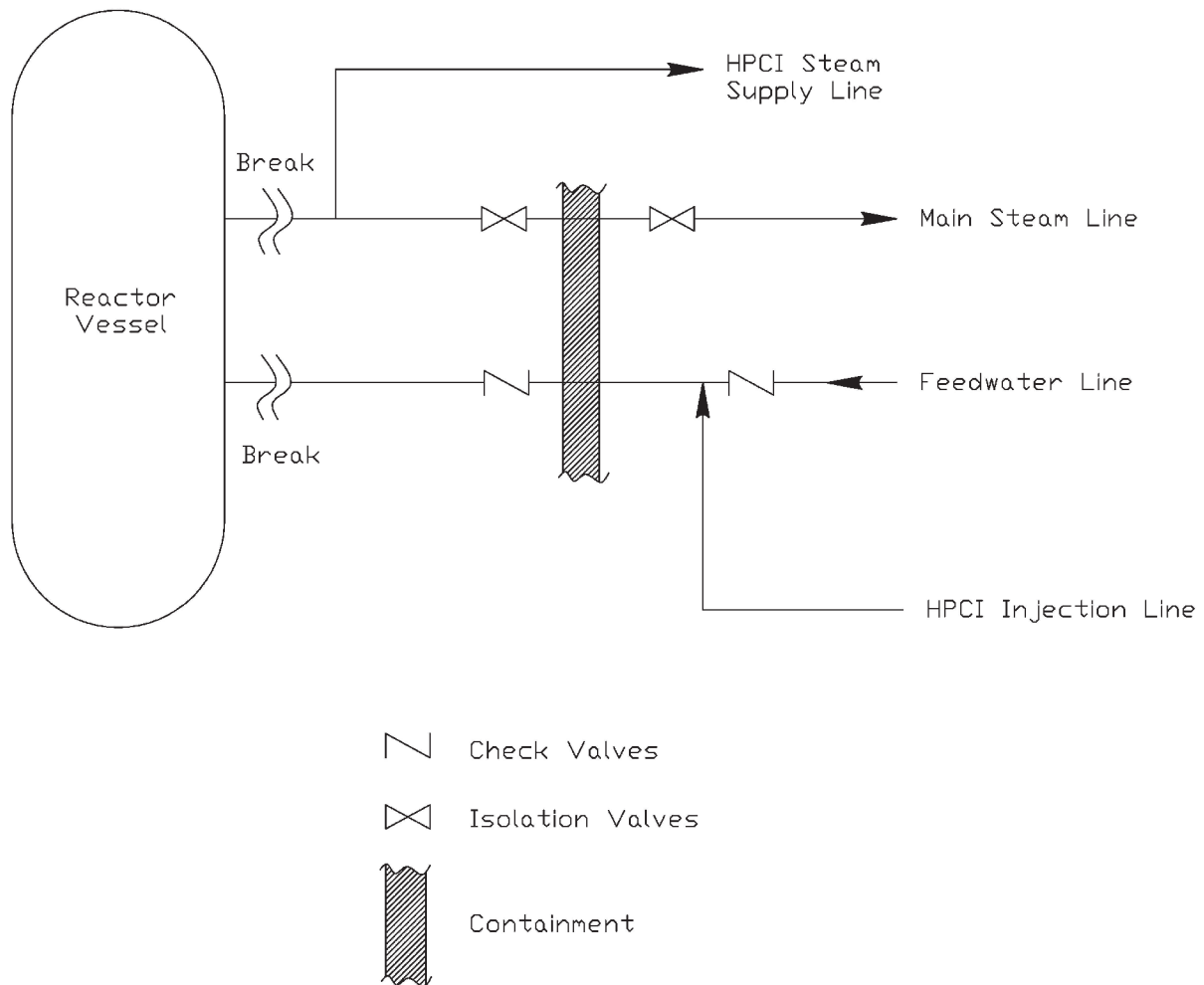
* Refer to footnotes of Table 5.1 for additional information.

† Assumes no credit for HPCI flow.

**Table 5.2 Available ECCS for
Non-Recirculation Line Break LOCAs
(Continued)**

Non-Recirculation Line Break	Assumed Failure	Available ECCS*	Disposition
LPCI	SF-BATT BA	6 ADS, 1 LPCS	Equivalent to recirculation pump discharge breaks (SF-BATT BA). Additional analysis not required.
	SF-BATT BB	4 ADS, HPCI, 1 LPCS	Equivalent to recirculation pump discharge breaks (SF-BATT BB). Additional analysis not required.
	SF-BATT BC	4 ADS, HPCI, 1 LPCS, 1 LPCI	Bound by SF-BATT BB
	SF-LOCA	6 ADS, HPCI, 1 LPCS	Bounded by SF-BATT BA and SF-BATT BB
	SF-LPCI	6 ADS, HPCI, 2 LPCS	Bounded by SF-BATT BA and SF-BATT BB
	SF-DGEN	6 ADS, HPCI, 1 LPCS	Bounded by SF-BATT BA and SF-BATT BB
	SF-HPCI	6 ADS, 2 LPCS, 2 LPCI	Bounded by SF-BATT BA
	SF-ADS IL	4 ADS, HPCI, 2 LPCS, 2 LPCI	Bounded by SF-BATT BB
	SF-ADS SV	5 ADS, HPCI, 2 LPCS, 2 LPCI	Bounded by SF-BATT BB

* Refer to footnotes of Table 5.1 for additional information.

**Figure 5.1 Steam, Feedwater,
and HPCI Lines**

6.0 TLO Recirculation Line Break Spectrum Analyses

The largest diameter recirculation system pipes are the suction line between the reactor vessel and the recirculation pump and the discharge line between the recirculation pump and the riser manifold ring. LOCA analyses are performed for breaks in both of these locations with consideration for both DEG and split break geometries. The break sizes considered included DEG breaks with discharge coefficients from 1.0 to 0.4 and split breaks with areas ranging between the full pipe area and [] ft². As shown in Table 5.1, the limiting single failures considered in the recirculation line break analyses are SF-BATT|BA and SF-BATT|BB.

[

]

6.1 Break Spectrum Analysis Results

The break spectrum analyses demonstrate that the recirculation line break case with the [] is the 3.5 ft² break in the pump discharge piping with a single failure of SF-BATT|BB and a top-peaked axial power shape when operating at 102% rated core power and [] The break case with the [] is also presented in Table 6.1.

Table 6.2 provides a summary of the [] from the recirculation line break calculations for each of the single failures, state points, and axial power shapes. The event times for the 3.5 ft² break in the pump discharge piping with a single failure of SF-BATT|BB and a top-peaked axial power shape when operating at 102% rated core power and [] are presented in Table 6.3 and plots of key parameters from the LOCA analyses of this case are provided in Figures 6.1 – 6.15.

Table 6.1 Break Spectrum Results* for
TLO Recirculation Line Breaks

Break spectrum case resulting []	3.5 ft ² pump discharge SF-BATT BB Top-peaked axial 102%P/[]
[]	[]
	]

* []

Table 6.2 Summary of Break Spectrum [
for TLO Recirculation Line Breaks



**Figure 6.1 [] from the
TLO Recirculation Line Break Spectrum Analysis
Upper Plenum Pressure**

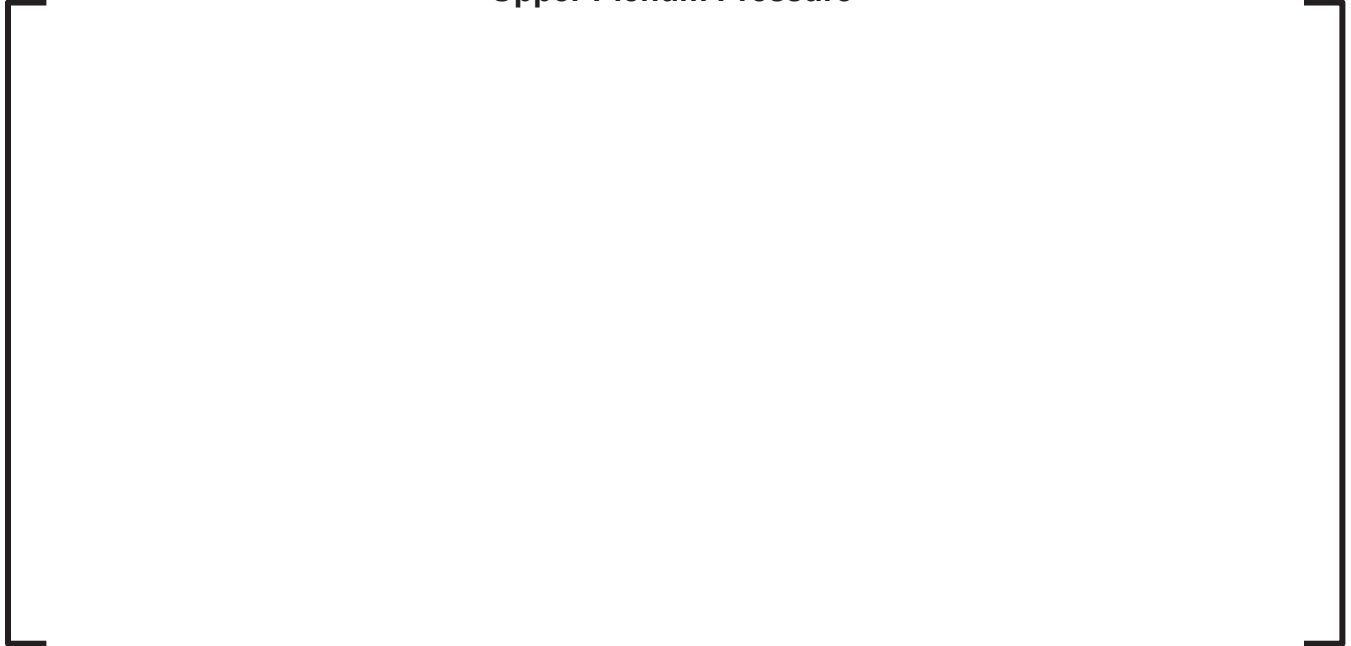


**Figure 6.2 [] from the
TLO Recirculation Line Break Spectrum Analysis
Total Break Flow Rate**



**Figure 6.3 [] from the
TLO Recirculation Line Break Spectrum Analysis
Core Inlet Flow Rate**



**Figure 6.4 [] from the
TLO Recirculation Line Break Spectrum Analysis
ADS Flow**



**Figure 6.5 [] from the
TLO Recirculation Line Break Spectrum Analysis
HPCI Flow**

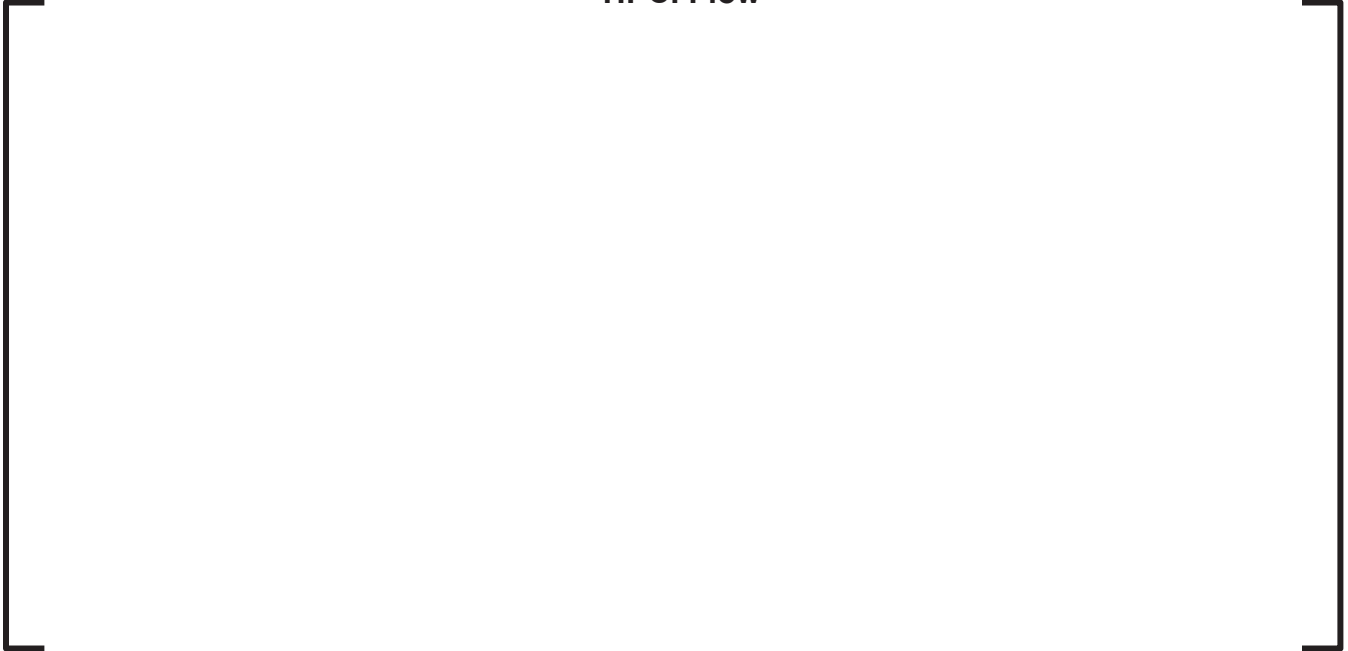


**Figure 6.6 [] from the
TLO Recirculation Line Break Spectrum Analysis
LPCS Flow**



**Figure 6.7 [] from the
TLO Recirculation Line Break Spectrum Analysis
LPCI Flow**



**Figure 6.8 [] from the
TLO Recirculation Line Break Spectrum Analysis
RDIV Flows**



**Figure 6.9 [] from the
TLO Recirculation Line Break Spectrum Analysis
Relief Valve Flow**



**Figure 6.10 [] from the
TLO Recirculation Line Break Spectrum Analysis
Downcomer LOCA Water Level**



**Figure 6.11 [] from the
TLO Recirculation Line Break Spectrum Analysis
Upper Plenum Liquid Level**

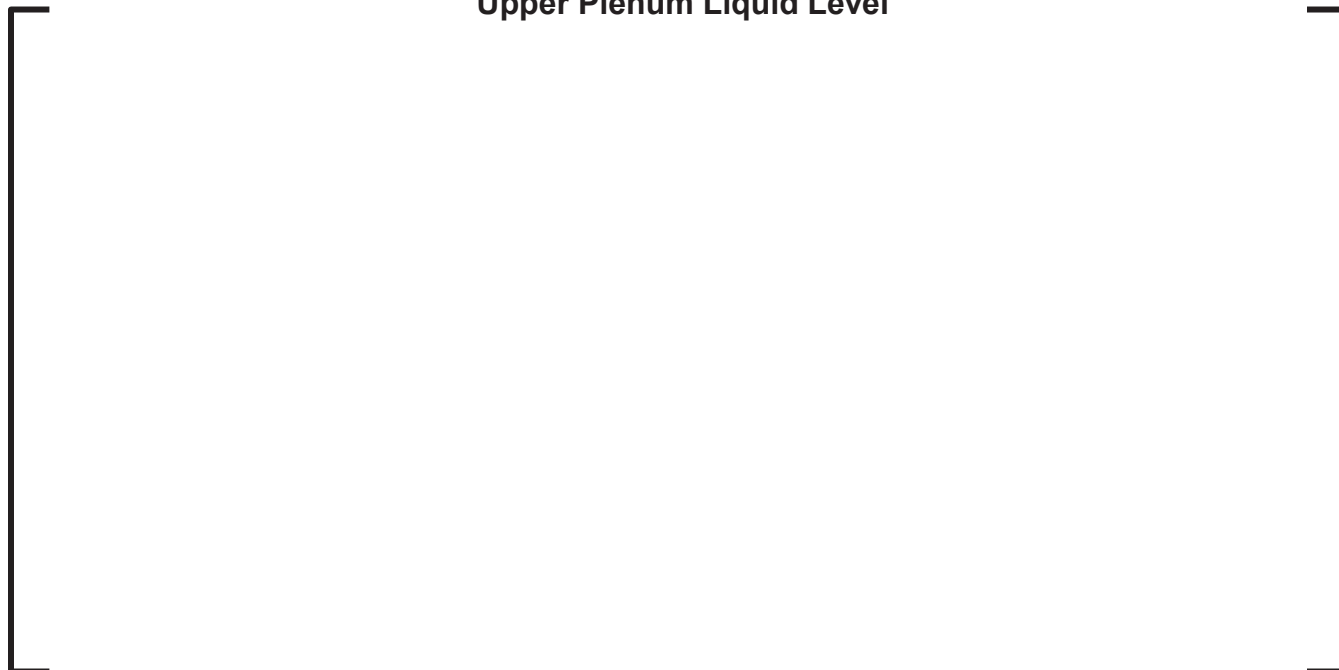


**Figure 6.12 [] from the
TLO Recirculation Line Break Spectrum Analysis
Hot Channel Liquid Level**



**Figure 6.13 [] from the
TLO Recirculation Line Break Spectrum Analysis
Core Bypass Liquid Level**

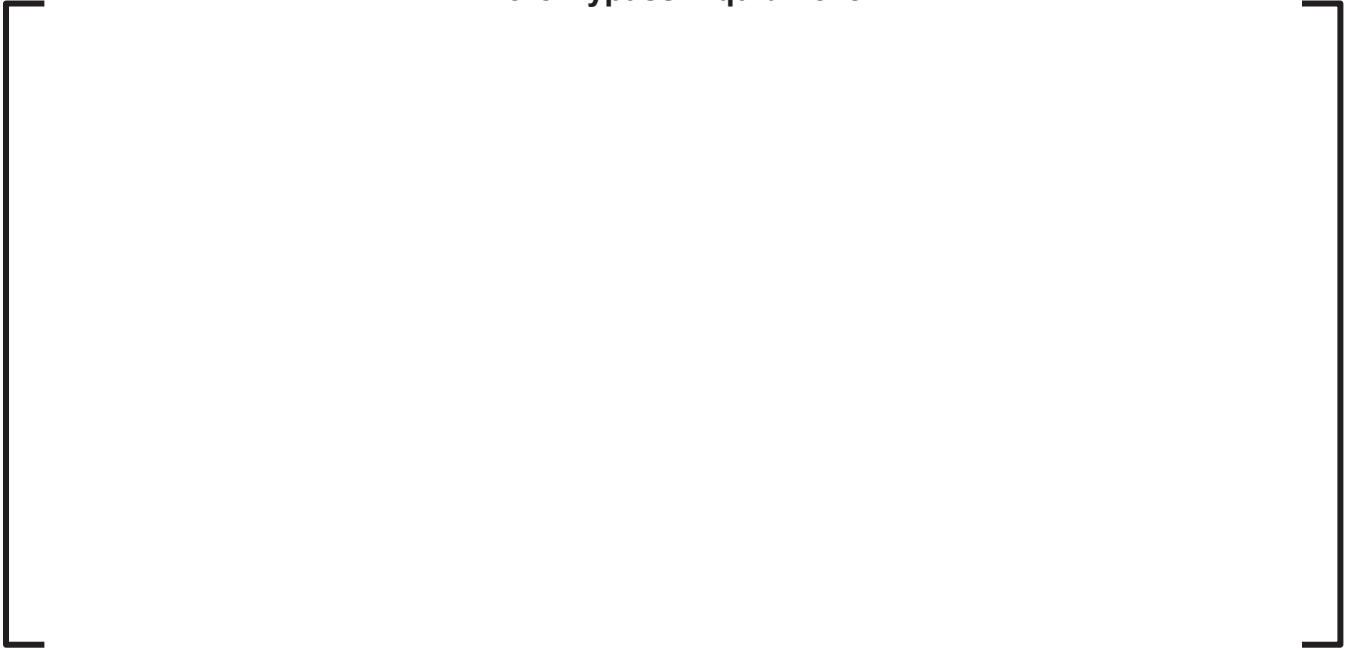


**Figure 6.14 [] from the
TLO Recirculation Line Break Spectrum Analysis
Lower Plenum Liquid Level**



**Figure 6.15 [] from the
TLO Recirculation Line Break Spectrum Analysis
Hot Channel Inlet Flow**



7.0 Single-Loop Operation LOCA Analysis

During SLO, the pump in one recirculation loop is not operating. A break may occur in either loop, but results from a break in the inactive loop would be similar to those from a two-loop operation break. If a break occurs in the inactive loop during SLO, the intact active loop flow to the reactor vessel would continue during the recirculation pump coastdown period and would provide core cooling similar to that which would occur in breaks during TLO. The system response would be similar to that resulting from an equal-sized break during two-loop operation. A break in the active loop during SLO results in a more rapid loss of core flow and earlier degraded core conditions relative to those from a break in the inactive loop. Therefore, only breaks in the active recirculation loop are analyzed.

A break in the active recirculation loop during SLO will result in an earlier loss of core heat transfer relative to a similar break occurring during two-loop operation. This occurs because there will be an immediate loss of jet pump drive flow. Therefore, fuel rod surface temperatures will increase faster in an SLO LOCA relative to a TLO LOCA. Also, the early loss of core heat transfer will result in higher stored energy in the fuel rods at the start of the heatup. The increased severity of an SLO LOCA can be reduced by applying an SLO multiplier to the two-loop MAPLHGR limit.

7.1 *SLO Analysis Modeling Methodology*

[

]

[] SLO is not considered for the MELLLA+ region since SLO is not allowed in the MELLLA+ region.

7.2 *SLO Analysis Results*

[

]

The SLO analyses are performed with a 0.85 multiplier applied to the two-loop MAPLHGR limit resulting in an SLO MAPLHGR limit of [] kW/ft. [

] The analyses are performed at maximum stored energy fuel conditions. The limiting SLO LOCA is the 3.5 ft² break in the pump discharge piping with a single failure of SF-BATT|BB and a top-peaked axial power shape when operating at []

A comparison of the limiting SLO and the limiting two-loop results is provided in Table 7.1. The results in Table 7.1 show that the two-loop LOCA results bound the limiting SLO results when a 0.85 multiplier is applied to the two-loop MAPLHGR limit. [

]

**Table 7.1 Single- and Two-Loop Operation
PCT Summary**

Operation		Limiting Case	PCT (°F)	
Single-loop		3.5 ft ² pump discharge top-peaked SF-BATT BB	[	]
Two-loop		3.5 ft ² pump discharge top-peaked SF-BATT BB	[	]

8.0 Long-Term Coolability

Long-term coolability addresses the issue of reflooding the core and maintaining a water level adequate to cool the core and remove decay heat for an extended time period following a LOCA. For non-recirculation line breaks, the core can be reflooded to the top of the active fuel and be adequately cooled indefinitely. For recirculation line breaks, the core will initially remain covered following reflood due to the static head provided by the water filling the jet pumps to a level of approximately two-thirds core height. Eventually, the heat flux in the core will not be adequate to maintain a two-phase water level over the entire length of the core. Beyond this time, the upper third of the core will remain wetted and adequately cooled by core spray. Maintaining water level at two-thirds core height with one core spray system operating is sufficient to maintain long-term coolability as demonstrated by the NSSS vendor (Reference 4). Since fuel temperatures during long-term cooling are low relative to the PCT and are not significantly affected by fuel design, this conclusion is applicable to ATRIUM 11 fuel. This LOCA analysis assesses conditions from the time of the initiation of the break to the time when long term cooling conditions can be established as demonstrated in Reference 4.

9.0 Exposure-Dependent LOCA Analysis Description and Results

Exposure-dependent LOCA results for ATRIUM 11 fuel are obtained by repeated analyses [] from the break spectrum analysis []

Table 9.1 shows the exposure-dependent LOCA analysis results for the ATRIUM 11 fuel. The S-RELAP5 model is applied to obtain these results as described in Section 4.2. The analysis is performed at []

[] which ensures appropriate limits are applied up to the monitored maximum assembly average and rod average exposure limits. The MAPLHGR input is consistent with the data in Figure 2.1. []

[] Exposure-dependent fuel rod data is provided from RODEX4 results []

[] The impact of thermal conductivity degradation is addressed with RODEX4.

The ATRIUM 11 limiting PCT is 1898°F at [] exposure for the 3.5 ft² break in the pump discharge piping with a single failure of SF-BATT|BB and a top-peaked axial power shape when operating at 102% rated core power and []

[]. The maximum local MWR of 8.27% occurred at [] exposure, []

[]. Analysis results show that the hot rod average MWR is 0.73%. Since all other rods in the core are at lower power, the core average metal water reaction (CMWR) will be significantly less.

Figure 9.1 shows the cladding temperature of the ATRIUM 11 PCT rod as a function of time for the limiting PCT result from the exposure-dependent LOCA analysis. The

maximum temperature of 1898°F occurs at []. These results demonstrate the acceptability of the ATRIUM 11 MAPLHGR limit shown in Figure 2.1.

**Table 9.1 ATRIUM 11 Exposure-Dependent
LOCA Analysis Results**

CMWR is < 0.73% at all exposures.*

* The rod average MWR for the hot rod is 0.73% which supports the conclusion that the CMWR is less than 0.73%.

**Figure 9.1 Limiting [] PCT
Exposure-Dependent LOCA Analysis**



10.0 Conclusions

The AURORA-B LOCA Evaluation Model was applied to confirm the acceptability of the ATRIUM 11 MAPLHGR limit and [] for Browns Ferry Units 1, 2, and 3. The following conclusions were made from the analyses presented in this report.

- The limiting PCT is obtained from Section 9.0 based on a recirculation line break of 3.5 ft² break in the pump discharge piping with a single failure of SF-BATT|BB and a top-peaked axial power shape when operating at 102% of rated core power and [].
- The limiting break analysis identified above satisfies all the acceptance criteria specified in 10 CFR 50.46. The analysis is performed in accordance with 10 CFR 50 Appendix K requirements.
- The multiplier applied to the MAPLHGR limit for SLO is 0.85 for ATRIUM 11 fuel. [] This multiplier ensures that a LOCA from SLO is less limiting than a LOCA from two-loop operation.
- The acceptance criteria of the Code of Federal Regulations (10 CFR 50.46) are met for operation at or below the ATRIUM 11 MAPLHGR limit given in Figure 2.1 [].
 - Peak PCT < 2200°F.
 - Local cladding oxidation thickness < 17%.
 - Total hydrogen generation < 1%.
 - Coolable geometry, satisfied by meeting peak PCT, local cladding oxidation, and total hydrogen generation criteria.
 - Core long-term cooling, satisfied by concluding core flooded to top of active fuel or core flooded to the jet pump suction elevation (Reference 4).
- The MAPLHGR limit and [] are applicable for ATRIUM 11 full cores as well as transition cores containing ATRIUM 11 fuel.

11.0 References

1. ANP-10332P-A Revision 0, *AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios*, Framatome, March 2019.
2. XN-NF-82-07(P)(A) Revision 1, *Exxon Nuclear Company ECCS Cladding Swelling and Rupture Model*, Exxon Nuclear Company, November 1982.
3. BAW-10247PA Revision 0, *Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors*, Framatome, February 2008.
4. NEDO-20566A, *General Electric Company Analytical Model for Loss of Coolant Analysis in Accordance with 10CFR50 Appendix K*, September 1986.

Appendix A Limitations from the Safety Evaluation for LTR ANP-10332PA

Compliance to the limitations and conditions from Section 5 of the safety evaluation in ANP-10332PA, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios" (Reference 1) is discussed in the following table.

Appendix A (Continued)

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
1	The AURORA-B LOCA evaluation model shall be supported by an approved nodal core simulator and lattice physics methodology. Plant-specific licensing applications referencing the AURORA-B LOCA evaluation model shall identify the nodal core simulator and lattice physics methods supporting the AURORA-B LOCA analysis and reference an NRC-approved TR confirming their acceptability for the intended application.	MICROBURN-B2 and the underlying cross section generation code, CASMO-4, are used for the nodal core simulator and lattice physics methodology from the following NRC-approved TR: EMF-2158(P)(A) Revision 0, "Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4 / MICROBURN-B2," Siemens Power Corporation, October 1999.
2	The full, stand-alone version of the RODEX4 code shall be used in accordance with an approved methodology to supply steady-state fuel thermal-mechanical inputs to the AURORA-B LOCA evaluation model.	The stand-alone version of RODEX4 is used to supply steady-state fuel thermal-mechanical input in accordance with the following NRC-approved methodology: BAW-10247PA Revision 0, "Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors," AREVA NP Inc., February 2008.
3	The AURORA-B LOCA evaluation model may not be used to perform analyses that result in any of its constituent components or supporting codes (i.e., S-RELAP5, RODEX4 kernel, RODEX4, core simulator and lattice physics methods) being operated outside approved limits documented in their respective TRs, SEs, code manuals, and plant-specific licensing applications.	The analyses are within the limits of the TRs, SEs, code manuals and plant-specific licensing applications.
4	TR ANP-10332P [].	[] LOCA report.

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
5	As discussed above in Section 2.1, the conclusions of this SE apply only to the use of the AURORA-B LOCA evaluation model for the purpose of demonstrating compliance with relevant regulatory requirements in effect at the time the NRC staff's technical review of ANP-10332P was completed (i.e., as of December 31, 2018).	The analyses only apply regulatory requirements in effect at the time the NRC staff's review was completed. They [].
6	This SE does not constitute [] of the evaluation model.	The evaluation model [].
7	[]	The [].
8	[]	The [] in the analyses.
9	Safety analyses performed with the AURORA-B LOCA evaluation model [].	[].

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
10	To ensure adequate conservatism in future plant-specific safety analyses, absent specific NRC staff approval for higher values, this SE limits [].	A [].
11	Plant-specific licensing applications referencing the AURORA-B LOCA evaluation model [].	BWR fuel rods are [].
12	The Appendix K lockout preventing the return to nucleate boiling [].	The analyses [].
13	[].	[].

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
14	Plant-specific licensing applications referencing the AURORA-B LOCA evaluation model [].	Analyses [].
15	[].	The [].
16	Plant-specific licensing applications referencing the AURORA-B LOCA evaluation model [].	[].

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
17	To assure satisfaction of GDC 35 (or similar plant-specific design criterion), [].	A [].
18	Safety analyses performed with the AURORA-B LOCA evaluation model [].	[].
19	Safety analyses for [].	The application of AURORA-B LOCA [].

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
		Approximately [].
20	Simulations supporting plant safety analyses [].	Simulations [].

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
21	As discussed in Section 3.3.5.7, Framatome used a [].	The [].
22	The NRC staff has not specifically reviewed any plant parameters in ANP-10332P or deemed them acceptable for use in plant safety analyses. Therefore, [].	The licensee [].

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
23	Safety analyses performed with the AURORA-B LOCA evaluation model shall include justification that [].	A [].
24	[].	[].
25	Plant-specific licensing applications referencing the AURORA-B LOCA evaluation model [].	The [].

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
26	Plant-specific licensing applications referencing the AURORA-B LOCA evaluation model [].	The [].
27	As discussed in Section 4.3 of this SE, new or modified Framatome [].	The analyses [].

ATTACHMENT 13a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3907P Revision 0

(Proprietary)

**Application of BEO-III Methodology with the Confirmation Density Algorithm at
Browns Ferry**

ATTACHMENT 13b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3907NP Revision 0

(Non Proprietary)

**Application of BEO-III Methodology with the Confirmation Density Algorithm at
Browns Ferry**



Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry

ANP-3907NP
Revision 0

April 2021

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Nature of Changes

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1	All	Initial Issue

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Nomenclature

Acronym	Definition
2RPT	Two-Pump Recirculation Pump Trip
AOO	Anticipated Operational Occurrences
APRM	Average Power Range Monitor
BEO-III	Best-estimate Enhanced Option III
BSP	Backup Stability Protection
BWROG	Boiling Water Reactor Owners Group
CDA	Confirmation Density Algorithm
CDAST	Confirmation Density Algorithm Scram Time (executable that processes LPRM signal with the CDA)
CHDR	Channel Decay Ratio
D&S	Detect and Suppress
DR	Decay Ratio
EFW	Extended Flow Window
EM	Evaluation Model
F/I MCPR	Ratio of Final to Initial Minimum Critical Power Ratio
FoM	Figure of Merit
FWHOOS	Feedwater Heater Out Of Service
GEH	GE Hitachi Nuclear Energy
ICO	Independent Channel Oscillations
LPRM	Local Power Range Monitor
MCPR	Minimum Critical Power Ratio
MELLLA+	Maximum Extended Load Line Limit Analysis Plus
OLMCPR	Operating Limit Minimum Critical Power Ratio
OPRM	Oscillation Power Range Monitor

Acronym	Definition
PBDA	Period Based Detection Algorithm
SAFDL	Specified Acceptable Fuel Design Limit
SLMCPR	Safety Limit Minimum Critical Power Ratio
SLO	Single Loop Operation
USNRC	United States Nuclear Regulatory Commission
Δ CPR	Delta Critical Power Ratio

ABSTRACT

This report presents a plant-specific Best-estimate Enhanced Option III (BEO-III) methodology that maintains the current Browns Ferry licensing basis Confirmation Density Algorithm (CDA), Reference 2. The method establishes the cycle-specific operating limit Minimum Critical Power Ratio (OLMCPR) based on statistical analyses of pump trip scenarios and evaluation of the time dependent local power range monitors (LPRMs) and core minimum critical power ratio (MCPR) to determine the most limiting event based on the Browns Ferry CDA detect and suppress (D&S) hardware response. This methodology replaces the DSS-CD OLMCPR calculation methodology from Reference 2. All other functions and requirements of Reference 2 will remain unchanged.

This report identifies the modifications made to the approved BEO-III evaluation model to incorporate the CDA in Section 2. Section 3 presents the BEO-III calculation procedure. Backup Stability Protection (BSP) is discussed in Section 4.0. Section 5.0 presents the validation of RAMONA5-FA against Browns Ferry specific data and Section 6.0 presents the ATRIUM 11 Equilibrium Cycle Sample Application. Finally Section 7.0 documents the compliance of the methodology to the NRC Limits and Conditions associated with the approved BEO-III methodology.

1.0 Introduction

The Best-estimate Enhanced Option-III methodology (BEO-III) was approved in Reference 1. The NRC determined that Framatome “*proposed an acceptable non parametric order statistics process, applied this process to suitable stability analysis calculations, determined statistical parameters and uncertainties appropriately, and established acceptable FoMs to ensure that relevant safety limits are not violated... provided that an appropriate calculation procedure is used to apply it to plant- and cycle-specific analyses.*” This plant-specific BEO-III methodology introduces a small change in the calculation procedure from Reference 1.

Specifically, the calculation procedure was approved for plant applications which rely on the Period-Based Detection Algorithm (PBDA) as the D&S algorithm to determine the appropriate trip times using the plant-specific PBDA settings. The Browns Ferry units do not use the PBDA as the licensing basis stability solution algorithm in its Oscillation Power Range Monitor (OPRM) System; they use the Confirmation Density Algorithm (CDA) as the licensing basis stability algorithm and PBDA is retained as a defense-in-depth algorithm. Therefore, this report presents a plant-specific BEO-III Evaluation Model (EM) that is modified from the approved BEO-III methodology to determine the appropriate trip times based on the CDA.

Other than the implementation of the CDA trip times, the calculation procedure remains unchanged from the procedure outlined in Reference 1 and is re-iterated for clarity in Section 3.0.

2.0 BEO-III Evaluation Model Revision

The BEO-III EM revision to support the introduction of the CDA algorithm adds post-processing steps [

].

To support these post-processing steps, the RAMONA5-FA code was modified to write both a time-dependent instrument data file and a file that contains the time dependent core MCPR [

]

Unlike a previous plant-specific methodology based on a hybrid BEO-III statistical analysis with customer post-processing of select statistical trials with the CDA to determine the 95/95 limiting MCPR response, Reference 3, the Browns Ferry application embeds the CDA post-processing calculations within the automated BEO-III statistical evaluations. This allows the Browns Ferry application to post-process all statistical trials with the CDA rather than just select statistical trials in the Reference 3 methodology.

For the Browns Ferry methodology, TVA contracted with GE Hitachi Nuclear Energy (GEH) to produce a CDA post-processor executable (CDAST) that reads the time dependent power, flow and simulated LPRM signals from the instrument data file written by RAMONA5-FA. The time dependent information is assessed consistent with the installed hardware at the Browns Ferry reactors. The scram time produced by CDAST is the time at which the CDA algorithm is satisfied, plus the OPRM and RPS hardware delays. The CDAST executable was sublicensed to Framatome to allow direct incorporation into the BEO-III statistical analysis.

2.1 *CDAST Installation*

The first step of implementing CDAST within the BEO-III statistical framework was verifying that software materials transmitted by GEH are installed correctly on the Framatome network. The transmittal of the software executables, supporting libraries, and test files was accomplished by a single encrypted archive file. This file was unzipped and all of the files were installed in the cstor archive on the Framatome network. The installation was then confirmed by comparing the SHA256 hash to the values provided by GEH.

2.2 *CDAST Verification*

The second step of implementing CDAST within the BEO-III statistical framework was verifying that the CDAST executable could be run on the Framatome computer network and reproduces exactly the results for a defined test suite run on the GEH computer platform. While many of these tests were simple tests for data exceptions, misconfigured data or command line errors, nine tests were RAMONA5-FA pump trip scenarios (both SLO and TLO) and covered a range of oscillation growth ratios and terminal amplitudes. These test cases were generated by Framatome using the RAMONA5-FA code and were transmitted to GEH for use in the CDAST code development. GEH ran CDAST for each test case and defined the reference CDA scram initiation signal time based on the Browns Ferry CDA and plant specific OPRM and RPS hardware delays. Execution of the CDAST code on the Framatome network reproduced the GEH results for all test cases exactly.

1

1.

3.0 BEO-III Calculation Procedure

The Browns Ferry BEO-III methodology is performed on a cycle-specific basis to confirm that pump trip scenarios that lead to instabilities are non-limiting relative to events that set the OLMCPR. [

] No changes to the Reference 1 calculation procedure are required other than the substitution of the CDA algorithm for the PBDA algorithm and updates to be consistent with the Reference 1 Safety Evaluation. This section is devoted to the general description of the Browns Ferry methodology and the procedure for performing the calculations is reproduced from Reference 1 for information.

In summary, the application procedure includes the following elements:

1. Definition of the state points to be analyzed.



2. The RAMONA5-FA base deck for the statistical analyses is prepared as a best estimate model [

]

-
3. Once the exposure points are identified [
-]
4. For each of the selected exposure steps, an ensemble of RAMONA5-FA multi-stage analyses are run (in accordance with Section 7.1.6 of Reference 1). For each successful calculation [
-] RAMONA5-FA also writes the instrumentation data file read by the CDAST post-processor.
5. For each of the RAMONA5-FA statistical trials, the CDAST calculation determines the CDA scram initiation signal time. [
-] suppression time.
6. For each exposure step, the 95/95 simultaneous tolerance limit values associated with the coupled reactor response and the limiting fuel assembly response are determined by the FIND9595 post-processing software. The FIND9595 code performs the following steps:

a. [

]

b. [

]

c. [

]

7. [

]

8. Review the [

]. If it is determined that the pump coastdown behavior would have a significant impact on the final MCPR, the uncertainties in the recirculation pump coastdown response should be included in the statistical analyses or otherwise accounted for.

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4.0 Backup Stability Protection

This section describes the Backup Stability Protection (BSP) methods that are currently incorporated in the Browns Ferry Technical Specifications. These methods will be maintained with the implementation of the plant specific BEO-III LTSS methodology. The preferred method is the Automated BSP (ABSP) scram region since it requires no operator action to protect against fast developing oscillations following a 2RPT from the MELLLA+ operating domain. If this feature is unavailable, manual BSP exclusion regions on the power/flow map will be employed and operation will be restricted to the MELLLA operating domain. This is enforced in the Browns Ferry Technical Specifications which requires operation to be lowered below the BSP Boundary (MELLLA Boundary) as specified in the cycle-specific Core Operating Limits Report (COLR) in the event the ABSP is not available.

The calculation process for the Manual BSP regions will be identical to that currently used at Browns Ferry to support MELLLA+.

4.1 *Automated BSP Scram Region*

The NUMAC APRM/OPRM hardware installed at Browns Ferry to support MELLLA+ implementation contains a feature to produce an automatic scram if potentially unstable regions of the power flow map are entered. This is done with adjustments to the ABSP flow-biased scram setpoints to encompass the nominal feedwater temperature manual scram region determined on a cycle specific basis. Due to the automatic scram upon entry into this region, operation in MELLLA+ is allowed since the automatic scram does not rely on operator actions in the event of an inadvertent flow reduction event that challenges the stability of the reactor core. No adjustments are needed to the ABSP setpoints for reduced feedwater temperature (RFWT) since the main purpose of the ABSP is to protect against high growth rate oscillations resulting from a 2RPT from the MELLLA+ region which does not allow RFWT. The process for creating the ABSP scram setpoints has not changed with the introduction of this methodology.

5.0 RAMONA5-FA Qualification for Browns Ferry

During the MELLLA+ Implementation testing, TVA collected OPRM data on all three Browns Ferry units between February 8, 2020 and May 13, 2020. For each reactor, the OPRM testing was performed at seven power/flow operating state-points. The testing started near 100% power / 85% flow and roughly followed the rod line down to the minimum core flow for the MELLLA+ domain as shown in Figure 5-1. Comparisons between the RAMONA5-FA statistical calculation of the OPRM amplitudes and the maximum measured amplitude are presented in Figure 5-2 through Figure 5-4 for the three units. [

]

Figure 5-1 Browns Ferry OPRM Testing

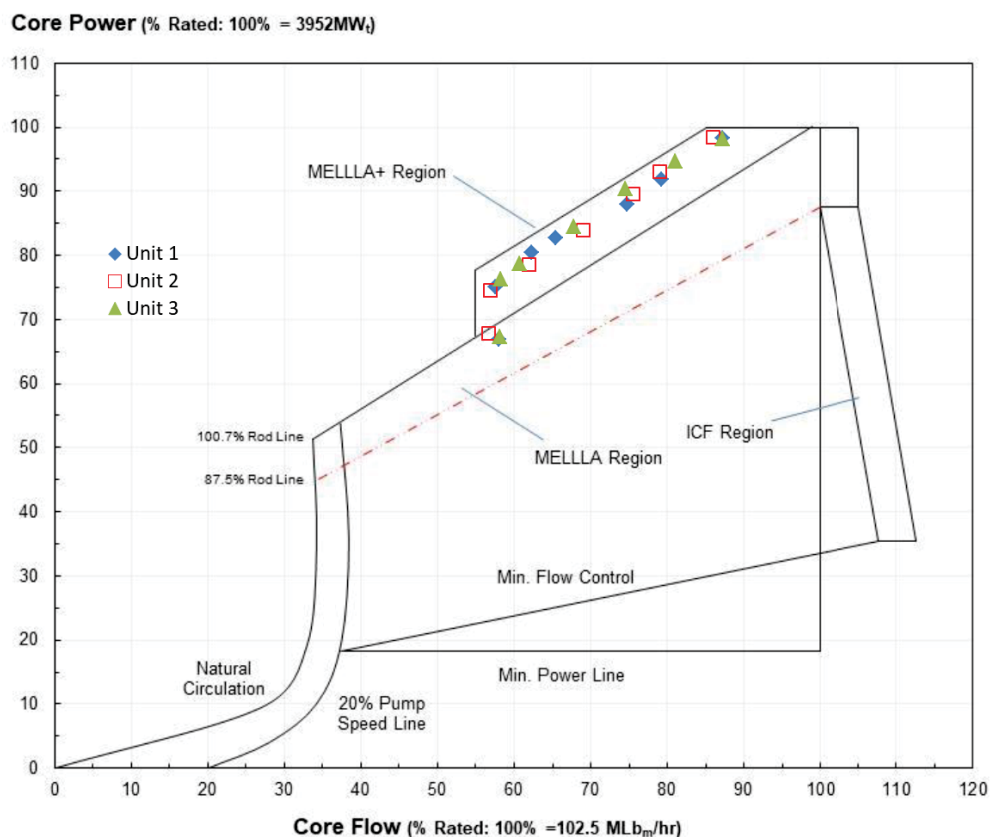


Figure 5-2 Browns Ferry Unit 1 OPRM Measurement



Figure 5-3 Browns Ferry Unit 2 OPRM Measurement



Figure 5-4 Browns Ferry Unit 3 OPRM Measurement



6.0 ATRIUM 11 Equilibrium Cycle Sample Application

The modified BEO-III methodology described in this document was applied to a Browns Ferry equilibrium ATRIUM 11 core design. The analyses demonstrate that the CDA hardware installed at the Browns Ferry reactors can detect and suppress oscillations with a high confidence level for the ATRIUM 11 fuel design. All of the full power cycle exposures in the equilibrium cycle design depletion were assessed [

] consistent

with Section 3.0.

The sampled parameters for the statistical analysis are consistent with those defined in Reference 1 and are presented in Table 6-1. As defined in Reference 1, there are [

]

For the Brown Ferry application, the RAMONA5-FA simulation provides the time dependent LPRM and core MCPR as a function of time to allow the determination of the MCPR response for every statistical trial as described in Section 2.3. To minimize the probability of [

]

6.1 *Limiting MELLLA+ 2RPT Scenario*

For the limiting MELLLA+ state point at rated core power and 85% of rated core flow, a sample size of [] trials was selected as a typical value from Table 7-1 of Reference 1. The statistical results for the core MCPR FoM are presented graphically in Figure 6-1. Based on a [] OLMCPR, the 95/95 MCPR of [] is shown to be well above the []
].

While the []

]

Therefore, ICO do not invalidate the assumption that the reactor protection system can detect and suppress the oscillations prior to violation of the specified acceptable fuel design limits.

6.1.1 Evaluation of Pump Coastdown

In order to assess the impact of pump coastdown on the FoM, the trip timings were compared against the pump coastdown time. []

[] While details of the CDA algorithm are proprietary to GEH, []

]

Table 6-1
Sampled Parameters for BEO-III ATRIUM 11 Statistical Analyses

Figure 6-1 Limiting MELLLA+ MCPR



Figure 6-2 Limiting MELLLA+ []



6.2 *Potentially Limiting Scenarios*

The other pump trip scenarios identified in Section 3.0 are the lowest core flow at rated core power within the MELLLA domain with the minimum feedwater temperature allowed by the licensee for the feedwater heater out-of-service (FWHOOS) or Final Feedwater Temperature Reduction (FFTR) scenario and the highest core power under single loop operation (SLO). These analyses used [] trials in the statistical analysis consistent with the analysis in Section 6.1.

The limiting reduced feedwater temperature statepoint at rated power for the MELLLA domain is at 99% of rated flow. The statistical results for the core MCPR FoM are presented in Figure 6-3 for this state point. Based on a []

]

The limiting single pump trip under SLO was analyzed at 67.95% of rated power and 54.4% of rated flow. The statistical results for the core MCPR FoM are presented in Figure 6-5 for this state point. Based on a conservatively assumed [] power-dependent OLMCPR, the core MCPR FoM of []

]

Figure 6-3 Reduced Feedwater Temperature MCPR





Figure 6-5 SLO MCPR



Figure 6-6 SLO []



6.3 *Tmin Confirmation*

The Browns Ferry plant-specific D&S hardware specifies a minimum oscillation period of [] seconds. The MELLLA+ 2RPT scenario yielded a minimum period, T_{min} , of [] seconds. The 1PT from the MELLLA+ corner produced stable results. [

] analyze this statepoint conservatively for the sample application. This was done for convenience as it minimizes the iterative process to identify the initial condition that would result in credible oscillations.

The statistical analysis for the [] statepoint was repeated [

] The 95/95 minimum period was [] seconds. Figure 6-7 presents the oscillation period for each of the MELLLA+ 2RPT trials, and the limiting trial for the MELLLA+ 1RPT scenario at each exposure [] Based on these analyses the T_{min} value of [] seconds is confirmed to bound the minimum oscillation period for any credible oscillations.

The use of [

] and is not required for any future cycle specific confirmation calculations.

Figure 6-7 MELLLA+ Pump Trip Calculation Periods



7.0 Compliance with ANP-10344P-A Limitations and Conditions

The Safety Evaluation for the Reference 1 topical report lists eight limitations and conditions that applications of the methodology must satisfy. The following section discusses how the plant specific methodology and analysis in this report comply with those limitations and conditions.

Limitation and Condition 1

*MICROBURN-B2 is an integral component in the BEO-III methodology.
Application of a new core simulator requires review and approval by the NRC.*

MICROBURN-B2 is the specified core simulator for the Browns Ferry Application Methodology.

Limitation and Condition 2

Selected settings and modeling options, including core and vessel nodalization and time step control parameters, shall be defined consistently with the validation basis presented in Section 6.0.

All settings and modeling options, including core and vessel nodalization and time step control parameters are consistent with the validation basis.

Limitation and Condition 3

[

]

[

]

Limitation and Condition 4

[

]

The [

] for protecting the SAFDL.

Limitation and Condition 5

Framatome must continue to use existing regulatory processes for any code modifications made to the RAMONA-5FA code. The existing regulatory processes do not allow changes to the RAMONA5-FA code that would substantively alter the BEO-III methodology, as described in ANP-10344P and supporting RAI responses, which the NRC staff relied upon as the basis for the finding of acceptability in this SE, without prior NRC review and approval.

The RAMONA5-FA code was modified for the Browns Ferry Application Methodology as described in Section 2.0 and was evaluated as per existing regulatory processes. There are no changes beyond those in Section 2.0 that would alter the basis of the methodology.

Limitation and Condition 6

Plant-specific applications shall justify whether the recirculation pump coastdown behavior will have a significant impact on the final MCPR for the specific plant and conditions being analyzed. If so, the uncertainties in the recirculation pump coastdown response should be included in the statistical analyses or otherwise accounted for.

The concern associated with this limitation and condition is that variations in the pump coastdown rate could lead to system resets that would cause the reactor trip to be delayed and allow the amplitude to grow to larger magnitudes. The assessment of [

] on the final MCPR for the

ATRIUM 11 equilibrium cycle.

Limitation and Condition 7

If the 1RPT EFW event remains stable, additional analyses are required using [] to ensure that the lowest oscillation period remains above T_{min} under any anticipated conditions.

As presented in Section 6.3 the 1RPT from the minimum core flow at rated power in the MELLLA+ domain remained stable. []

]

Limitation and Condition 8

After applying the []

[] If trends are observed which indicate that the most limiting exposure point(s) may be outside the analyzed range of exposures, additional exposure points should be analyzed until reasonable assurance is attained that the limiting exposure point is analyzed.

The [] Review of the FoM trend as a function of exposure indicates that there is a reasonable assurance that the limiting exposure points were analyzed.

8.0 References

1. ANP-10344P-A Revision 0 *Framatome Best-estimate Enhanced Option III Methodology*, March 2021.
2. NEDC-33075P-A, *GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density*, Revision 8, November 2013.
3. U.S. NRC, "Brunswick Steam Electric Plant, Units 1 and 2 – Issuance of Amendment Nos. 299 And 327 to Revise Technical Specification 5.6.5b to Allow Application of Advanced Framatome ATRIUM 11 Fuel Methodologies (EPID L-2018-LLA-0273)," ADAMS Accession No. ML20073F186, March 6, 2020.

ATTACHMENT 14a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3906P Revision 0

(Proprietary)

Browns Ferry ATWS-I Evaluation for ATRIUM 11 Fuel

ATTACHMENT 14b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3906NP Revision 0

(Non Proprietary)

Browns Ferry ATWS-I Evaluation for ATRIUM 11 Fuel



Browns Ferry ATWS-I Evaluation for ATRIUM 11 Fuel

ANP-3906NP
Revision 0

April 2021

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Nomenclature

(If applicable)

Acronym	Definition
2RPT	Two Recirculation Pump Trip
ATWS	Anticipated Transient Without Scram
ATWS-I	Anticipated Transient Without Scram With Instability
BOC	Beginning of Cycle
CPR	Critical Power Ratio
CPROM	Critical Power Reduced Order Model
EOC	End of Cycle
EOI	Emergency Operating Instruction
EOP	Emergency Operating Procedure
EPU	Extended Power Uprate
L&C	Limitation and Condition
LHGR	Linear Heat Generation Rate
MELLLA+	Maximum Extended Load Line Limit Analysis Plus
PCT	Peak Clad Temperature
PHE	Peak Hot Excess
SRV	Safety/Relief Valve
TR	Topical Report
TTWB	Turbine Trip With Bypass
TVA	Tennessee Valley Authority

1.0 INTRODUCTION

This document presents the results of calculated BWR instability transients that are not terminated by scram and thus power and flow oscillations are allowed to grow to large amplitudes. This class of transients is referred to as Anticipated Transients Without Scram with Instability (ATWS-I). The code used for simulating this event is RAMONA5-FA, which was developed and approved in Reference 1.

The scope of this analysis covers the Browns Ferry EPU/MELLLA+ operating domain using an equilibrium ATRIUM 11 core. The simulations have been performed using a Unit 3 model. As noted in Reference 2, the differences between the three Browns Ferry Units are minor such that this analysis will be applicable for all three units.

2.0 RAMONA5-FA ATWS-I METHODOLOGY

The Framatome generic methodology for the evaluation of Anticipated Transients Without Scram with Instability (ATWS-I) is presented in Reference 1. This report documents a RAMONA5-FA based method for evaluating the fuel specific portion of the event. This method is intended to cover the initial ATWS-I event through the time that operator actions suppress core oscillations. This method is not intended for use in evaluating containment effects or over pressurization during the event.

A key improvement of the RAMONA5-FA code is the addition of [

] This model is described in Section 5.5.5 of Reference 1, and the benchmarking of the ATRIUM 10XM fuel type with this new correlation is given in Appendix A of Reference 1. This correlation was extended to ATRIUM 11 using the procedure provided in Section A.4 of Reference 1, with the results of the benchmarking given in Section 4.0 of this report.

Analyses performed here are in compliance with the calculation procedure defined in Section 8.0 of Reference 1. Section 6.0 of this report also provides additional descriptions of how each Limitation and Condition for the topical report was implemented.

3.0 SCENARIO IDENTIFICATION

3.1 *Turbine Trip With Bypass*

The first event, the TTWB, is initiated by a turbine trip. The recirculation pumps are tripped either by the turbine stop valve closure, or an ATWS high pressure pump trip. Core flow drops rapidly to natural circulation which drives core power lower. As the core settles at natural circulation, the feedwater temperature begins to decrease due to the loss of extraction steam. The feedwater temperature decrease causes core power to rise. If no action is taken, then core power will rise to the point that it crosses the instability boundary. Without the ability to scram, and if mitigating operator action is sufficiently delayed, oscillations will begin to grow and will reach large magnitudes, accompanied by reverse flow at the inlet of the hot channels. Once the oscillations reach sufficient magnitude, cyclical dryout and rewetting of the cladding surface will begin. If the oscillations continue to grow, they can reach sufficient magnitude that rewetting is no longer possible and large excursions of clad temperature that could potentially challenge acceptance criteria will occur.

In order to prevent large amplitude oscillations plant Emergency Operating Instructions (EOI) or Emergency Operating Procedures (EOP) instruct the operators to reduce water level upon recognition of an ATWS scenario. This reduction in water level has two primary effects. The first is to reduce core flow by reducing the density head on the downcomer side of the loop. The resulting reduction in core flow also serves to reduce core power. At this point in the transient scenario, the cold feedwater is spraying through a steam environment and falling a significant distance until it reaches the water level. Passing through the steam environment heats the feedwater to the point that it approaches saturation. This significantly reduces the core inlet subcooling, which not only directly adds a stabilizing force to the system, but also reduces core power further stabilizing the system. The suppression of oscillations and reduction in power terminate any temperature excursion in the fuel and ends the fuel-specific portion of the ATWS-I event.

For this event, the rate of feedwater temperature decrease and the time of operator action are of primary importance. As such, the values used for these two input assumptions are the same as the current Browns Ferry ATWS-I analysis of record. The feedwater temperature decrease is assumed to start 14 seconds after the valve closure. Temperature is then assumed to decrease at a rate of 1.1 °F/s for the first minute followed by a decrease rate of 1.4 °F/s until the final temperature is reached. The time critical operator action for water level reduction is assumed to begin at 120 seconds, consistent with the current analysis of record for Browns Ferry.

3.2 *Two Recirculation Pump Trip*

The two recirculation pump trip event (2RPT) evolves similarly to the TTWB event with two exceptions, the event initiation and the feedwater temperature excursion. Since the 2RPT event does not involve a turbine isolation, the turbine remains online and extraction steam to the feedwater heaters is maintained so the feedwater temperature remains significantly higher than the TTWB event. Because of this, the power excursion in the 2RPT event is mild which results in a less severe event for the same operator intervention times. One difference between the two transient scenarios is that the TTWB event should generate an automatic scram very early in the event leading to earlier identification of the ATWS scenario by the operators. There may not be a scram signal at the initiation of the 2RPT which means the event may be allowed to progress further due to a delayed identification of ATWS by the operator. As such, the 2RPT may become limiting if operator action in the TTWB event occurs fast enough to suppress oscillations prior to dryout. For the evaluations presented in this report, the water level reduction is assumed to occur at 180 seconds consistent with the current analysis of record for Browns Ferry.

4.0 ATRIUM 11 CPROM CORRELATION

A new dryout correlation was presented in Appendix A of Reference 1. This correlation, named Critical Power Reduced Order Model (CPROM), has been developed based on Framatome correlation development guidelines similar to dryout licensing correlations such as ACE. The CPROM correlation range of applicability is wide [] making it well-suited to fitting into transient models of post-dryout that include cyclical dryout and rewetting with possible failure to rewet. CPROM is an integral part of the RAMONA5-FA transient model described in Section 5.5.5 of Reference 1.

4.1 CPROM Correlation for ATRIUM 11

1

[

]



Figure 4-1 Calculated versus measured critical power, []



Figure 4-2 [

]



Figure 4-3 [

]



Figure 4-4 [

]



Figure 4-5 [

]

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Evaluation for ATRIUM 11 Fuel

Page 4-6



Figure 4-6 []

Table 4-3 Statistics [

1



Figure 4-7 Calculated versus measured critical power, []



Figure 4-8 [

]



Figure 4-9 [

]



Figure 4-10 [

]



Figure 4-11 [

]



Figure 4-12 []

Table 4-6 Statistics []



The figure below shows comparison of the calculated and measured critical power for the combined data set. The mean critical power ratio is [] and the standard deviation of the calculated versus measured critical power for the entire database is [] and the number of data points is [].



Figure 4-13 Calculated versus measured critical power

4.2 *ATRIUM 11 CPROM Bounds of Applicability*

The bounds of applicability are determined by the data available to benchmark the correlation. For ATRIUM 11, the [

]

5.0 DISCUSSION OF RESULTS

5.1 *Turbine Trip With Bypass*

For this evaluation, [] are analyzed consistent with the procedure identified in Section 8.0 of Reference 1. An equilibrium ATRIUM 11 core was utilized. The events were initiated from rated power at the MELLLA+ boundary. As discussed in Section 6.0, in order to ensure that these results will be bounding of future cycles, []

]

Table 5-1 gives the TTWB results from the Browns Ferry MELLLA+ ATRIUM 11 analysis including the results of the sensitivity analyses. For each case (assuming operator intervention to lower the water level after 120s), the peak clad temperature (PCT) is provided. Relevant system and limiting channel plots for the limiting case can be found in Figure 5-1 through Figure 5-6.

5.2 *Two Recirculation Pump Trip*

Table 5-2 gives the 2RPT results from the Browns Ferry MELLLA+ ATRIUM 11 analyses. The base statepoints analyzed were chosen consistent with those analyzed for the TTWB event. For each case it was assumed that operator intervention to lower the water level to two feet below the feedwater spargers occurs after 180s. The results show []

]

Table 5-1 Browns Ferry MELLLA+ ATRIUM 11 TTWB ATWS-I Calculations

Table 5-2 Browns Ferry MELLLA+ ATRIUM 11 2RPT ATWS-I Calculations

* [

]

† [

]

Figure 5-1 ATRIUM 11 [
TTWB Core Power Response]

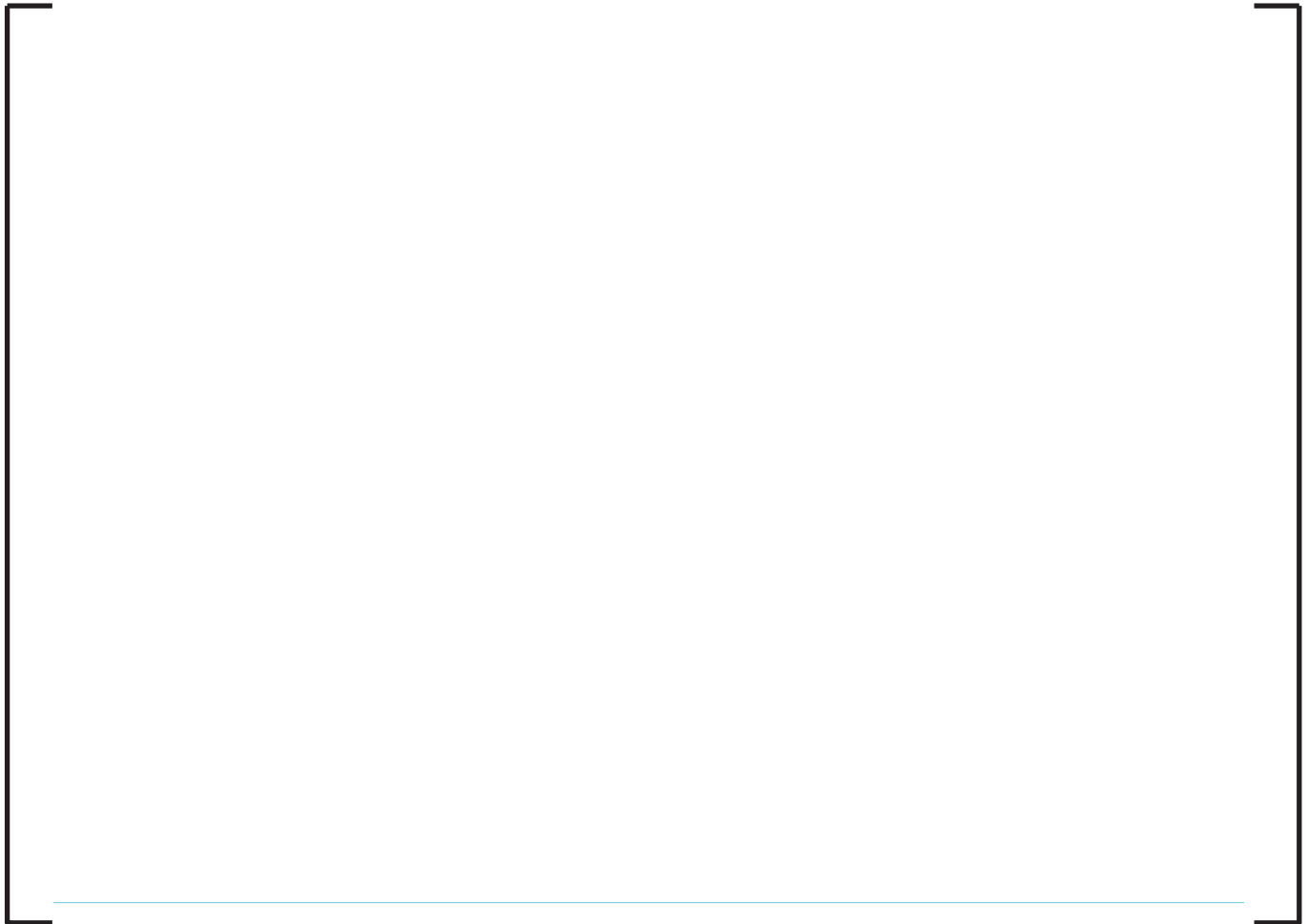


Figure 5-2 ATRIUM 11 [

Subcooling Response

] TTWB Core Inlet



Figure 5-3 ATRIUM 11 [

Flow Response

] TTWB Core Inlet



Figure 5-4 ATRIUM 11 [

Response

] TTWB Water Level



Figure 5-5 ATRIUM 11 [Channel Inlet Flow Results] TTWB Limiting



Figure 5-6 ATRIUM 11 [Channel PCT Response] TTWB Limiting

6.0 COMPLIANCE WITH LIMITATIONS AND CONDITIONS

The SE for the Reference 1 topical report lists seven limitations and conditions that applications of the methodology must satisfy. The following section discusses how the calculations in this package comply with those limitations and conditions.

Limitation and Condition 1

The gap conductance sensitivity shall be repeated or otherwise justified for transitions to new fuel designs.

A gap conductance sensitivity study was performed for the limiting statepoint, []. The gap conductance was varied by []. This sensitivity showed that the PCT for the limiting channel can vary between []. This shows the overall impact is [] within the available margin for ATRIUM 11 fuel at Browns Ferry.

Limitation and Condition 2

If the acceptance criteria for the first paragraph in Step 3 of Section 8.0 of the TR are met, additional justification must still be provided to demonstrate adequate margin in operator action timing for variations in neutron kinetics response from specific core designs. This justification may be provided by following Steps 3.a through 3.c, as amended by the response to RAI 15, or providing an alternative justification on a plant-specific basis.

In order to ensure that this calculation will bound future core designs, []

]

[

] ensure that it will remain bounding of future cycles.

In addition, during the Browns Ferry MELLLA+ review, an extensive amount of data was provided to validate the use of a 120 second operator action time, Reference 3.

Simulator testing confirmed that the use of a 120 second operator action time is very conservative relative to actual operator performance data.

Limitation and Condition 3

Plant-specific evaluations that are intended to be bounding of all core designs must be confirmed to provide reasonable assurance that neutron kinetics characteristics such as possible differences in dominant oscillation modes or the potential for multiple oscillation modes to be active simultaneously are bounded by the analysis of record.

As discussed in the compliance to L&C 2, [

] providing for a bounding calculation regardless of oscillation mode.

Limitation and Condition 4

Due to the unique neutron kinetics characteristics associated with transition cycles, all transition cycles must be dispositioned in a manner consistent with Limitations and Conditions #2 and #3.

As discussed in the compliance to L&C 2, [

]. These effects introduce significant conservatism and will bound the effects associated with transition cycles.

Limitation and Condition 5

The ATWS-I analysis must be performed for both the TTWB and 2RPT events during the initial implementation of this methodology, to confirm which event is limiting. Subsequent evaluations may only consider the event determined to be limiting, except which changes are made to the plant design or operation that may affect stability behavior during ATWS, such as: turbine bypass capability, fraction of steam-driven feedwater pumps, and changes expected to significantly increase core inlet subcooling during ATWS events.

Analyses were performed for both TTWB and 2RPT events and the results are reported in Section 2. These results demonstrate that [].

Limitation and Condition 6

The steam line and valve modeling options shall be confirmed to accurately capture the expected plant-specific system performance during ATWS-I events.

The steam line and valve models were built based on plant geometry and setpoints as supplied by TVA. This allows for an accurate representation of the evolution of the event. A review of the system transient plots show reasonable behavior during the event.

Limitation and Condition 7

Plant-specific applications must justify that the selected settings and modeling options are appropriate, including core and vessel nodalization, time step control parameters, and noise parameters. In particular, the modeling should be reasonably consistent with both the characteristics of the plant in question and

the validation basis for the RAMONA5-FA ATWS-I methodology as discussed in this SE.

All nodalization is consistent with the nodalization of the benchmarks and sample problem from the original Reference 1 topical report. In addition, the time step control and noise parameters were identical to those used in the topical report.

7.0 CONCLUSIONS

The results of the Browns Ferry EPU/MELLLA+ ATRIUM 11 ATWS-I analyses have been presented. Both the TTWB and the 2RPT event have been simulated. The results of these analyses demonstrate that the limiting peak clad temperatures remain below the 1204 °C temperature criteria.

8.0 REFERENCES

1. ANP-10346P-A Revision 0, *ATWS-I Analysis Methodology for BWRs Using RAMONA5-FA*, October 2019.
2. Proposed Technical Specifications (TS) Change TS-510 – Request for License Amendments – Maximum Extended Load Line Limit Analysis Plus, February 23, 2018 (ML 18079B140).
3. E.K. Henderson (TVA) to USNRC, “Proposed Technical Specifications (TS) Change TS-510 – Request for License Amendments – Maximum Extended Load Line Limit Analysis Plus – Supplement 2, Operator Training Results,” July 23, 2018 (ML 18205A498).

ATTACHMENT 15a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3874P Revision 2

(Proprietary)

**Browns Ferry ATRIUM 11 Control Rod Drop Accident Analysis with the
AURORA-B CRDA Methodology**

ATTACHMENT 15b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3874NP Revision 2

(Non Proprietary)

**Browns Ferry ATRIUM 11 Control Rod Drop Accident Analysis with the
AURORA-B CRDA Methodology**



Browns Ferry ATRIUM 11 Control Rod Drop Accident Analysis with the AURORA-B CRDA Methodology

ANP-3874NP
Revision 2

March 2021

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0414-12-F04 (Rev. 004, 04/27/2020)

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	Page 4-3	Explanation added for cladding hydrogen content
2	Page 4-4	Figure 4-2 updated with revised PCMI thresholds
3	Page 4-5	Typo corrected in case names in Table 4-2
4	Page 4-6	Figure 4-3 updated with revised hydrogen content
5	Page 8-2	Comment on L&C 21 updated
6	Page B-4	Proprietary information has been marked for redaction

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Nomenclature

Acronym	Definition
AOO	anticipated operational occurrence
ASME	American Society of Mechanical Engineers
BOC	beginning of cycle
BPWS	Banked Position Withdrawal Sequence
BWR	boiling water reactor
CCD	component calculational device
CFR	code of federal regulations
CHF	critical heat flux
CPR	critical power ratio
CRDA	control rod drop position
CWSR	cold work stress relief aka SRA
CZP	cold zero power
EFP	end of full power
EM	evaluation model
EOC	end of cycle
GMUL	TFGR weighting factor
LAR	license amendment request
LOCA	loss of coolant accident
LBRF	licensing basis release fraction
LWR	light water reactor
LUT	look up table
L&C	limitation and condition
MOC	middle of cycle corresponding to peak hot excess reactivity
NRC	Nuclear Regulatory Commission, U.S.
PCMI	pellet-clad mechanical interaction
RAI	request for additional information
RG	regulatory guide
SER	safety evaluation report
SRA	stress relief annealed
SRP	standard review plan
SSRF	steady state release fraction

Acronym	Definition
TFGR	transient fission gas release
TH	thermal hydraulic
TOTR	total release fraction
UFSAR	updated final safety analysis report
U.S. NRC	Nuclear Regulatory Commission, U.S.
ΔH	transient change in enthalpy
Δk	change in eigenvalue

1.0 INTRODUCTION

The Framatome AURORA-B CRDA methodology has been used to evaluate the Browns Ferry ATRIUM 11 equilibrium fuel cycle (Reference 1). The methodology includes the use of a nodal three-dimensional kinetics solution with both thermal-hydraulic (TH) and fuel temperature feedback. These models provide more precise localized neutronic and thermal conditions than previous methods to show compliance with regulatory guidance criteria presented in Regulatory Guide RG 1.236 (Reference 3). The report summarizes the application of the AURORA-B CRDA methodology (Reference 5) on the Browns Ferry ATRIUM 11 equilibrium cycle.

The control rod drop calculations were performed with the AURORA-B CRDA methodology. All startup sequences were evaluated and no fuel rod failures were identified through end of full power. Evaluations of the drops at the licensing basis end of cycle identified potential fuel rod failures in one startup sequence.

2.0 REGULATORY BASIS

This demonstration evaluation utilizing the methodology of Reference 5 is applied using the acceptance criteria of RG 1.236 (Reference 3).

3.0 INITIAL METHODOLOGY DEMONSTRATION

The initial application of the AURORA-B CRDA methodology involves sensitivity studies and determination of an evaluation boundary. The determination of the evaluation boundary provided in Appendix A is a demonstration of the process discussed in Reference 5 for Browns Ferry with ATRIUM 11 fuel.

3.1 *Initial Conditions*

Sensitivity studies are performed [

]

3.2 *Group Pull Sequence*

All allowed pull orders are evaluated such that each control rod group, with the exception of groups 5 and 6, is pulled as the second group as indicated in Table 3-1. The third and fourth groups are assumed to be banked. It is assumed that the first and second groups selected for withdrawal are completely withdrawn prior to pulling control rods in the third group. For clarification since both the first and second groups must be out before the third group, both pull sequences A1234 and A2134 have the same starting control rod pattern for the third group. Therefore the sequences A1234 and A2143 also cover sequences A2134 and A1243.

Table 3-1 Group Pull Sequences

	Analyzed Groups for both A and B sequences
1 st and 2 nd groups	(1,2), (2,1), (3,4), (4,3)
3 rd and 4 th groups	(3,4), (4,3), (1,2), (2,1)

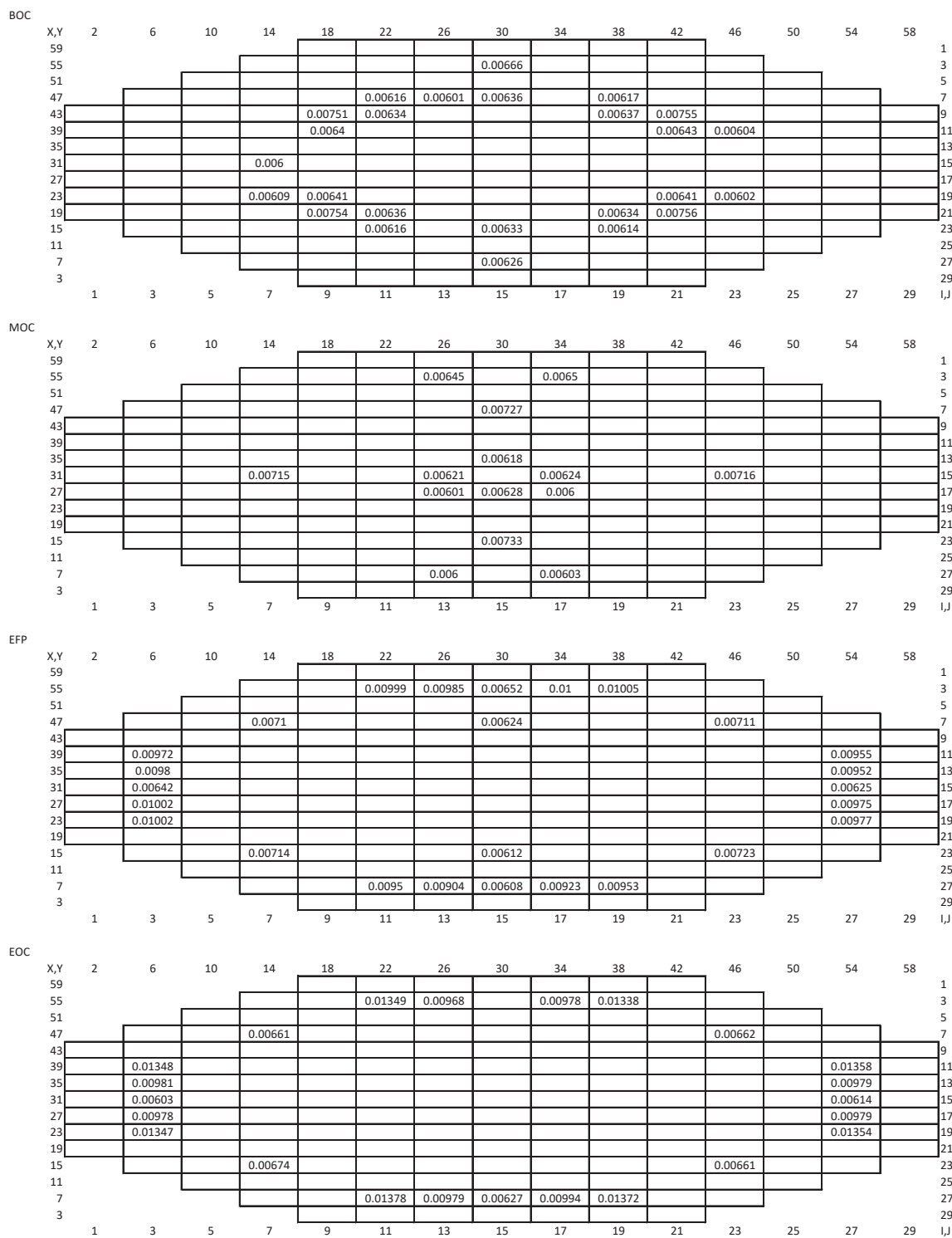
3.3 *Inoperable Control Rod Position*

A maximum of 8 inoperable control rods are allowed for this plant with up to three inoperable per group. To maximize the worth of the drops in the second and third groups, three inoperable control rods are assigned to both the first and second group in each sequence and then two more are assigned to the third. The assignment of inoperable control rods adhered to the separation criteria on group bases.

The locations of high worth control rod drops without inoperable control rods were identified as indicated in Figure 3-1. Only control rod drops with static worth greater than 6 mk are shown. Banked groups produced low static rod worth, so investigation of control rod worth was constrained to rods dropped in second group with no banking. Inoperable control rods were assigned to increase these dropped worth values as indicated in Figure 3-2. Where possible, they are selected to be in the opposite half the core as the highest worth rods while avoiding locations known to have low impact on static rod worth. Because of inoperable rod spacing requirements, it was not possible to get the third group's rods into the same half, but they are selected outside of the quadrant where the dominant rods are located.

Browns Ferry ATRIUM 11 Control Rod Drop Accident
Analysis with the AURORA-B CRDA Methodology

Figure 3-1 Second Group Rod Drops with All Rods Operable



* Values provided are the dropped rod's static worth (Δk).

Figure 3-2 Browns Ferry Inoperable Rods



* [

]

3.4 *Time in Cycle*

[

]

3.5 *Group Critical Position*

The first step is to evaluate the end of group or bank position k-effective values to determine where criticality is anticipated to occur for the given control rod withdrawal sequence. The near critical range, determined per Section 7.4.1 of Reference 5, is given in Table 3-2. The calculated k-effective values at the end of groups 1 through 4 for the A and B sequence withdrawals are given in Table 3-3. The highlighted groups and bank positions in Table 3-3 will be considered as credibly near critical.

Table 3-2 Near Critical Range

3.6 *Determination of Static Control Rod Worth*

Based on the results of the group worth, static control rod worths were then determined. From the static rod drops, [

] The rods selected for transient evaluation are given in Table 3-4.

3.7 *Transient Evaluation*

The evaluation of each rod drop is performed with the AURORA-B system. The initial pre-rod drop state point is established with the MICROBURN-B2 core simulator. The initial conditions used for the transient calculation are identified in Table 3-5.

Table 3-5 Initial Conditions

The channel grouping with a [] is used for this analysis

(Figure 3-3 illustrates the assemblies evaluated for the drop of control rod [

]). Once the channel grouping is defined, the power history information is processed to obtain the fuel rod characteristics for use in the RODEX-4 fuel rod mechanical models. The maximum prompt enthalpy increase for the peak fuel rod and the maximum total enthalpy reported include the application of the uncertainty multiplier of [] on the enthalpy increase (L&C 34 of Reference 5). The prompt enthalpy increase along with total enthalpy for the drops is given in Table 3-6. Although there are high worth banked drops, the actual nodal enthalpy increase is small for the BOC banked drops compared to drops later in cycle with a top peaked power shape.

Figure 3-3 Map of Assemblies Evaluated for Drop of Control Rod []



Table 3-6 Maximum Prompt Enthalpy Rise and Total Enthalpy

Table 3-6 Maximum Prompt Enthalpy Rise and Total Enthalpy (continued)

4.0 EVALUATION AGAINST CLADDING FAILURE CRITERIA

4.1 *High Temperature Cladding Failure*

All of the control rod drops which had inoperable control rods were evaluated against the high temperature failure threshold at nominal fuel rod pressure utilizing nominal burnup. For each assembly, the fuel rod with the highest enthalpy was evaluated against the high temperature threshold from RG 1.236. One case had assemblies with enthalpy values which exceeded the high temperature cladding failure criteria as indicated in Table 4-1.

Table 4-1 shows the maximum enthalpy for all assemblies from all drops with at least one assembly exceeding 100 cal/g maximum radial enthalpy. An additional evaluation was performed to investigate the impact of utilizing a high burnup power history wherein these cases were re-evaluated at a bounding pressure by utilizing a high fuel rod burnup. The evaluation was performed with the [] assemblies around the dropped control rod with both nominal fuel rod pressure and bounding fuel rod pressure. Only the clad differential pressure from the high burnup evaluation is indicated in Table 4-1. Nominal and elevated differential pressure cases are shown together in Figure 4-1 to illustrate the difference. The primary impact of the high burnup is lowering the failure threshold a small amount. The assembly circled in red in Figure 4-1 shows how fuel that was initially below the high temperature failure threshold might exceed it after increasing the burnup.

Table 4-1 Assemblies with Fuel Rod High Temperature Failures

Figure 4-1 High Temperature Nominal and High Burnup Total Enthalpy



4.2 PCMI Cladding Failure

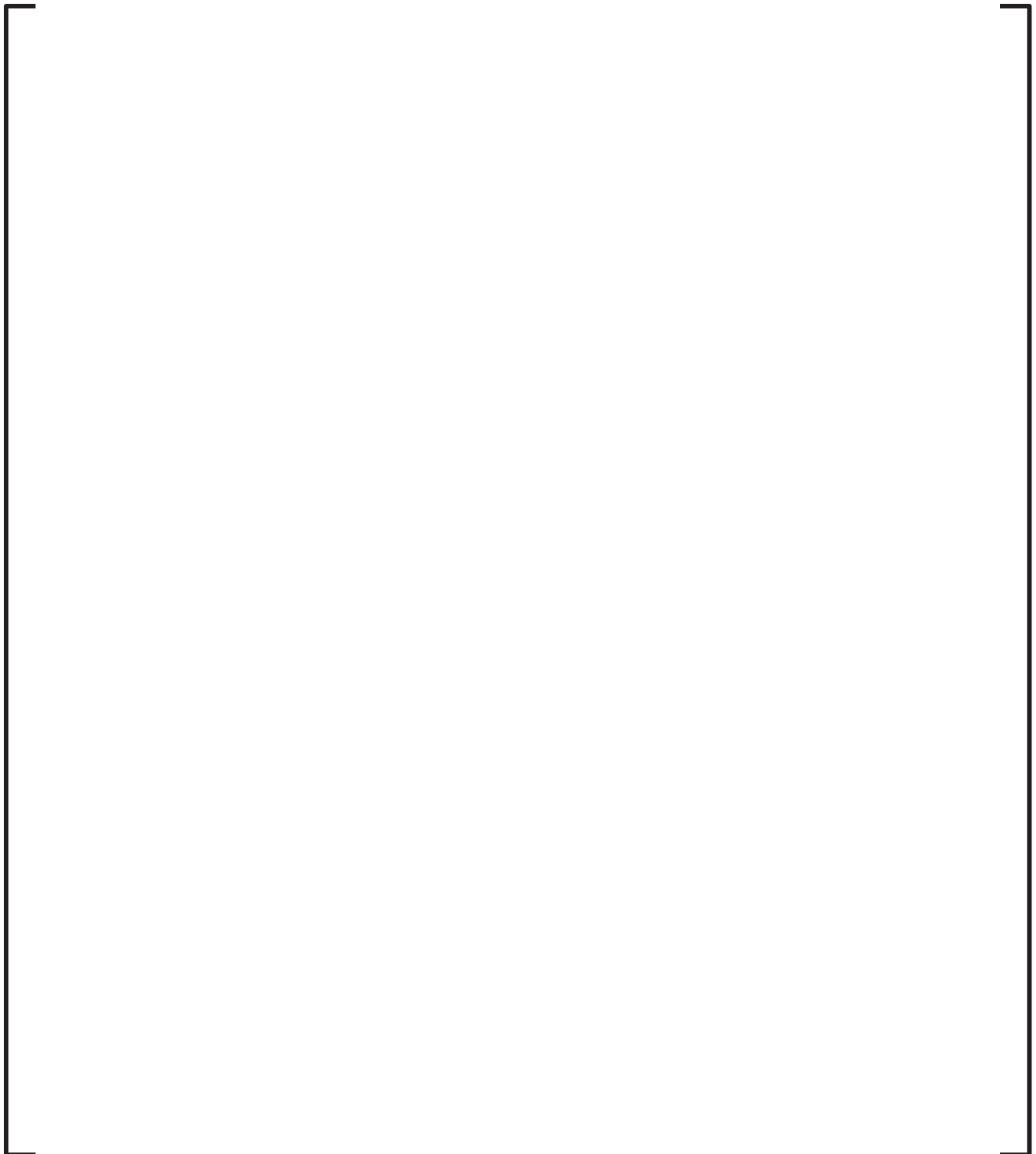
The ATRIUM 11 fuel is clad with stress relief annealed (SRA) Zircaloy-2 cladding. (Framatome uses the term Cold Work Stress Relieved CWSR to refer to SRA material.) Therefore, the SRA low temperature failure threshold from Reference 3 is applied.

To establish the minimum failure threshold, the maximum fuel rod nodal hydrogen at end of cycle was tabulated for each assembly using the hydrogen model of Reference 8 [

]

The cladding failure threshold for the core is shown in Figure 4-2.

Figure 4-2 Minimum Failure Threshold Based on EOC Hydrogen Content



Since 150 $\Delta\text{cal/g}$ is the maximum of the failure threshold curve, [

] The rod drops are evaluated with assumed inoperable
control rods. [

] There were no failures before or at end of full power.
The assemblies with fuel rod failures are given in Table 4-2.

Table 4-2 Assemblies with Fuel Rod PCMI Failures

Figure 4-3 PCMI Cladding Failure Results



4.3 Molten Fuel Cladding Failure Threshold

[

]

5.0 RADIOLOGICAL CONSEQUENCES

The dose consequences for the CRDA event determined for Browns Ferry are summarized in the UFSAR. The licensing basis dose evaluation determined that 850 8x8 fuel rods could fail. A smaller dose would result if the same number of 11x11 rods were to fail, given the smaller rod diameter. Therefore, demonstrating that there is significantly less than 850 fuel rod failures will confirm that the radiological consequences are bounded by those in the Browns Ferry UFSAR.

Evaluation of dose consequences for fuel rod failures

Since fuel rod failures had been identified, revised release fractions or total release fraction (TOTR) are determined using the values from RG 1.183 as the steady state release fraction (SSRF) with the transient fission gas release (TFGR) as described in DG-1327 (Reference 2). A ratio of the new TOTR to the licensing basis release fractions (LBRF) used in the original licensing basis is then generated following the method in ANP-10333P-A to determine the dose-equivalent weight of each failed fuel rod.

The transient release terms from Reference 2 expressed as a fraction are:

$$TFGR = \begin{cases} \frac{0.26 \cdot \Delta H - 13}{100}, & \text{Pellet BU} < 50 \text{ GWd/MTU} \\ \frac{0.26 \cdot \Delta H - 5}{100}, & \text{Pellet BU} \geq 50 \text{ GWd/MTU} \end{cases}$$

The TOTR is dependent on the nuclide group and the enthalpy-dependent TFGR averaged over the 25 nodes of fuel for full length fuel rods (if the fuel failure were in a shorter fuel rod, the number of axial nodes would decrease accordingly).

$$TOTR_i = SSRF_i + GMUL_i \cdot \frac{1}{25} \sum_{k=1}^{25} TFGR_k$$

Where,

ΔH is the fuel enthalpy increase (cal/g)

$TFGR_k$ is the transient fission gas release fraction as determined above at the k^{th} axial node

$SSRF_i$ is the steady state release fraction of the i^{th} isotope group

$GMUL_i$ is the TFGR weighting factor from Reference 2 for the i^{th} isotope group

$TOTR_i$ is the total release fraction of a given rod weighted by the i^{th} isotope group

Three TFGR weighting multipliers are established by DG-1327:

Isotope Group	GMUL	Applied to
Stable, long-lived isotopes (e.g. Kr-85)	1.0	Kr-85
Cs-134 and Cs-137	1.414	Alkali Metals
Short-lived radioactive isotopes (e.g. halogens, Xe and Kr noble gases other than Kr-85)	0.333	Iodines, nobles, halogens

For this analysis of the ATRIUM 11 fuel, a maximum of [] full length and [] part length fuel rods exceeded one or more failure criteria in any control rod drop case. Based on the enthalpy increase, the enthalpy dependent release terms were determined for the fuel rods. The transient fission gas release fractions for the limiting fuel rod are provided in Table 5-1 based on nodal values of the peak fuel rod enthalpy increase. []

[illegible]

Table 5-2 Fission Gas Release Fractions and Weighting Factors

* [

]

Table 5-3 TOTR to LBRF Ratio []

Table 5-4 Fuel Rod Failures

* Unique rod failures

6.0 SYSTEM PRESSURE AND CPR

The impact of the CRDA on system pressure was addressed in Reference 5 and does not cause stresses to exceed Emergency Condition (Service Level C), as defined in Section III of the ASME Boiler and Pressure Vessel code. This generic evaluation on the impact of CRDA on system pressure remains applicable for Browns Ferry. The CPR response was evaluated in Section 7.7 of Reference 5 and resulted in a conclusion that the CRDA in the power range is

[

]

7.0 CORE COOLABILITY

Two criteria are identified in Reference 3 for allowable limits with respect to core coolability:

- Peak radial average enthalpy < 230cal/g
- The peak fuel temperature in the outer 90 percent of the pellet's volume must remain below incipient fuel melting conditions

[

]

Table 7-1 Peak Radial Average Fuel Enthalpy

8.0 LIMITATIONS AND CONDITIONS

The SER for the Reference methodology included a number of limitations and conditions. Some of the conditions are from the base AURORA-B AOO methodology (Reference 6) and additions specific to the CRDA are included. The numbering of the limitations and conditions below is consistent with that found in the AURORA-B CRDA SER.

1. AURORA-B may not be used to perform analyses that result in one or more of its CCDs (S-RELAP5, MB2-K, MICROBURN-B2, RODEX4) operating outside the limits of approval specified in their respective TRs, SEs, and plant-specific license amendment requests (LARs). In the case of MB2-K, MB2-K is subject to the same limitations and conditions as MICROBURN-B2. *(This is Condition 1 of the SE for the base AURORA-B TR. It remains applicable to CRDA analyses for BWRs/2-6.)*

This condition is met for the application of AURORA-B CRDA methodology to Browns Ferry.

14. The scope of the NRC staff's approval of AURORA-B does not include the ABWR design. *(This is Condition 14 of the SE for the base AURORA-B TR. It remains applicable to CRDA analyses for BWRs/2-6.)*

This condition is met for all Browns Ferry Units since they are BWR/4 designs.

20. The implementation of any new methodology within the AURORA-B EM (i.e., replacement of an existing CCD) is not acceptable unless the AURORA-B EM with the new methodology incorporated into it has received NRC review and approval. An existing NRC-approved methodology cannot be implemented within the AURORA-B EM without NRC review of the updated EM. *(This is a revised version of Condition 20 of the SE for the base AURORA-B TR, rewritten to be specific to the CRDA application. It remains applicable to CRDA analyses for BWRs/2-6.)*

The evaluation model will be implemented for Browns Ferry as described in the base AURORA-B and AURORA-B CRDA Topical Reports. No CCD as described in the TR are replaced and therefore the intent of this condition is met.

21. NRC-approved changes that revise or extend the capabilities of the individual CCDs comprising the AURORA-B EM may not be incorporated into the EM without prior NRC

approval. *(This is Condition 21 of the SE for the base AURORA-B TR. It remains applicable to CRDA analyses for BWRs/2-6.)*

22. As discussed in Section 3.3.1.5 and Section 4.0 of Reference 6 (the SE for the base AURORA-B TR), the SPCB and ACE CPR correlations for the ATRIUM-10 and ATRIUM-10XM fuels, respectively, are approved for use with the AURORA-B EM. Other CPR correlations (existing and new) that would be used with the AURORA-B EM must be reviewed and approved by the NRC or must be developed with an NRC-approved approach such as that described in EMF-2245(P)(A), Revision 0, "Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel". Furthermore, if transient thermal-hydraulic simulations are performed in the process of applying AREVA CPR correlations to co-resident fuel, these calculations should use the AURORA-B methodology. *(This is Condition 22 of the SE for the base AURORA-B TR. It remains applicable to at-power CRDA analyses for BWRs/2-6.)*

Approved CPR correlations are used for at-power CRDA analyses.

23. Except when prohibited elsewhere, the AURORA-B EM may be used with new or revised fuel designs without prior NRC approval provided that the new or revised fuel designs are

substantially similar to those fuel designs already approved for use in the AURORA-B EM (i.e., thermal energy is conducted through a cylindrical ceramic fuel pellet surrounded by metal cladding, flow in the fuel channels develops into a predominantly vertical annular flow regime, etc.). New fuel designs exhibiting a large deviation from these behaviors will require NRC review and approval prior to their implementation in AURORA-B. *(This is Condition 23 of the SE for the base AURORA-B TR. It remains applicable to CRDA analyses for BWRs/2-6.)*

The condition is met as ATRIUM 11 exhibits the structural similarities described in the restriction.

24. Changes may be made to the AURORA-B EM in the [

] areas discussed in Section 4.0 of Reference 6 (the SE for the base AURORA-B TR) without prior NRC approval. *(This is Condition 24 of the SE for the base AURORA-B TR. It remains applicable to CRDA analyses for BWRs/2-6.)*

No confirmation is required for this condition.

25. The parallelization of individual CCDs may be performed without prior NRC approval as discussed in Section 4.0 of Reference 6 (the SE for the base AURORA-B TR). *(This is Condition 25 of the SE for base AURORA-B TR. It remains applicable to CRDA analyses for BWRs/2-6.)*

No confirmation is required for this condition.

26. AREVA must continue to use existing regulatory processes for any code modifications made in the [

] areas discussed in Section 4.0 of Reference 6 (the SE for the base AURORA-B TR). *(This is Condition 26 of the SE for the base AURORA-B TR. It remains applicable to CRDA analyses for BWRs/2-6.)*

This condition is met through the use of the Framatome software development procedures, which provides information for use in the licensee's 10 CFR 50.59 licensing evaluation.

27. The control rod model at each location in the core used for CRDA analyses with the AURORA-B EM shall use a control rod geometry and composition that is verified to bound the control rod worth for the physical control rod used that location, for all axial elevations. *(This is a new condition from this report.)*

[

] Therefore, this condition is met.

28. Licensees utilizing AURORA-B to perform CRDA analyses using the methodology described in this TR shall confirm that the recommended maximum rod velocity of 3.11 ft/s is conservative for their control rods. *(This is a new condition from this report.)*

The licensee has confirmed the conservatism of this value.

29. If the check to verify that the total enthalpy is limiting at 10 percent core flow CZP conditions by [

] fails, AREVA shall perform a more comprehensive evaluation to verify that they have identified the limiting initial conditions for that plant. This evaluation should consider a range of flow values and corresponding plant-specific minimum temperatures that is sufficiently broad to clearly identify the combination of initial conditions which maximizes the total enthalpy for the limiting rod. *(This is a new condition from this report.)*

[

] is conservative for

Browns Ferry with ATRIUM 11 for determining total enthalpy.

30. When individual control rods are evaluated using the CRDA analysis methodology, if necessary, alternate distributions of inoperable rods should be utilized to ensure inclusion of at least one evaluation within each group of 4 quadrant symmetric control rods that maximizes the change in face- and/or diagonally-adjacent uncontrolled cells as a result of the candidate control rod withdrawal. *(This is a new condition from this report.)*

The inoperable control blade patterns were evaluated for all rods [

] For the Browns Ferry core, localizing the inoperable rods to one area of the core increases the static worth of the dropped rod in the opposite part of the core.

31. The evaluation boundary curve used to determine candidate control rods for further evaluation based on their static rod worths must be verified to bound the following local characteristics of the fuel being evaluated: design pin peaking factors, fuel assembly design, location in or adjacent to the outermost ring of control rods, and average burnup for the 16 fuel assemblies surrounding the rod of interest.

This evaluation boundary region of applicability is presented in Appendix A of this analysis and shows that this condition is met.

32. If the highest worth rod at a given core statepoint results in a total enthalpy that is higher than the minimum high temperature failure threshold (i.e., lowest threshold for all rod internal pressures), additional rods must be considered for evaluation. This may be done by evaluating the next highest worth rods at the core statepoint of interest until the minimum high temperature failure threshold is met, or by using an approach analogous to the evaluation boundary curve used for the PCMI failure threshold (as subject to condition 29).

The highest rod dropped resulted in a total enthalpy which exceeded the minimum high temperature failure threshold. Therefore, additional rods were evaluated to address this condition.

33. If the methodology described in ANP-10333 is used to analyze the CRDA event with a fuel assembly design that has a different fuel rod geometry and/or manufacturing tolerances than the one used as a basis for the sensitivity study on gap width, the sensitivity study shall be repeated for the new fuel assembly design, using bounding values consistent with the uncertainty range for [

] limiting increase in the peak total enthalpy, the total uncertainty shall be increased accordingly for total enthalpies calculated based on the new fuel assembly design. (*This is a new condition from this report.*)

The ATRIUM 11 product line requires an evaluation of the gap sensitivity study. The sensitivity studies were performed with a bounding value for the uncertainty range of [

] The resulting increase in peak total enthalpy is []

34. The uncertainty designated in the CRDA TR of [

] for the enthalpy rises calculated using the CRDA analysis methodology may not be reduced without prior NRC approval. (This is a new condition from this report.)

The uncertainty of [] is used in this evaluation.

9.0 REFERENCES

1. ANP-3854P, Revision 1, *Browns Ferry ATRIUM 11 Equilibrium Cycle, Fuel Cycle Design*, Framatome, June 2020.
2. DG-1327, *Pressurized-Water Reactor Control Rod Ejection and Boiling-Water Reactor Control Rod Drop Accidents*, July 2019 (NRC ADAMS ML18302A106).
3. RG 1.236, *Pressurized-Water Reactor Control Rod Ejection and Boiling-Water Reactor Control Rod Drop Accidents*, June 2020 (NRC ADAMS ML20055F490).
4. RG 1.183, *Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors*, July 2000 (ML003716792).
5. ANP-10333P-A, Revision 0, *AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)*, Framatome Inc., March 2018.
6. ANP-10300P-A, Revision 1, *AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios*, Framatome Inc., January 2018.
7. ANP-10335P-A, Revision 0, *ACE/ATRIUM 11 Critical Power Correlation Topical Report*, Framatome Inc., May 2018.
8. BAW-10247PA Revision 0 Supplement 1P-A Revision 0, *Realistic Thermal- Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 1: Qualification of RODEX4 for Recrystallized Zircaloy-2 Cladding*, AREVA Inc., April 2017.
9. BRUNSWICK STEAM ELECTRIC PLANT, UNITS 1 AND 2 – ISSUANCE OF AMENDMENT NOS. 299 AND 327 TO REVISE TECHNICAL SPECIFICATION 5.6.5b TO ALLOW APPLICATION OF ADVANCED FRAMATOME ATRIUM 11 FUEL METHODOLOGIES (EPID L-2018-LLA-0273) (ADAMS ML 20073F186).

Appendix A Evaluation Threshold Determination

Limitation and Condition 31 states:

31. The evaluation boundary curve used to determine candidate control rods for further evaluation based on their static rod worths must be verified to bound the following local characteristics of the fuel being evaluated: design pin peaking factors, fuel assembly design, location in or adjacent to the outermost ring of control rods, and average burnup for the 16 fuel assemblies surrounding the rod of interest.

The process to generate an evaluation threshold is demonstrated based upon the process described in the response to RAI-5 in ANP-10333Q1P (included in Reference 5). The peak fuel rod enthalpy rise was elevated using a multiplication factor of [] to double the uncertainty. The elevated enthalpy rise values were then tabulated against the static control rod worth.

Figure A-1 Establishing Evaluation Boundary



Figure A-2 Evaluation Boundary for ATRIUM 11 Core



The local characteristics of fuel used to establish the evaluation boundary with respect to design fuel rod peaking factors, fuel assembly design, core location, and the average burnup of the 16 assemblies around the dropped rod have been are provided in Table A-1. This table is for use with future core licensing to confirm the applicability of the evaluation boundary curve.

Table A-1 Example Evaluation Boundary Characteristics

Appendix B Critical Heat Flux Application in Startup Range

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ANP-3874NP

Revision 2

Browns Ferry ATRIUM 11 Control Rod Drop Accident
Analysis with the AURORA-B CRDA Methodology

Page B-2

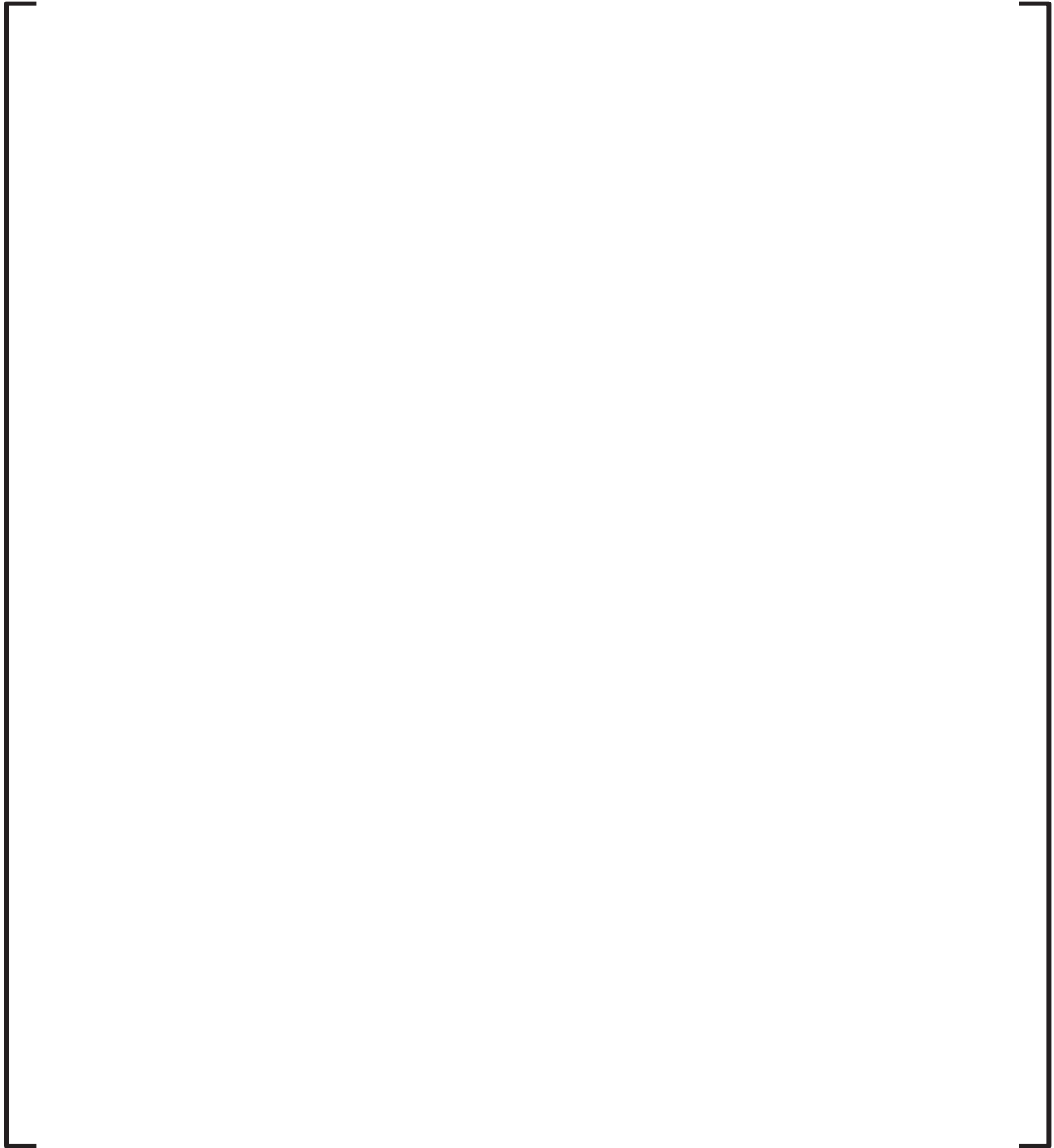


Figure B-1 Total Enthalpy Rise with CHF Multipliers



B-1. []

B-2. []

B-3. []

B-4. []

B-5. []

B-6. []

B-7. []

ATTACHMENT 16a

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3904P Revision 4

(Proprietary)

Browns Ferry ATRIUM 11 Transient Demonstration

ATTACHMENT 16b

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

ANP-3904NP Revision 4

(Non Proprietary)

Browns Ferry ATRIUM 11 Transient Demonstration



Browns Ferry ATRIUM 11 Transient Demonstration

ANP-3904NP
Revision 4

July 2021

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	Page 6-1	Reference 4 is changed to update the revision number.

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Nomenclature

AOO	anticipated operational occurrence
AOT	abnormal operational transient
ASME	American Society of Mechanical Engineers
AST	alternate source term
ATWS	anticipated transient without scram
ATWS-RPT	anticipated transient without scram recirculation pump trip
BFN	Browns Ferry Nuclear Plant
BOC	beginning of cycle
BWR	boiling water reactors
COLR	core operating limits report
CRDA	control rod drop accident
EM	evaluation model
EOC-RPT	end of cycle recirculation pump trip
EOC-RPT-OOS	end of cycle recirculation pump trip out of service
EOCLB	end of cycle licensing basis
EOFP	end of full power
EOOS	equipment out of service
FFTR	final feedwater temperature reduction
FHOOS	feedwater heater out of service
FoM	figure of merit
FSAR	final safety analysis report
FWCF	feedwater controller failure
HPCI	high pressure coolant injection
IHPS	inadvertent HPCI pump start
IORV	inadvertent opening of relief valve
LAR	license amendment request
LFWH	loss of feedwater heating
LHGR	linear heat generation rate
LHGRFACp	power dependent linear heat generation rate multipliers
LOCA	loss of coolant accident
LOFW	loss of feedwater flow
LRNB	generator load rejection no bypass
LTR	licensing topical report

Nomenclature (continued)

MAPLHGR	maximum average planar linear heat generation rate
MCPR	minimum critical power ratio
MCPR _p	power dependent minimum critical power ratio
MELLLA+	maximum extended load line limit analysis plus
MSIV	main steam isolation valve
NEOC	near end of cycle
NRC	Nuclear Regulatory Commission, U.S.
NSS	nominal scram speed
Pbypass	power below which direct scram on TSV/TCV closure is bypassed
PLU	power load unbalance
PLUOOS	power load unbalance out of service
PRFO	pressure regulator failure open
RHR	residual heat removal
RPT	recirculation pump trip
SRV	safety/relief valve
SRVOOS	safety/relief valve out-of-service
TBVOOS	turbine bypass valves out of service
TCV	turbine control valve
TSV	turbine stop valve
TTNB	turbine trip no bypass
Δ MCPR	change in minimum critical power ratio

1.0 INTRODUCTION

This report summarizes the results of a subset of transient analyses performed to support the license amendment request (LAR) to include the Reference 1 and Reference 2 Licensing Topical Reports (LTR) into the Browns Ferry Nuclear Plant (BFN) Technical Specifications.

For a typical reload, a full assessment of the power/flow map, cycle exposure, and scram speed are done on a cycle specific basis for the actual core configuration to develop thermal limits. The intention of this report is to demonstrate the applicability of the AURORA-B AOO methodology (Reference 1) to Browns Ferry for the transient analyses that are typically limiting on a cycle-specific basis. Therefore, this document is a subset of transient analysis typically performed for each cycle.

The analyses presented in Section 4 of this document are based upon a representative equilibrium cycle of ATRIUM 11 fuel, Reference 3. A variety of power/flow state points are performed at a cycle exposure and scram speed discussed in each subsection of Section 4.

The AURORA-B AOO analysis is used to calculate the change in the minimum critical power ratio (ΔMCPR) during the anticipated operational occurrence (AOO). The ΔMCPR is combined with the safety limit MCPR to establish or confirm the plant operating limits for MCPR.

The AURORA-B AOO analysis is also used to calculate the maximum reactor vessel pressure and the maximum dome pressure during the ASME and ATWS events. The calculated maximum reactor vessel pressure is compared to the ASME acceptance criterion (110% of vessel design pressure) and the calculated maximum steam dome pressure is compared to the pressure safety limit in the plant Technical Specifications. For the ATWS event, the calculated maximum reactor vessel pressure is compared to ASME Service Level C (120% of design pressure) to demonstrate that the event

acceptance criterion is met. Meeting the acceptance criteria confirms that the plant safety valve performance (number of valves available, capacity per valve, and setpoints) is acceptable.

The ACE/ATRIUM 11 critical power correlation (Reference 2) is used to evaluate the thermal margin of the ATRIUM 11 fuel.

2.0 ANTICIPATED OPERATIONAL OCCURRENCES

2.1 *AURORA-B AOO Evaluation Model*

AURORA-B is a comprehensive evaluation model developed for predicting the dynamic response of boiling water reactors (BWRs) during transient, postulated accident, and beyond design-basis accident scenarios. The evaluation model (EM) contains a multi-physics code system with flexibility to incorporate all the necessary elements for analysis of the full spectrum of BWR events that are postulated to affect the nuclear steam supply system of the BWR plant. Deterministic analysis principles are applied to satisfy plant operational and Technical Specification requirements through the use of conservative initial conditions and boundary conditions.

The foundation of AURORA-B AOO is built upon three computer codes, S-RELAP5, MB2-K, and RODEX4. Working together as a system, they make up the multi-physics evaluation model that provides the necessary systems, components, geometries, processes, etc. to assure adequate predictions of the relevant BWR event characteristics for its intended applications. The three codes making up the foundation of the code system are;

- S-RELAP5 – This code provides the transient thermal-hydraulic, thermal conduction, control systems, and special process capabilities (i.e. valves, jet-pumps, steam separator, critical power correlations, etc.) necessary to simulate a BWR plant.
- MB2-K – This code uses advanced nodal expansion methods to solve the three-dimensional, two-group, neutron kinetics equations. The MB2-K code is consistent with the MICROBURN-B2 steady state core simulator. MB2-K receives a significant portion of its input from the steady state core simulator.

- RODEX4 – A subset of routines from this code are used to evaluate the transient thermal-mechanical fuel rod (including fuel/clad gap) properties as a function of temperature, rod internal pressure, etc. The fuel rod properties are used by S-RELAP5 when solving the transient thermal conduction equations in lieu of standard S-RELAP5 material property tables.

2.2 *Description of [*

] Analysis Process

The AURORA-B AOO methodology (Reference 1) includes an evaluation of the impact of code uncertainties on Figures of Merit (FoM) (e.g. Δ MCPR, peak pressure) [

]

that has wide acceptance in the nuclear industry.

Table 2.1 [

]

2.2.1 Sampled Parameters [

The set of code and modeling uncertainty parameters to be sampled for AOO calculations is shown in Table 2.2.

2.2.2 **Sampling Ranges**

The sampling ranges shown in Table 2.2 are applicable to Browns Ferry Units 1, 2, and 3. Per the approved methodology (Reference 1), the sampling ranges address uncertainties inherent in the S-RELAP5 models [

]

* Framatome Inc. formerly known as AREVA Inc.

A description of the basis for the sampling ranges used for each of the above sampled variables is found in Reference 1 Safety Evaluation, Sections 3.6.4.1 – 3.6.4.17.



2.3 Application [] for Demonstration Cases

The statistical analysis process presented in the previous sections will be used to determine the [] values for FoMs associated with the nominal transient simulations performed to demonstrate the methodology application to the equilibrium ATRIUM 11 core. Section 3.6.5 of the Safety Evaluation (Reference 1) allows for subsequent analyses to utilize the [] to determine base conservative measures to be applied for calculation of the key FoM in future reload licensing. []

1

3.0 **AURORA-B AOO METHODOLOGY IMPLEMENTATION TO BROWNS FERRY FSAR CHAPTER 14 EVENTS**

3.1 ***Disposition of Events***

The objective of the disposition of events is to identify the limiting events which must be analyzed to support operation at the Browns Ferry Nuclear Plant with the introduction of ATRIUM 11 fuel. Events and analyses identified as potentially limiting are either evaluated generically or on a cycle-specific basis.

The first step is to identify the licensing basis of the plant. Included in the licensing basis are descriptions of the postulated events/analyses and the associated criteria. Fuel-related system design criteria must be met, ensuring regulatory compliance and safe operation. The licensing basis, related to fuel and applicable for reload analysis, is contained in the Final Safety Analysis Report (FSAR), the Technical Specifications, Core Operating Limits Reports (COLR), and other reload analysis reports.

For the introduction of ATRIUM 11 fuel, Framatome reviewed all fuel-related design criteria, events, and analyses identified in the licensing basis. In many cases, when operating limits are established to ensure acceptable consequences of an abnormal operational transient (AOT) or accident, the fuel-related aspects of the system design criteria are met. All fuel-related events were reviewed and dispositioned into one of the following categories:

1. No further analysis required. This classification may result from one of the following:
 - a. The consequences of the event are bound by consequences of a different event.
 - b. The consequences of the event are benign, i.e., the event causes no significant change in margins to the operating limits.
 - c. The event is not affected by the introduction of ATRIUM 11 fuel and/or the current analysis of record remains applicable.
2. Address event each reload. The consequences of the event are potentially limiting and need to be addressed each reload.

3. Address for initial reload. This classification may result from one of the following:
 - a. The analysis is performed using conservative bounding assumptions and inputs such that the initial reload results will remain applicable for future reloads of the same fuel design.
 - b. Results from the first reload will be used to quantitatively demonstrate that the results remain applicable for future reloads of the same fuel design because the consequences are benign or bound by those of another event.

A disposition of events summary is presented in Table 3.1. The disposition summary presents a list of the events and analyses, the corresponding FSAR section, the disposition status, and any applicable comments. In each comment, the basis of the disposition is categorized as:

- FSAR analysis
- Generic analysis. A bounding analysis that is independent of plant type.
- Plant specific analysis. The analysis is based on Browns Ferry (independent of unit) and is bounding for cycle-to-cycle variations.
- Cycle specific analysis. The analysis is specific to the Unit and Cycle.

**Table 3.1 Disposition of Events Summary for
Introduction of ATRIUM 11 Fuel at Browns Ferry**

FSAR Section	Event /Analysis	Disposition Status	Comments
14.5.2.1	Generator trip (TCV fast closure)	No further analyses required	Bound by the generator trip with turbine bypass valve failure.
14.5.2.2	Generator trip (TCV fast closure) with turbine bypass valve failure	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.2.2.4	LRNB with EOC-RPT-OOS	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.2.3	Loss of condenser vacuum	No further analyses required	FSAR analysis. Transient is equivalent to the turbine trip with bypass operable; therefore, this event is bound by the turbine trip with turbine bypass valve failure.
14.5.2.4	Turbine trip (TSV closure)	No further analyses required	Bound by the turbine trip with turbine bypass valve failure.
14.5.2.5	Turbine bypass valves failure following turbine trip (TTNB), high power	Address initial reload	Plant specific analysis, unless determined to potentially be limiting. Generally bound by the generator trip with turbine bypass valve failure. Comparison provided in Table 4.1.
14.5.2.6	Turbine bypass valves failure following turbine trip (TTNB), low power	No further analysis required.	FSAR analysis. Generally bound by the generator trip with turbine bypass valve failure. Comparison provided in Table 4.1.
14.5.2.7	Main steam isolation valve closure	No further analyses required	FSAR analysis. The MSIV closure is bound by the LRNB event.
14.5.2.8	Pressure regulator failure (downscale)	No further analyses required	FSAR analysis. Eliminated as an AOT by the installation of a digital fault-tolerant main turbine electro-hydraulic control system.

FSAR Section	Event /Analysis	Disposition Status	Comments
14.5.3.1	Loss of feedwater heater (LFWH)	Address each reload	Cycle specific analysis. Generally bound by the FWCF event. Addressed each cycle to demonstrate it remains bound by the other events.
14.5.3.2	Shutdown cooling (RHR) malfunction – decreasing temperature	No further analyses required	FSAR analysis. Benign event.
14.5.3.3	Inadvertent HPCI pump start (IHPS)	Address for initial reload	Plant specific analysis. Generally bound by the FWCF event. The IHPS event is similar to the LFWH event. The IHPS is slightly more CPR limiting, whereas the LFWH is slightly more thermal-mechanical limiting. Both IHPS and LFWH events have considerable margin to the limiting FWCF event. The LFWH transient is analyzed for each cycle to demonstrate, on a relative basis, that the LFWH and IHPS events remain non-limiting.
14.5.4.1	Continuous rod withdrawal during power range operation	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.4.2	Continuous rod withdrawal during reactor startup	No further analyses required	FSAR analysis. Benign event.
14.5.4.3	Control rod removal error during refueling	No further analyses required	FSAR analysis. Event is not credible.
14.5.4.4	Fuel assembly insertion error during refueling	No further analyses required	FSAR analysis. An unplanned criticality during refueling due to a single fuel assembly insertion error is not credible.
	Mislocated or misoriented fuel assembly	Address each reload	Cycle specific analysis

FSAR Section	Event /Analysis	Disposition Status	Comments
14.5.5.1	Pressure regulator failure open (PRFO)	Address each reload	FSAR analysis and cycle specific analysis. The pressure regulator failure open – maximum steam demand is a potentially limiting ATWS overpressurization event, which is addressed each reload. Relative to AOT thermal operating limits, the PRFO is a benign event.
14.5.5.2	Inadvertent opening of a MSRV (IORV)	No further analysis required	FSAR analysis. Benign event.
14.5.5.3	Loss of feedwater flow (LOFW)	No further analysis required	FSAR analysis. Benign event.
14.5.5.4	Loss of auxiliary power	No further analyses required	FSAR analysis. Benign event.
14.5.6.1	Recirculation flow control failure – decreasing flow	No further analysis required	FSAR analysis. Consequences of the event are bound by the pump seizure event.
14.5.6.2	Trip of one recirculation pump	No further analyses required	FSAR analysis. Consequences of this event are benign and bound by the TTNB event.
14.5.6.3	Trip of two recirculation pumps	No further analyses required	FSAR analysis. Consequences of this event are benign and bound by the TTNB event.
14.5.6.4	Recirculation pump seizure	Address initial reload	Plant specific analysis unless determined to be limiting. Evaluate the TLO and SLO pump seizure event as part of the initial reload to determine the impact, if any, on thermal limits.
14.5.7.1	Recirculation flow control failure - increasing flow	Address each reload	Cycle specific analysis. Consequences of the slow flow run-up event determine the flow-dependent MCPR and LHGR operating limits and are evaluated each reload.
14.5.7.2	Startup of idle recirculation loop	No further analysis required	FSAR analysis. Benign event.

FSAR Section	Event /Analysis	Disposition Status	Comments
14.5.8.1	Feedwater controller failure (FWCF) - maximum demand	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.8.2	Feedwater controller failure (FWCF) - maximum demand with EOC-RPT-OOS	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.8.3	Feedwater controller failure (FWCF) - maximum demand with TBVOOS	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.9	Loss of habitability of the control room	No further analyses required	FSAR analysis. This is postulated as a special event to demonstrate the ability to safely shutdown the reactor from outside the control room. Not impacted by AURORA-B AOO implementation or addition of ATRIUM 11 fuel design
14.6.2	Control rod drop accident (CRDA)	Address each reload	Cycle specific analysis. Consequences of the CRDA are evaluated to confirm the acceptance criteria are satisfied.
14.6.3	Loss-of-coolant accident (LOCA)	Address initial reload	Plant specific analysis and cycle specific parameter confirmation. The break spectrum analysis is addressed for the initial ATRIUM 11 reload, Reference 5. Consequences of the LOCA are evaluated to determine appropriate fuel-specific MAPLHGR limits which are independent of cycle specific assembly designs. Limiting power history, gad LHGR confirmation, and MAPLHGR checks are performed for follow-on reloads.
14.6.4	Refueling accident	Address each reload	Plant specific analysis. Consequences of the refueling accident are evaluated to confirm the acceptance criteria are satisfied.

FSAR Section	Event /Analysis	Disposition Status	Comments
14.6.5	Main steam line break accident	No further analysis required	FSAR analysis and Reference 5. The consequences of a large steam line break are far from limiting with respect to 10 CFR 50.46 acceptance criteria. Radiological dose consequences are performed utilizing AST in accordance with 10 CFR 50.67. The consequences of the event are not a function of fuel type since no fuel failures are calculated to occur. The dose is a function of the radionuclide inventory in the coolant itself prior to the event.
10.11	Fire protection systems	Address initial reload	Plant specific analysis. Confirmation of NFPA 805 acceptance criteria for ATRIUM 11 will be addressed in the Reload Safety Analysis report.

3.2 ***Cycle-Specific Calculation Plan Development and Analysis Considerations for Limit Generation and Plant Operation***

The disposition of events evaluation for a plant defines the transient events to be analyzed on a cycle specific basis. Prior to a specific cycle's licensing campaign, a calculation plan is generated, which defines the minimum analysis set required to license a given cycle. This plan is reviewed and approved by Browns Ferry. Additional analyses may be added during the evaluation process if unexpected trends arise. These are added on an as-needed basis to ensure that the thermal limits used to monitor actual plant operation are appropriately developed.

The calculation plan will also define all operational flexibility options that are to be supported. System pressurization transient results are sensitive to scram speed assumptions. The calculation plan will provide details regarding what scram insertion speeds will be supported for cycle specific analyses. Additional items discussed are equipment out-of-service options (EOOS) and exposure windows.

3.2.1 **Exposure Analysis**

Cycle specific thermal limits are developed based on exposure ranges discussed in the calculation plan. The limiting exposure for rated power pressurization transients is typically at end of full power (EOFP) when the control rods are fully withdrawn. To provide additional margin to the operating limits, thermal limits are typically developed for multiple exposures ranges for the cycle being evaluated. The typical exposure ranges cover beginning-of-cycle (BOC) to a near end-of-cycle (NEOC) core average exposure, BOC to the end-of-cycle licensing basis (EOCLB) analysis, and BOC to extended cycle operation with FFTR and power coastdown.

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3.2.2 **State Point Determination**

The statepoints to be analyzed are also defined in the calculation plan. The initial transition to AURORA-B methods will include [



4.0 ANALYSIS OF PLANT TRANSIENTS

Framatome's licensing methodology is based upon core conditions established by a detailed step-through calculation. In support of demonstrating the AURORA-B AOO method to the Browns Ferry units, plant transients are analyzed for a small subset of power and flow conditions at a cycle exposure and scram speed discussed in each subsection. The transient analyses, presented in this section, are performed using plant parameters provided by the utility for a full core of ATRIUM 11 fuel.

The transient events chosen to demonstrate the application of the AURORA-B AOO method are typical limiting events for Browns Ferry as determined from previous cycle analyses and a review of Chapter 14 of the final safety analysis report (FSAR), as shown in Section 3.1 of this report.

4.1 *Transient Events – Base Case*

4.1.1 Load Rejection No Bypass (LRNB)

Load rejection causes a fast closure of the turbine control valves. The resulting compression wave travels through the steam lines into the vessel and creates a rapid pressurization. The increase in pressure causes a decrease in core voids, which in turn causes a rapid increase in power. Fast closure of the turbine control valves also causes a reactor scram and recirculation pump trip (RPT). Turbine bypass system operation, which also mitigates the consequences of the event, is not credited. The excursion of the core power due to the void collapse is terminated primarily by the reactor scram and revoiding of the core.

LRNB analyses assume the power load unbalance (PLU) is inoperable for power levels less than 50% of rated. The LRNB sequence of events is different than the standard event when the PLU is inoperable. Instead of a fast closure, the TCVs close in servo mode and there is no direct scram on TCV closure. The power and pressure excursion continues until the high pressure scram occurs. Given that there is no direct scram

when the PLU is inoperable, the LRNB event above and below P_{bypass} at 26% power is identical for the same state point.

To demonstrate the AURORA-B AOO transient methodology models the LRNB event appropriately, LRNB analyses were performed for the following range of conditions within the approved MELLLA+ power/flow map:

- 100% core power, with 105%, 95%, and 85% core flow
- 77.6% core power, with 109% and 95% core flow
- 50% core power, with 113% core flow
- 26% core power above P_{bypass} , with 113% core flow
- 26% core power below P_{bypass} , with 100% core flow

Table 4.1 presents the change in MCPR for the LRNB event. The transient analyses are performed at the end of full power (EOFP) cycle exposure, utilizing NSS insertion times. Table 4.2 presents the sequence of event timing for the LRNB event at 100% power with 105% core flow. Figures 4.1 – 4.3 show the responses of various reactor and plant parameters during the LRNB event initiated at 100% of rated power and 105% of rated core flow with NSS insertion times.

4.1.2 **Turbine Trip No Bypass (TTNB)**

A turbine trip event can be initiated as a result of several different signals. The initiating signal causes the TSV to close in order to prevent damage to the turbine. The TSV closure creates a compression wave traveling through the steam lines into the vessel causing a rapid pressurization. The increase in pressure results in a decrease in core voids, which in turn causes a rapid increase in power. Closure of the TSV also causes a reactor scram and an RPT which helps mitigate the pressurization effects. In addition to the TSV closure, the TCVs also close in the fast closure mode. Because of the partially closed initial position of the control valves, they will typically close faster than the stop valves and control the pressurization portion of the event. However, TCV closure characteristics are nonlinear so that the resulting core pressurization and

Δ MCPR results may not always bound those of the slower TSV closure at rated power. The limiting of TCV or TSV closure, for the initial operating conditions, was used in the TTNB analyses based on sensitivity analyses. Turbine bypass system operation, which also mitigates the consequences of the event, is not credited. The excursion of the core power due to the void collapse is terminated primarily by the reactor scram and revoiding of the core.

To demonstrate the AURORA-B AOO transient methodology models the TTNB event appropriately, TTNB analyses were performed for the following range of conditions within the approved MELLLA+ power/flow map:

- 100% core power, with 105%, 95%, and 85% core flow
- 77.6% core power, with 109% and 95% core flow
- 26% core power above P_{bypass}, with 113% core flow
- 26% core power below P_{bypass}, with 100% core flow

Table 4.1 presents the change in MCPR for the TTNB event. The transient analyses are performed at the EOF cycle exposure, utilizing NSS insertion times. Table 4.3 presents the sequence of event timing for the TTNB event at 100% power with 105% core flow. Figures 4.4 – 4.6 show the responses of various reactor and plant parameters during the TTNB event initiated at 100% of rated power and 105% of rated core flow with NSS insertion times.

4.1.3 **Feedwater Controller Failure (FWCF)**

The increase in feedwater flow due to a failure of the feedwater control system to maximum demand results in an increase in the water level and a decrease in the coolant temperature at the core inlet. The increase in core inlet subcooling causes an increase in core power. As the feedwater flow continues at maximum demand, the water level continues to rise and eventually reaches the high water level trip setpoint. The initial water level is conservatively assumed to be at the low level normal operating range to delay the high-level trip and maximize the core inlet subcooling resulting from

the FWCF. The high water level trip causes the TSVs to close in order to prevent damage to the turbine from excessive liquid inventory in the steam line. Valve closure creates a compression wave traveling back to the core, causing void collapse and subsequent rapid power excursion. The closure of the TSVs also initiates a reactor scram and an RPT. In addition to the TSV closure, the TCVs also close in the fast closure mode. Because of the partially closed initial position of the control valves, they will typically close faster than the stop valves and control the pressurization portion of the event. However, TCV closure characteristics are nonlinear so that the resulting core pressurization and ΔMCPR results may not always bound those of the slower TSV closure at rated power (steam flow increases above rated before fast TCV closure). The limiting of TCV or TSV closure, for the initial operating conditions, was used in the FWCF analyses based on sensitivity analyses. The turbine bypass valves are assumed operable and provide some pressure relief. The core power excursion is mitigated in part by pressure relief, but the primary mechanisms for termination of the event are reactor scram and revoiding of the core

To demonstrate the AURORA-B AOO transient methodology models the FWCF event appropriately, FWCF analyses were performed for the following range of conditions within the approved MELLLA+ power/flow map:

- 100% core power, with 105%, 95%, and 85% core flow
- 77.6% core power, with 109%, 95%, and 55% core flow
- 26% core power above P_{bypass}, with 113% core flow
- 26% core power below P_{bypass}, with 100% core flow

Table 4.1 presents the change in MCPR for the FWCF event. The transient analyses are performed at the EOFP cycle exposure, utilizing NSS insertion times. Table 4.4 presents the sequence of event timing for the FWCF event at 100% power with 105% core flow. Figures 4.7 – 4.9 show the responses of various reactor and plant parameters during the FWCF event initiated at 100% of rated power and 105% of rated core flow with NSS insertion times.

4.1.4 **ASME Overpressurization Analysis**

This section describes the maximum overpressurization analyses performed to demonstrate compliance with the ASME Boiler and Pressure Vessel Code. The analysis shows that the safety/relief valves at Browns Ferry have sufficient capacity and performance to prevent the reactor vessel pressure from reaching the safety limit of 110% of the design pressure.

To demonstrate the applicability of the AURORA-B AOO (Reference 1) methodology for ASME overpressurization analyses, a main steam isolation valve (MSIV) closure analysis was performed for 102% power and 105% flow and 102% power and 85% flow at the latest exposure in the cycle design. The MSIV closure event is similar to the other steam line valve closure events in that the valve closure results in a rapid pressurization of the core. The increase in pressure causes a decrease in void which in turn causes a rapid increase in power. The following assumptions were made in the analysis:

- The most critical active component (direct scram on valve position) was assumed to fail. However, scram on high neutron flux and high dome pressure is available.
- The plant configuration analyzed assumed that one of the lowest setpoint safety/relief valves (SRVs) was inoperable.
- TSSS insertion times were used.
- The initial dome pressure was set at the maximum allowed by the Technical Specifications plus an additional 5 psi bias, 1070 psia (1055 psig).
- A fast MSIV closure time of 3.0 seconds was used.
- The analytical limit ATWS-RPT setpoint and function were assumed.
- The SRV opening setpoints used in the analysis were set to the Technical Specification values increased by 3%, plus an additional 5 psi.

Results of the MSIV closure overpressurization analysis are presented in Table 4.5 and demonstrate that the maximum vessel pressure limit of 1375 psig and dome pressure limit of 1325 psig are not exceeded. Table 4.6 presents the sequence of event timing

for the ASME event at 102% power with 105% core flow. Figures 4.10 – 4.13 show the response of various reactor plant parameters during the MSIV closure event.

4.1.5 **ATWS Overpressurization Analysis**

This section describes the analyses performed to demonstrate that the peak vessel pressure for the limiting ATWS event is less than the ASME Service Level C limit of 120% of the design pressure (1500 psig). To demonstrate the applicability of the AURORA-B AOO (Reference 1) methodology for ATWS overpressurization analyses, the ATWS event analyses were performed at 100% power at 85% and 105% flow at the beginning of cycle (BOC) exposure based on historically limiting analyses. The MSIV closure and pressure regulator failure open (PRFO) events were evaluated. Failure of the pressure regulator in the open position causes the turbine control and turbine bypass valves to open such that steam flow increases until the maximum combined steam flow limit is attained. The system pressure decreases until the low pressure setpoint is reached, resulting in the closure of the MSIVs. The resulting pressurization wave causes a decrease in core voids and an increase in core pressure thereby increasing the core power.

The following assumptions were made in the analyses:

- The analytical limit ATWS-RPT setpoint and function were assumed.
- To support operation with one SRVOOS, the plant configuration analyzed assumed that one of the lowest setpoint SRVs was inoperable.
- All scram functions were disabled.
- The initial dome pressure was set to the nominal pressure of 1050 psia.
- The MSIV closure is based on a nominal closure time of 4.0 seconds for both events.
- The SRV opening setpoints used in the analysis were set to the Technical Specification values increased by 3%, plus an additional 5 psi.

Results of the ATWS overpressurization analyses are presented in Table 4.5 and demonstrate that the ATWS maximum vessel pressure limit of 1500 psig is not

exceeded. Table 4.7 presents the sequence of event timing for the ATWS MSIV closure event at 100% power with 85% core flow. Figures 4.14 – 4.17 show the response of various reactor plant parameters during the ATWS MSIV closure event, the event which results in the maximum vessel pressure.

4.2 ***Transient Events – Equipment Out-Of-Service***

4.2.1 **EOC Recirculation Pump Trip Out-of-Service (EOC-RPT-OOS)**

When EOC-RPT is inoperable, no credit is assumed for RPT on TSV position or TCV fast closure. The function of the EOC-RPT feature is to reduce the severity of the core power excursion caused by the pressurization transient. The RPT accomplishes this by helping revoid the core, thereby reducing the magnitude of the reactivity insertion resulting from the pressurization transient. Failure of the RPT feature can result in more restrictive operating limits.

Analyses were performed for LRNB and FWCF events assuming EOC-RPT-OOS at the end of full power (EOFP) cycle exposure, utilizing NSS insertion times. Results for the LRNB and FWCF events at 100% power with 105% core flow are presented in Table 4.8 for the EOC-RPT-OOS EOOS scenario.

4.2.2 **Turbine Bypass Valves Out-of-Service (TBVOOS)**

The effect of operation with TBVOOS is a reduction in the system pressure relief capacity, which makes the pressurization events more severe. While the base case LRNB and TTNB events are analyzed assuming the turbine bypass valves out-of-service, operation with TBVOOS has an adverse effect on the FWCF event.

Analyses of the FWCF event with TBVOOS were performed at the end of full power (EOFP) cycle exposure, utilizing NSS insertion times. Results for the FWCF event at 100% power with 105% core flow are presented in Table 4.8 for the TBVOOS EOOS scenario.

4.2.3 **Feedwater Heaters Out-of-Service (FHOOS)**

The FHOOS scenario assumes a feedwater temperature reduction of 70°F (55°F + 15°F bias) at rated power and steam flow. The effect of reduced feedwater temperature is an increase in core inlet subcooling, changing axial power shape and core void fraction. Additionally, steam flow for a given power level decreases because more power is required to increase coolant enthalpy to saturated conditions. Generally, LRNB and TTNB events are less severe with FHOOS conditions due to the decrease in steam flow relative to nominal conditions. FWCF events with FHOOS conditions are generally worse due to a larger change in inlet subcooling and core power prior to the pressurization phase of the event.

Analyses were performed for LRNB and FWCF events assuming FHOOS at the end of full power (EOFP) cycle exposure, utilizing NSS insertion times. Results for the LRNB and FWCF events at 100% power with 105% core flow are presented in Table 4.8 for the FHOOS EOOS scenario.

4.2.4 **Power Load Unbalance Out-of-Service (PLUOOS)**

The power load unbalance (PLU) device in normal operation is assumed to not function below 50% power. PLUOOS is assumed to mean the PLU device does not function for any power level, and does not initiate fast TCV closure. The following PLUOOS scenario was assumed for the load reject event.

- Initially, the TCVs remain in pressure/speed control mode. There is no direct scram or EOC-RPT on valve motion.
- Loss of load results in increasing turbine speed. Depending on initial power, a turbine overspeed condition may be reached to initiate a turbine trip resulting in scram and EOC-RPT.
- Without a turbine trip signal, scram occurs on either high flux or high dome pressure to terminate the event.

Analyses were performed for the LRNB event assuming PLUOOS at the end of full power (EOFP) cycle exposure, utilizing NSS insertion times. Results for the LRNB event

at 100% power with 105% core flow are presented in Table 4.8 for the PLUOOS EOOS scenario.

4.2.5 **Reduced Feedwater Temperature at Startup**

During reactor startup, it is beneficial to reduce feedwater temperature to avoid excessive wear on reactor equipment. The desired feedwater temperature is less than the temperature assumed in the FHOOS licensing analyses performed each cycle. Therefore, previously defined EOOS scenarios are not adequate to cover operation during startup with the desired reduction in feedwater temperature. The reduced feedwater temperatures supporting this EOOS scenario are only applicable at 50% of rated power, and below.

Analyses were performed for the FWCF event assuming these reduced feedwater temperatures, supporting both with and without TBVOOS at the beginning of cycle (BOC) exposure based on historically limiting analyses, utilizing NSS insertion times. Results for the FWCF event at 50% power with 113% core flow are presented in Table 4.8 for the reduced feedwater temperature at startup EOOS scenario.

Table 4.1 Base Case Transient Results

State Point Power / Flow (% of rated)	ATRIUM 11 ΔMCPR
Load Rejection No Bypass	
100 / 105	[]
100 / 95	[]
100 / 85	[]
77.6 / 109	[]
77.6 / 95	[]
50 / 113	[]
26 / 113	[]
26 / 100 below Pbyypass	[]
Turbine Trip No Bypass	
100 / 105	[]
100 / 95	[]
100 / 85	[]
77.6 / 109	[]
77.6 / 95	[]
26 / 113	[]
26 / 100 below Pbyypass	[]
Feedwater Controller Failure	
100 / 105	[]
100 / 95	[]
100 / 85	[]
77.6 / 109	[]
77.6 / 95	[]
77.6 / 55	[]
26 / 113	[]
26 / 100 below Pbyypass	[]

Table 4.2 Sequence of Events Timing for the LRNB Event

Event	Time (sec)
TCV Closure Event	0.000
TCV Fast Closure Scram Signal	0.090
Reactor Scram	0.090
Time of TCV Full Closure	0.100
Recirculation Pump Trip	0.185
Peak Power	0.545
Peak Heat Flux	0.655
Time of critical heat flux	0.665
SRV Actuation	1.600
Peak Dome Pressure (1266.79 psia)	1.825
Peak Vessel Pressure (1297.17 psia)	1.830
Peak Steam Line Pressure (1279.62 psia)	2.105

Table 4.3 Sequence of Events Timing for the TTNB Event

Event	Time (sec)
TSV/TCV Closure Event*	0.000
TSV/TCV Fast Closure Scram Signal *	0.090
Reactor Scram	0.090
Time of TSV Full Closure *	0.100
Time of TCV Full Closure *	0.100
Recirculation Pump Trip	0.185
Peak Power	0.545
Peak Heat Flux	0.655
Time of critical heat flux	0.665
SRV Actuation	1.600
Peak Dome Pressure (1266.75 psia)	1.825
Peak Vessel Pressure (1297.13 psia)	1.830
Peak Steam Line Pressure (1279.63 psia)	2.105

* Analyses performed with the limiting TCV or TSV valve closure, based on sensitivity results. See Section 4.1.2 for further discussion.

Table 4.4 Sequence of Events Timing for the FWCF Event

Event	Time (sec)
FWCF Event Initiator	0.000
Level 8 – High Water Level – Trip	16.535
Level 8 – TSV/TCV Closure Signal*	18.690
TSV/TCV Motion Scram Signal*	18.780
Reactor Scram	18.780
Turbine Bypass Valves Open	18.795
Recirculation Pump Trip	18.875
Peak Power	19.235
Peak Heat Flux	19.340
Time of critical heat flux	19.350
SRV Actuation	20.445
Peak Steam Line Pressure (1233.67 psia)	20.550
Peak Dome Pressure (1238.23 psia)	20.605
Peak Vessel Pressure (1267.70 psia)	20.610

* Analyses performed with the limiting TCV or TSV valve closure, based on sensitivity results. See Section 4.1.3 for further discussion.

Table 4.5 ASME and ATWS Overpressurization Analysis Results

Event	Maximum Vessel Pressure Lower Plenum (psig)	Maximum Dome Pressure (psig)
ASME Overpressurization		
MSIV closure (102P/105F)	1346	1313
MSIV closure (102P/85F)	1341	1313
ATWS Overpressurization		
MSIV closure (100P/105F)	1,419	1,400
MSIV closure (100P/85F)	1,454	1,438

**Table 4.6 Sequence of Events Timing for the ASME
Overpressurization Event**

Event	Time (sec)
MSIV Closure Event Initiator (3.0 sec full closure time)	0.000
High Neutron Flux Setpoint	2.545
Reactor Scram	2.640
Peak Power	3.195
SRV Actuation	3.855
Recirculation Pump Trip	4.040
Peak Heat Flux	4.135
Peak Vessel Pressure (1359.57 psia)	4.845
Peak Steam Line Pressure (1325.69 psia)	5.150
Peak Dome Pressure (1326.94 psia)	5.155

**Table 4.7 Sequence of Events Timing for the ATWS
Overpressurization Event**

Event	Time (sec)
MSIV Closure Event Initiator (4.0 sec full closure time)	0.000
Recirculation Pump Trip Setpoint – High Pressure	4.325
Peak Power	4.840
SRV Actuation	4.890
Peak Heat Flux	5.035
Recirculation Pump Trip – High Pressure	5.080
Peak Vessel Pressure (1,468.36 psia)	11.740
Peak Steam Line Pressure (1,450.09 psia)	11.865
Peak Dome Pressure (1,451.70 psia)	11.915

Table 4.8 EOOS Transient Results

State Point Power / Flow (% of rated)	ATRIUM 11 ΔMCPR
100 / 105 Base Case – all equipment in service	
FWCF	[]
LRNB	[]
100 / 105 EOC-RPT-OOS	
FWCF	[]
LRNB	[]
100 / 105 FHOOS	
FWCF	[]
LRNB	[]
100 / 105 FHOOS with EOC-RPT-OOS	
FWCF	[]
LRNB	[]
100 / 105 PLUOOS	
LRNB	[]
100 / 105 PLUOOS with EOC-RPT-OOS	
LRNB	[]
100 / 105 PLUOOS with FHOOS	
LRNB	[]
100 / 105 PLUOOS, FHOOS with EOC-RPT-OOS	
LRNB	[]
100 / 105 TBVOOS	
FWCF	[]
100 / 105 TBVOOS with EOC-RPT-OOS	
FWCF	[]
100 / 105 TBVOOS with FHOOS	
FWCF	[]
100 / 105 TBVOOS, FHOOS with EOC-RPT-OOS	
FWCF	[]
50 / 113 Reduced Feedwater Temperature at Startup	
FWCF with startup FHOOS	[]
FWCF with startup FHOOS and TBVOOS	[]

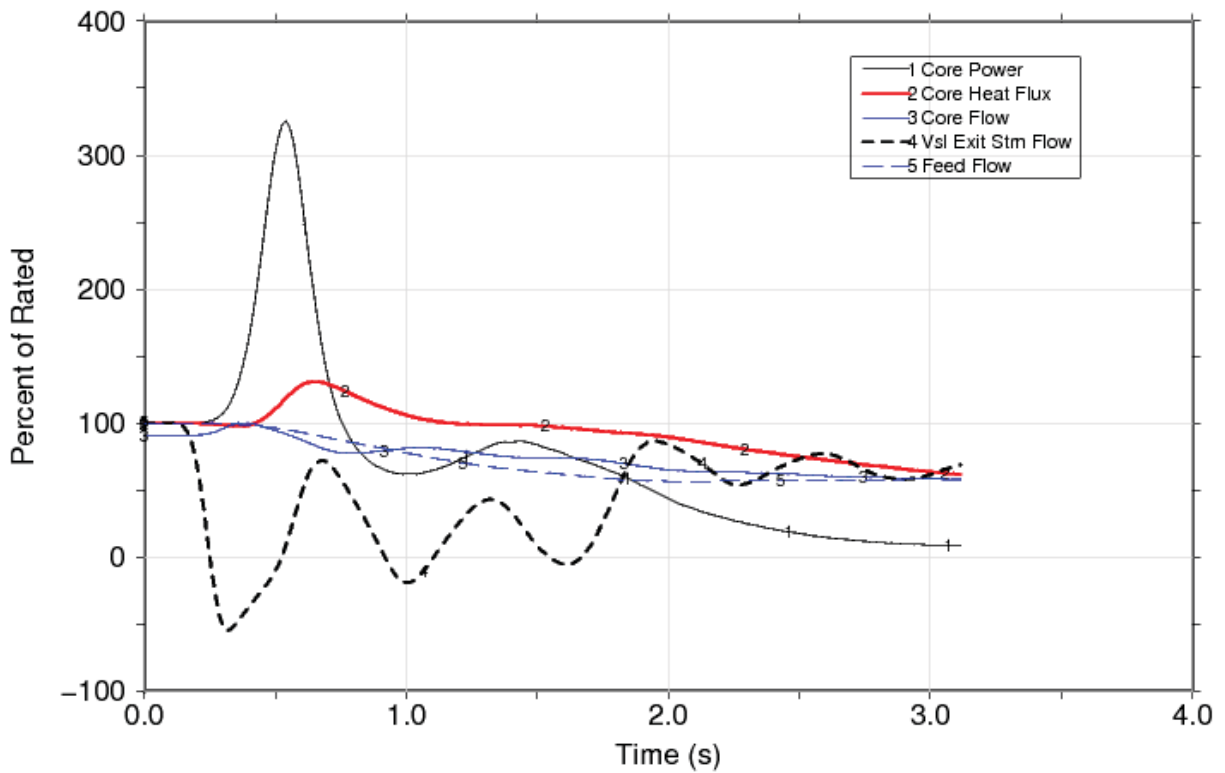


**Figure 4.1 EOFP LRNB at 100P/105F – NSS
Key Parameters**

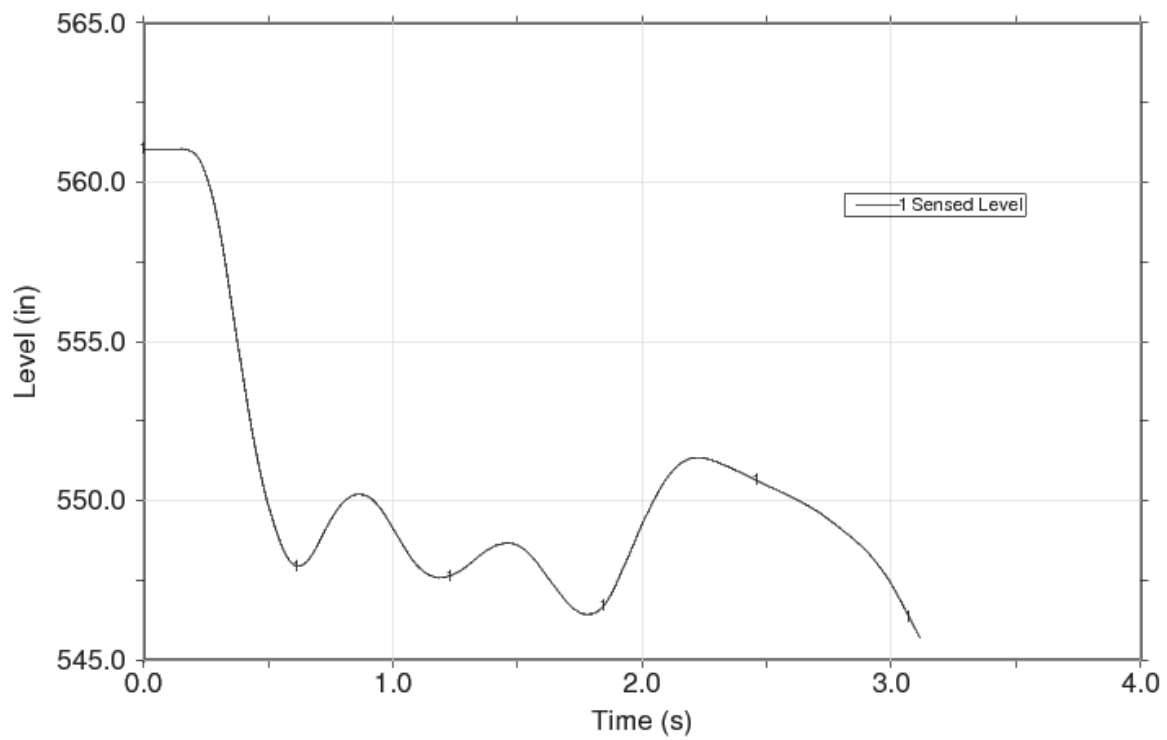


**Figure 4.2 EOFP LRNB at 100P/105F – NSS
Sensed Water Level**

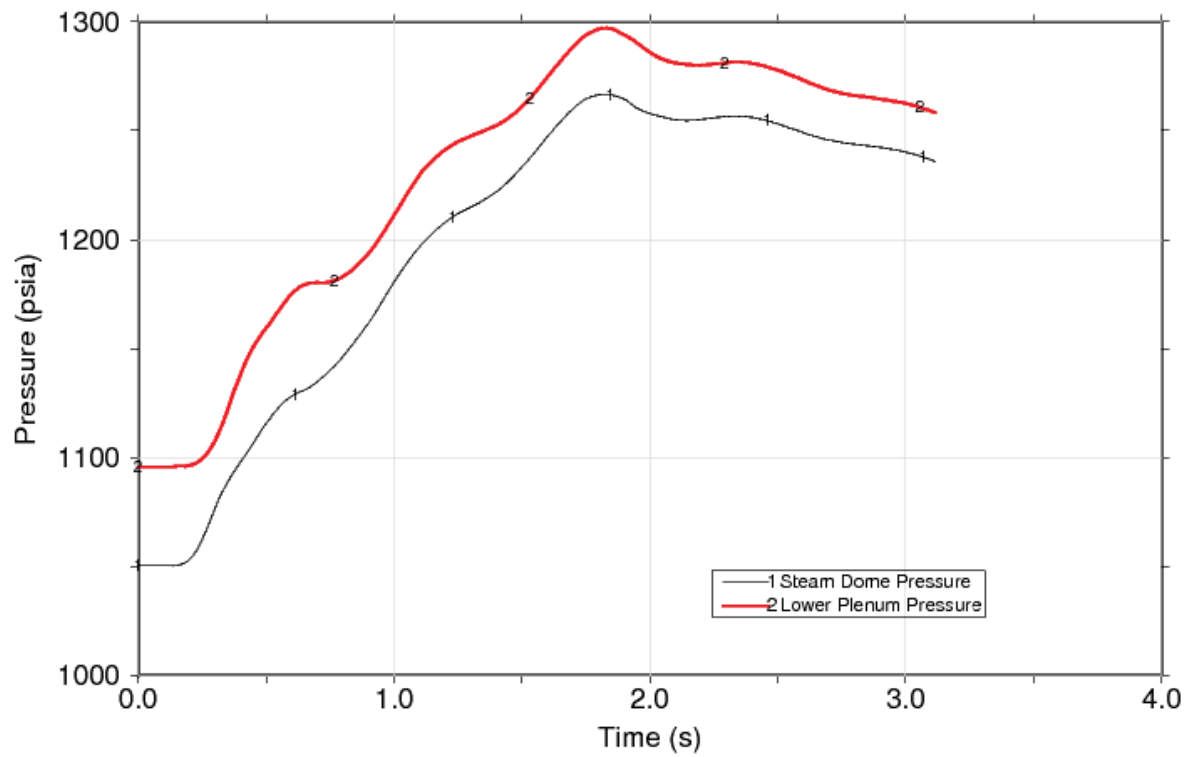


**Figure 4.3 EOFP LRNB at 100P/105F – NSS
Vessel Pressures**

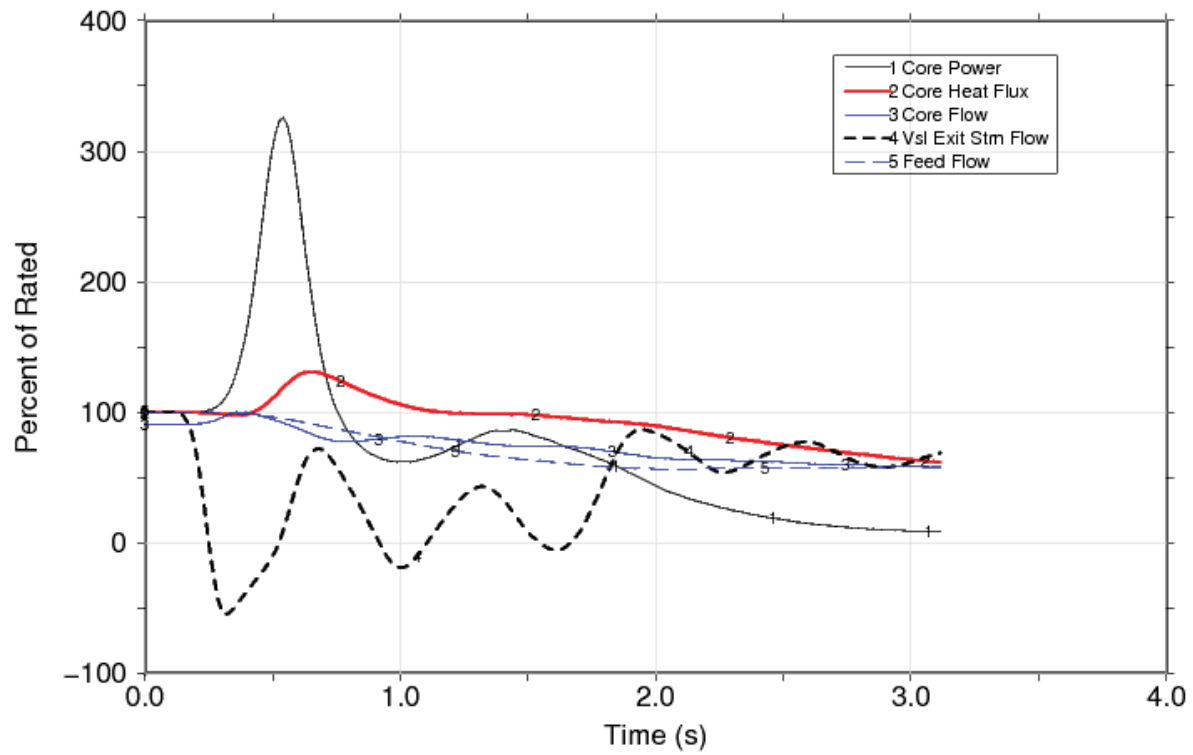


**Figure 4.4 EOFP TTNB at 100P/105F – NSS
Key Parameters**

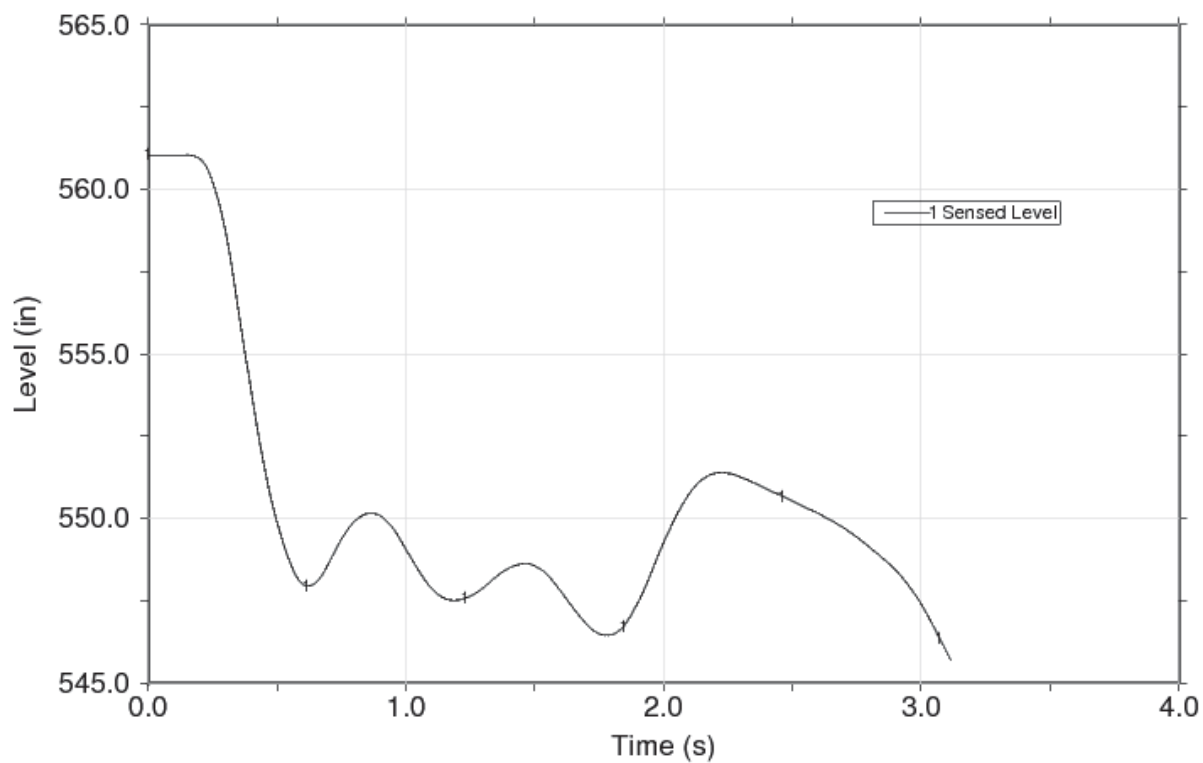


**Figure 4.5 EOFP TTNB at 100P/105F – NSS
Sensed Water Level**

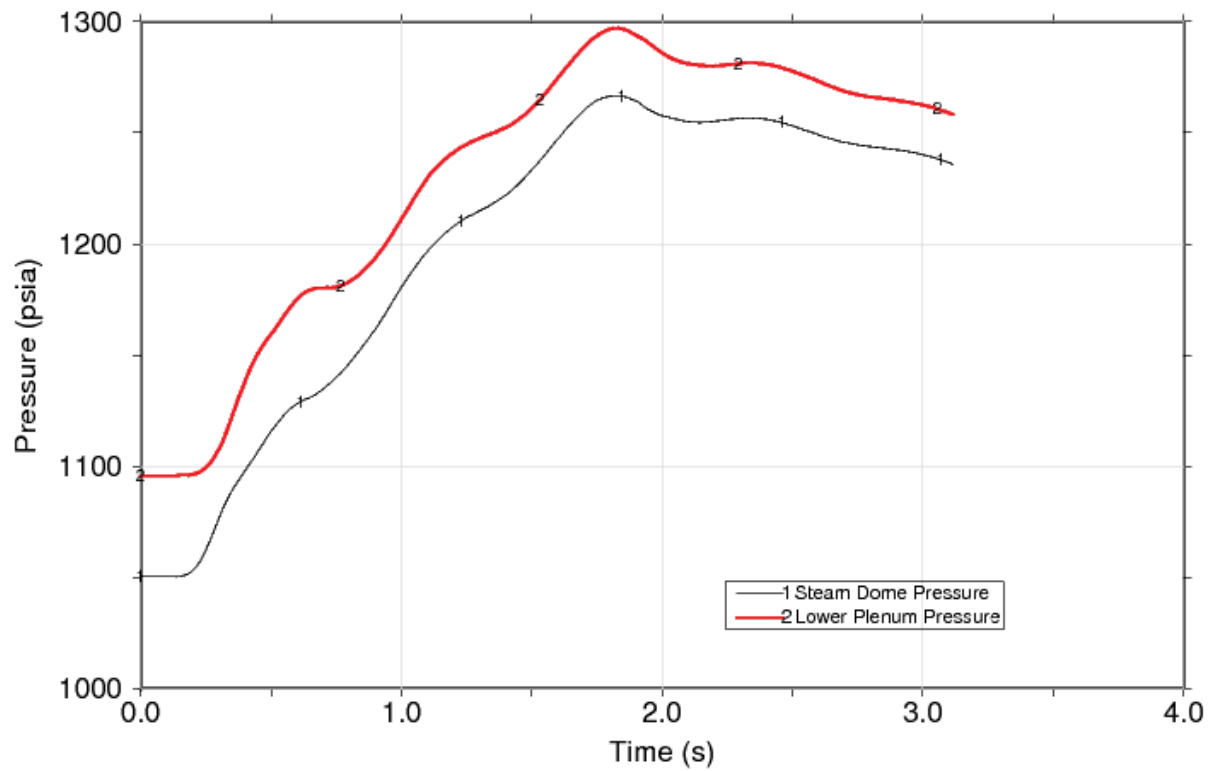


**Figure 4.6 EOFP TTNB at 100P/105F – NSS
Vessel Pressures**

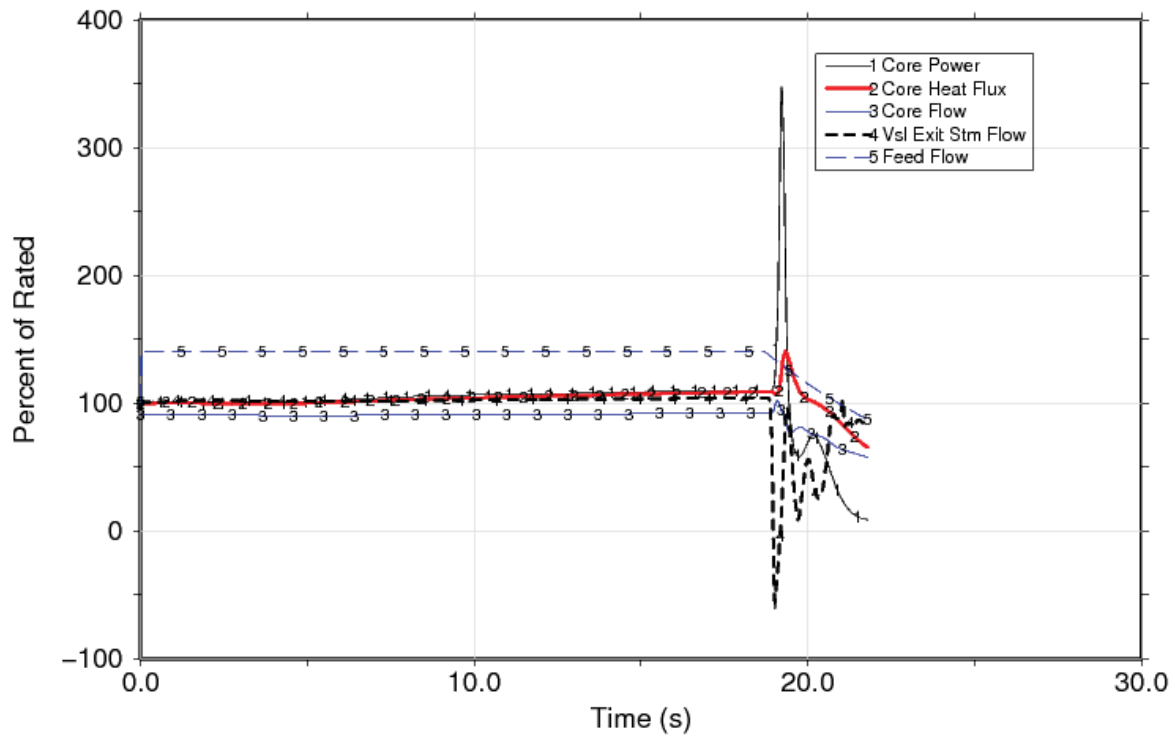


**Figure 4.7 EOFP FWCF at 100P/105F – NSS
Key Parameters**

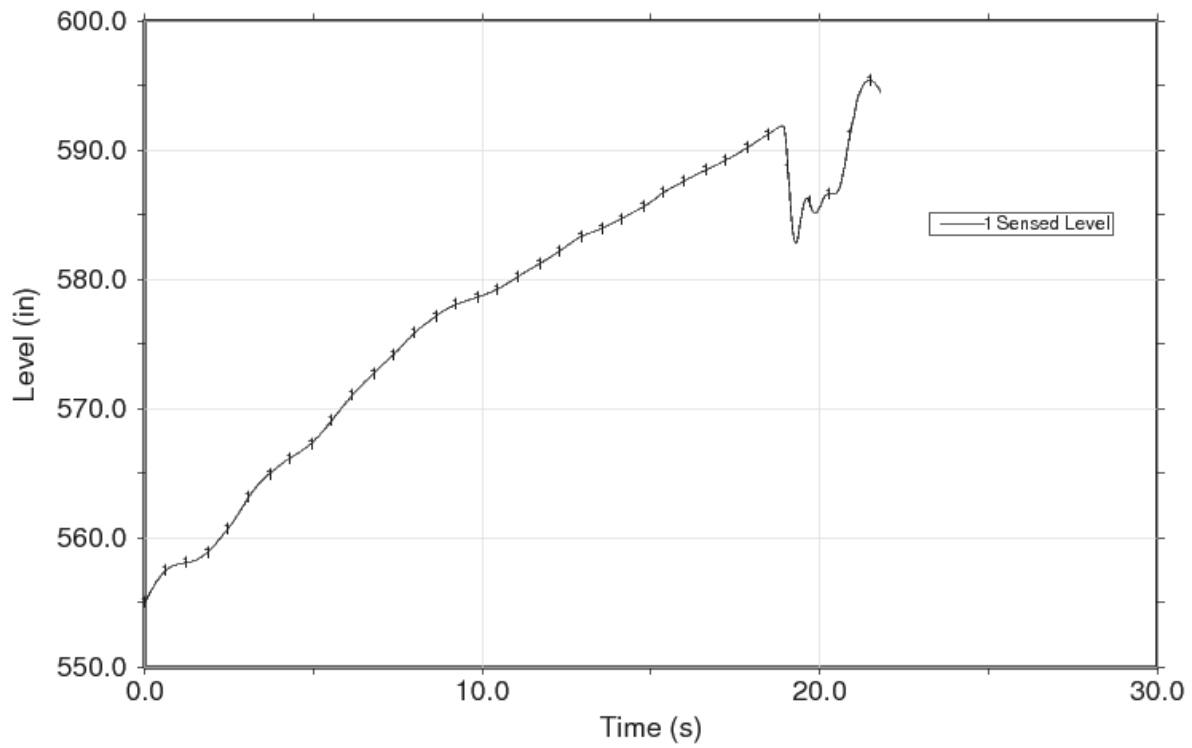


**Figure 4.8 EOFP FWCF at 100P/105F – NSS
Sensed Water Level**

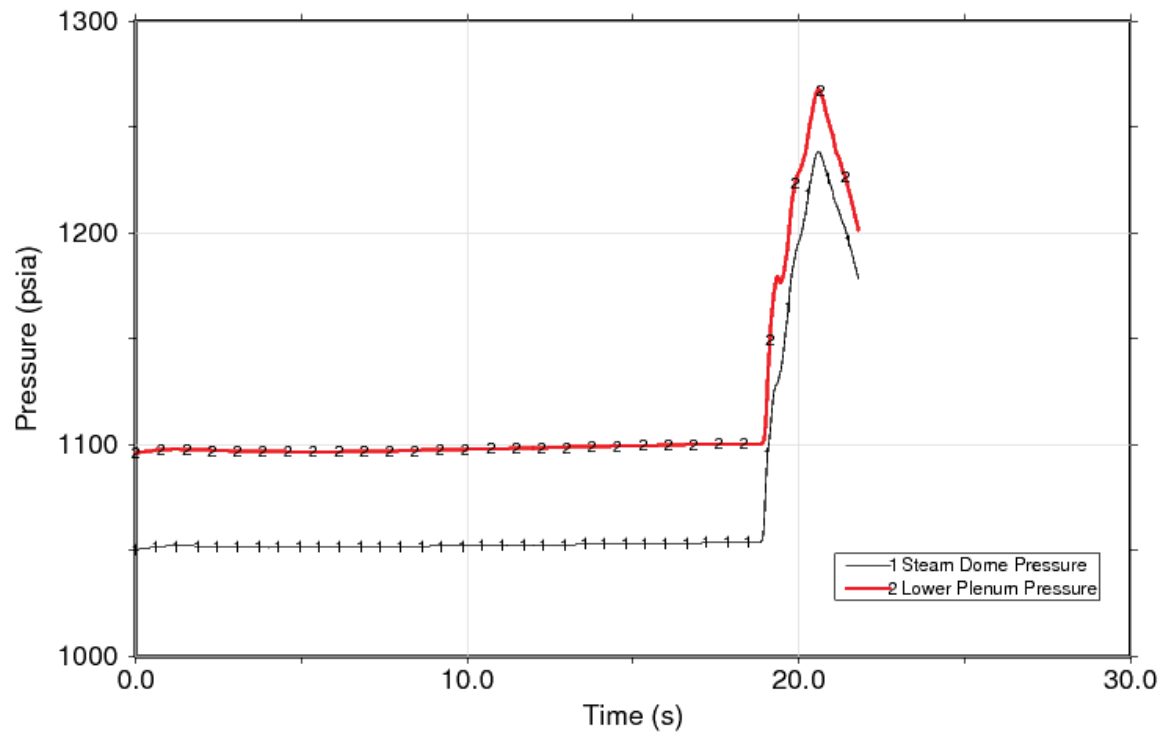


**Figure 4.9 EOFP FWCF at 100P/105F – NSS
Vessel Pressures**

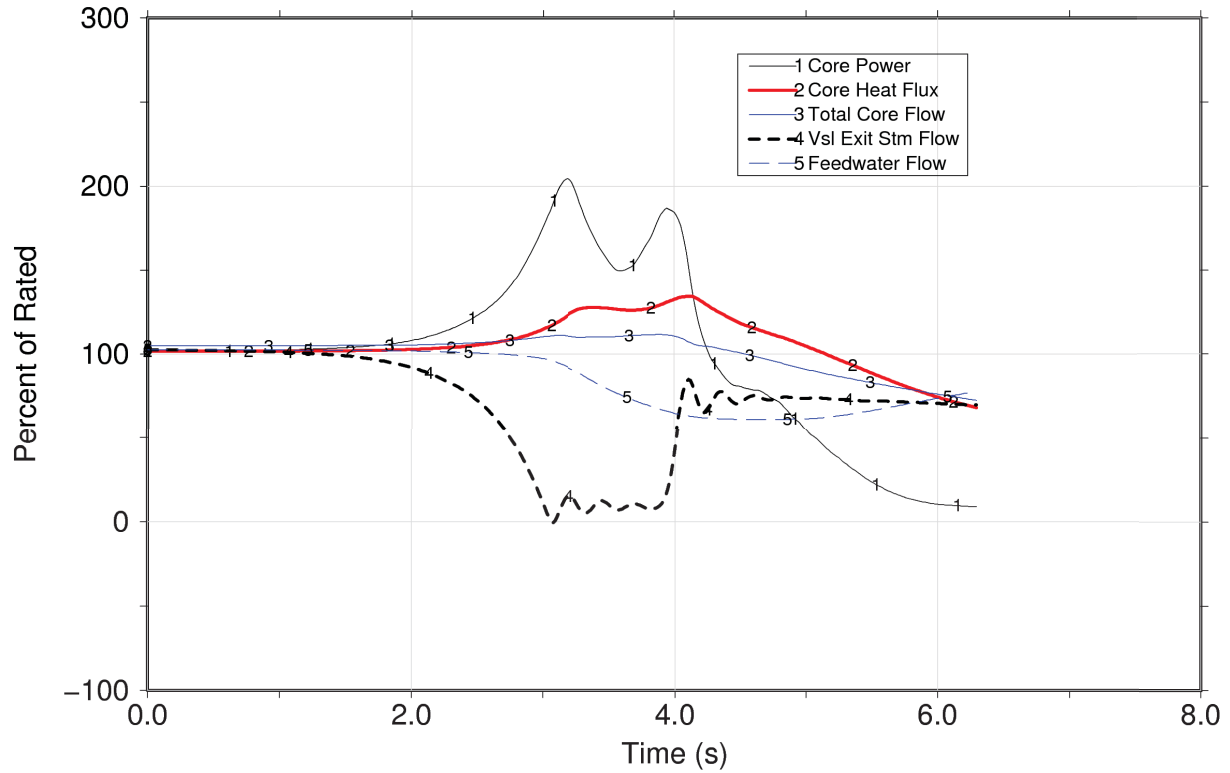


Figure 4.10 MSIV Overpressurization Event at 102P/105F – Key Parameters

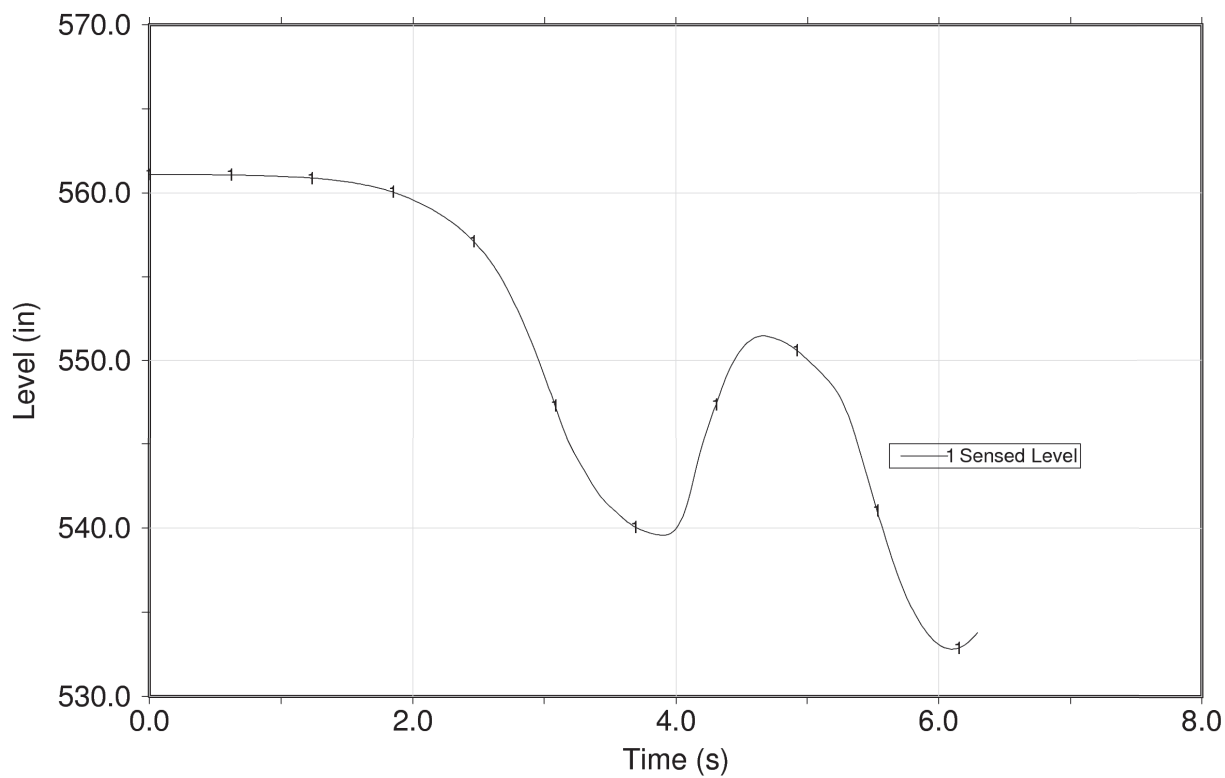


**Figure 4.11 MSIV Overpressurization Event at
102P/105F – Sensed Water Level**

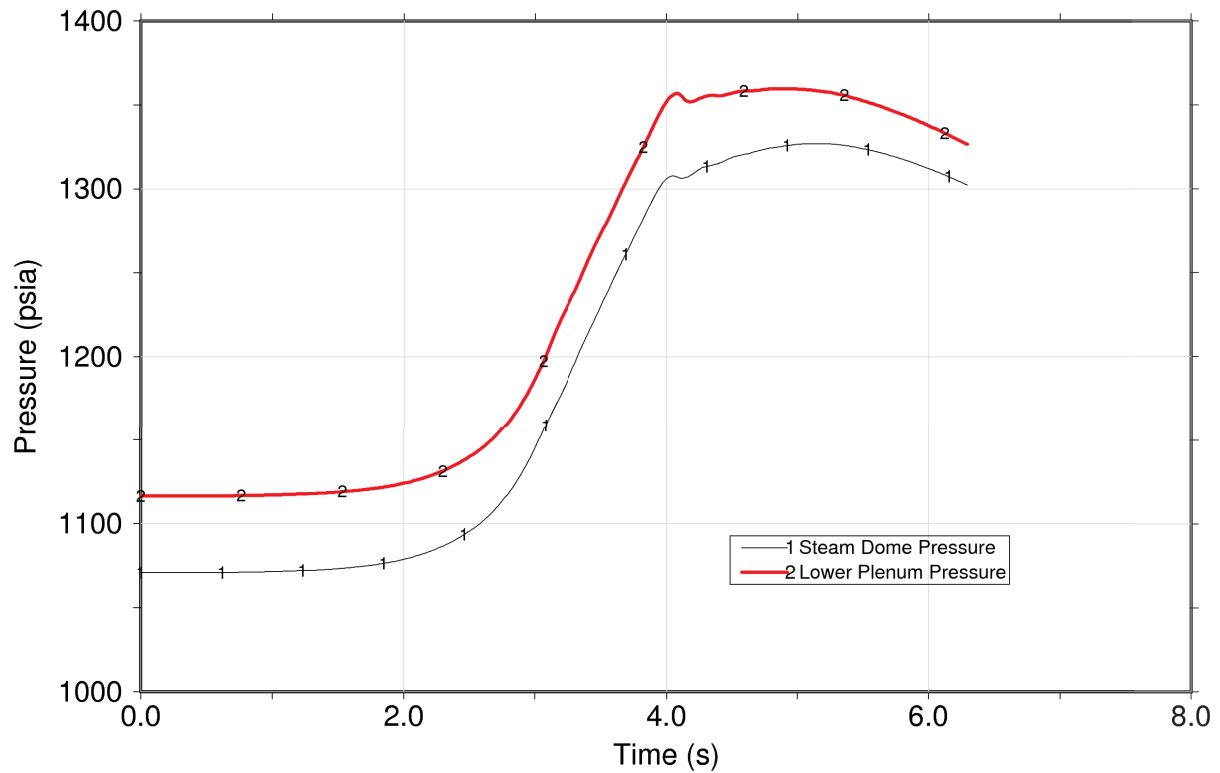


**Figure 4.12 MSIV Overpressurization Event at
102P/105F – Vessel Pressures**

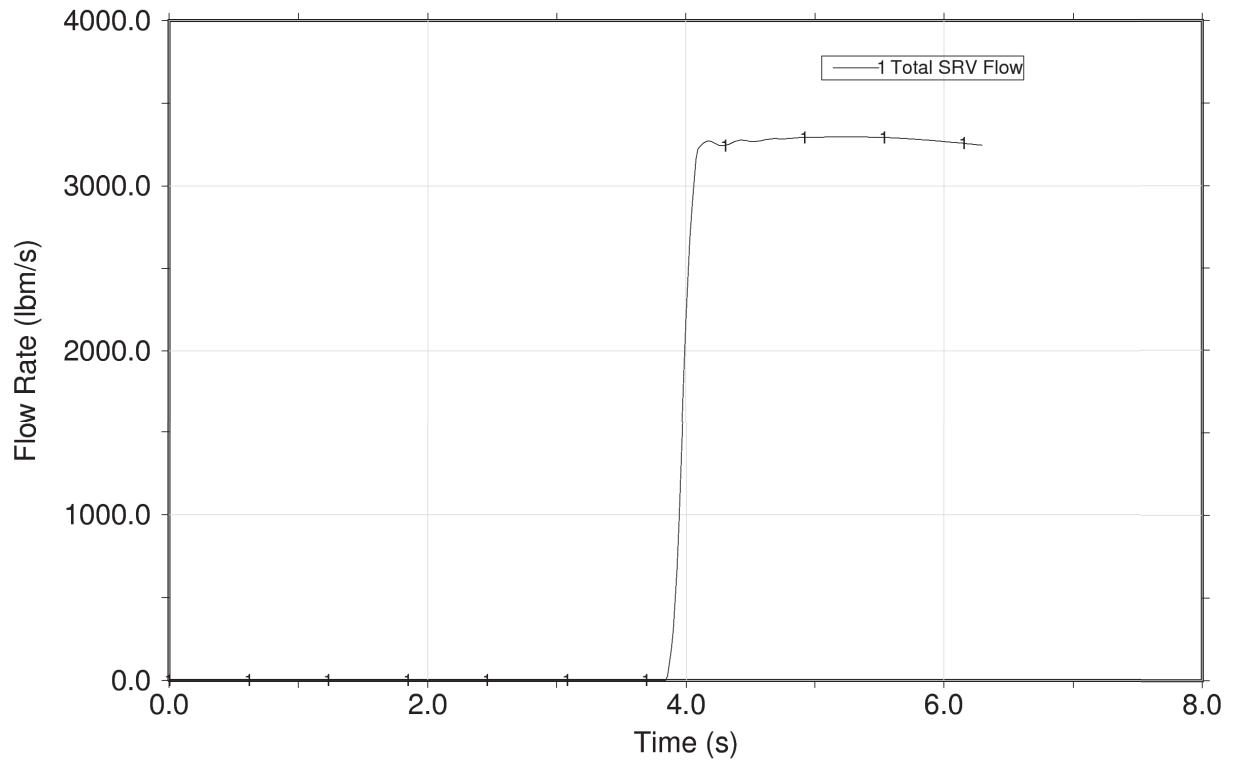


**Figure 4.13 MSIV Overpressurization Event at
102P/105F – Safety/Relief Valve Flow Rates**

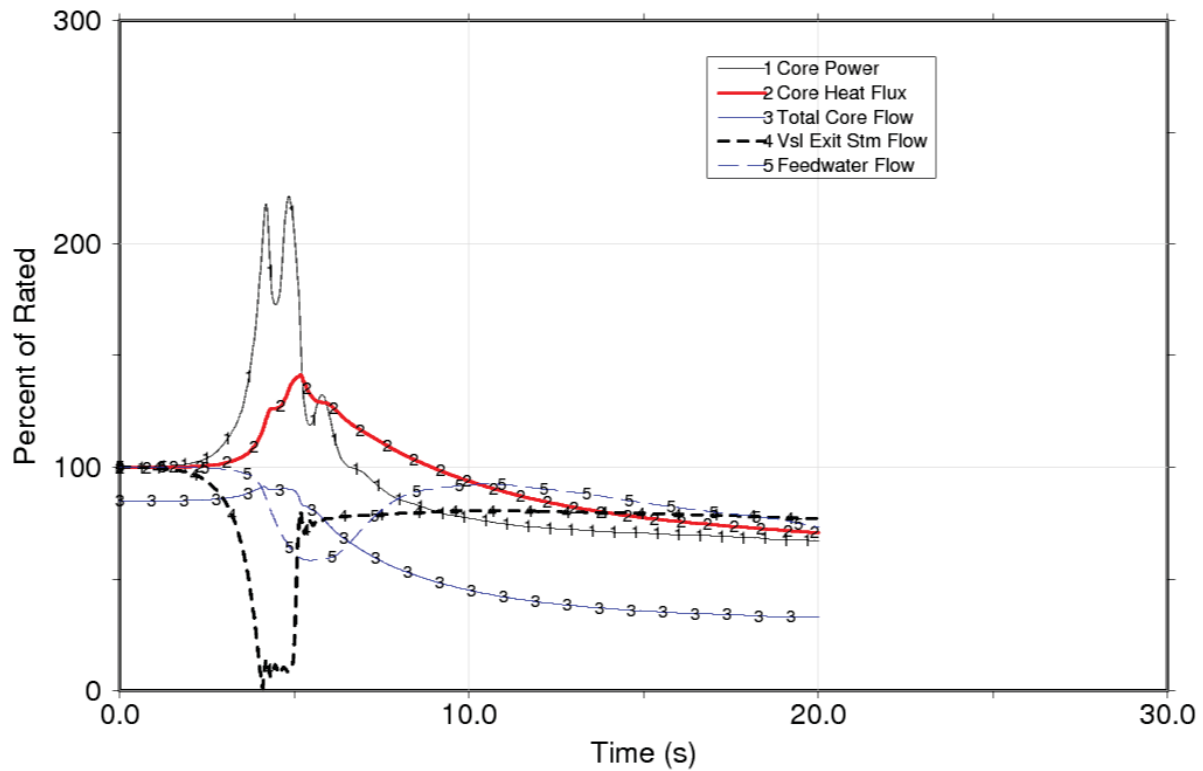


Figure 4.14 MSIV ATWS Overpressurization Event at 100P/85F – Key Parameters

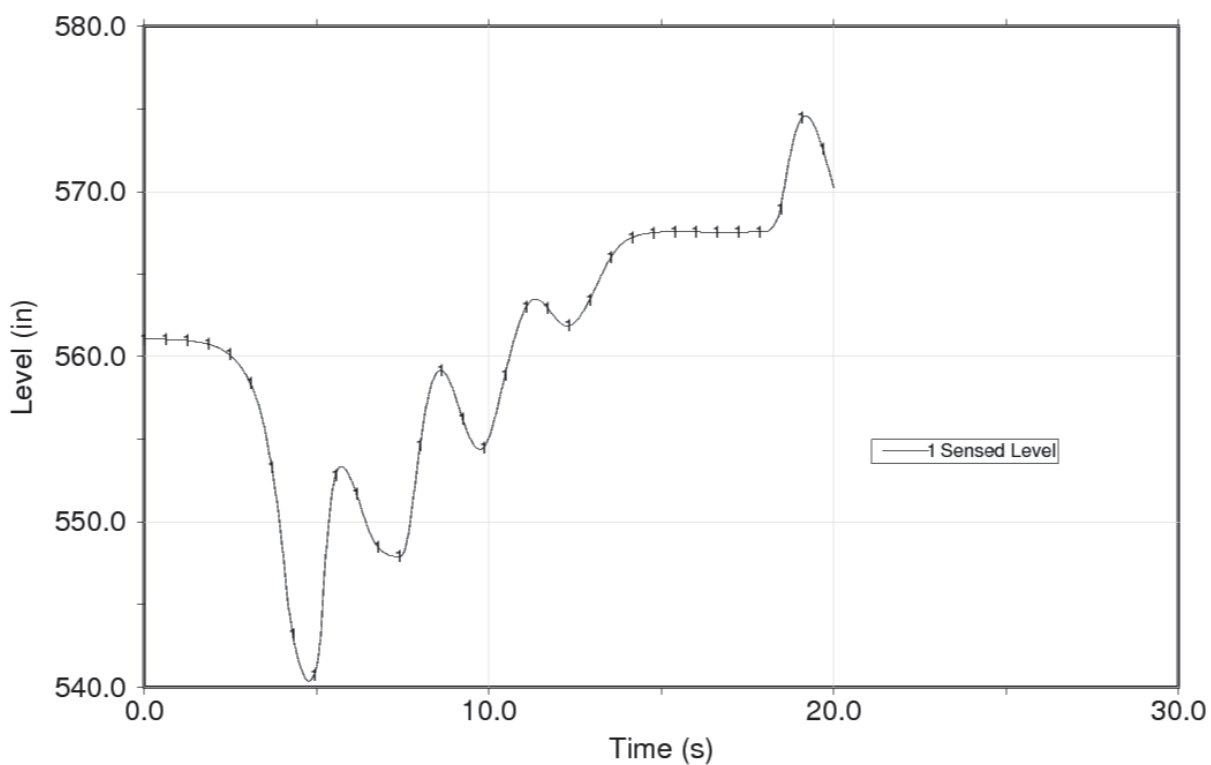


**Figure 4.15 MSIV ATWS Overpressurization Event at
100P/85F – Sensed Water Level**

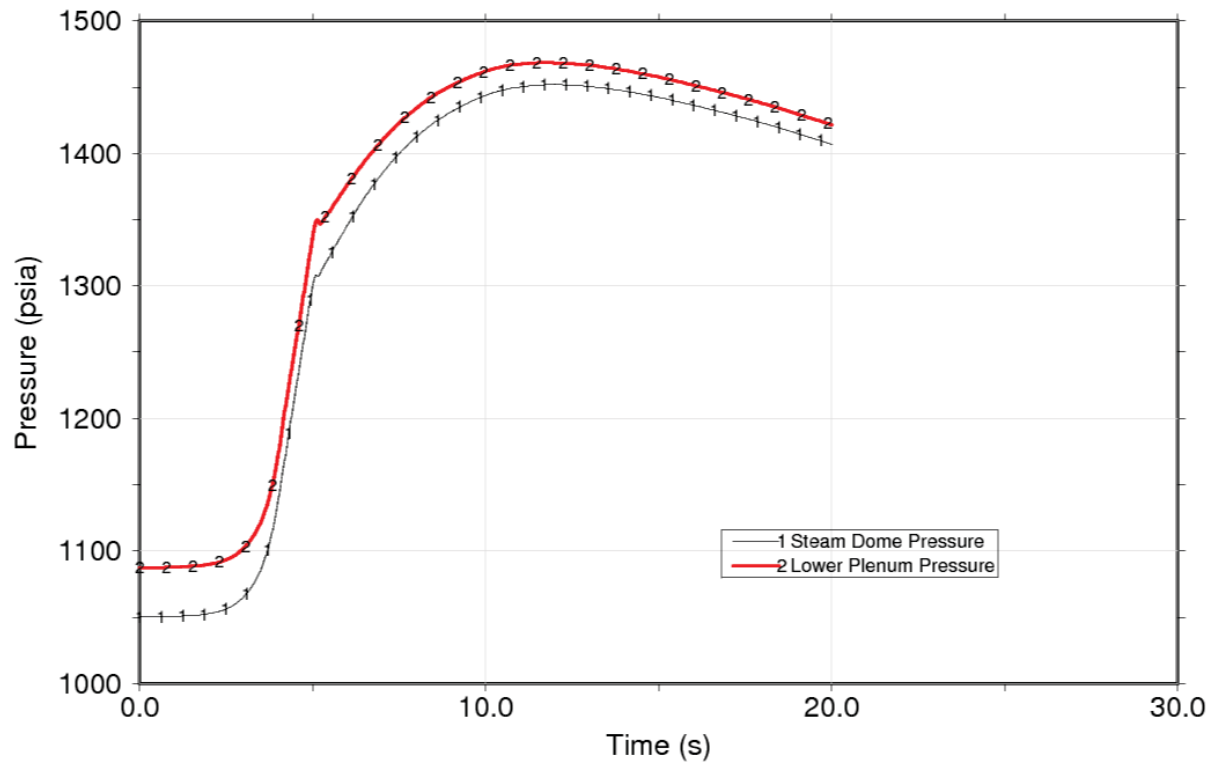


Figure 4.16 MSIV ATWS Overpressurization Event at 100P/85F – Vessel Pressures

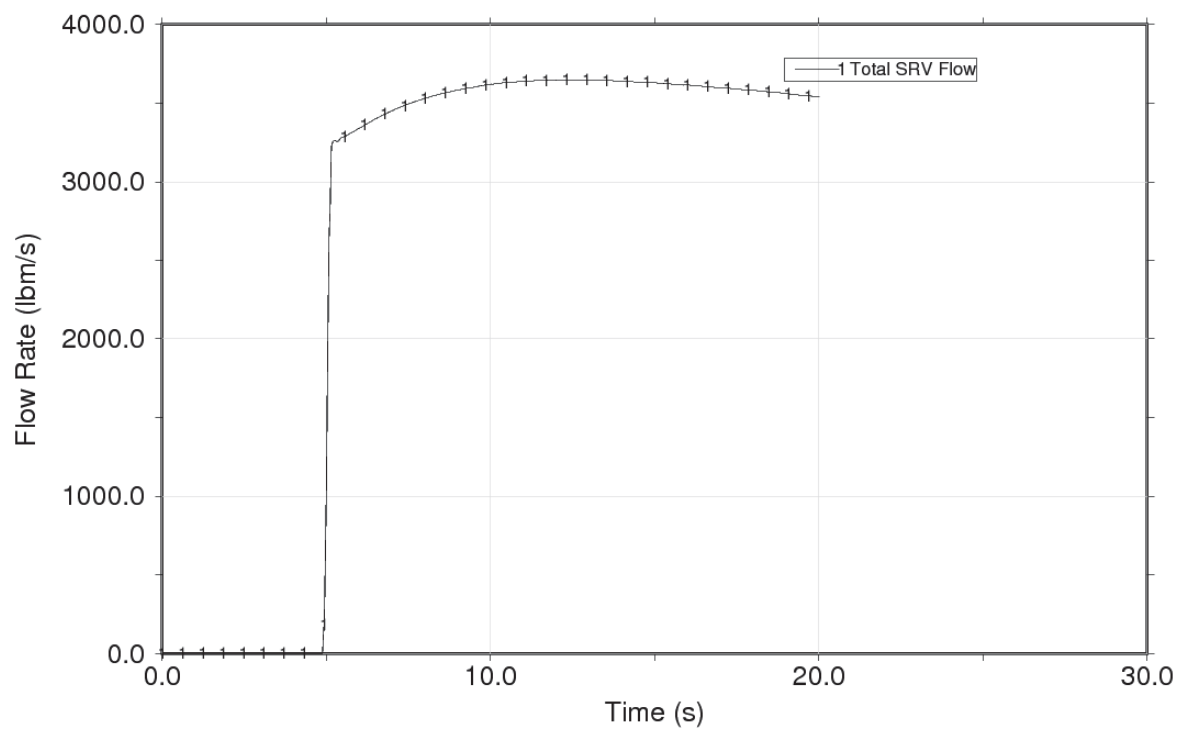


**Figure 4.17 MSIV ATWS Overpressurization Event at
100P/85F – Safety/Relief Valve Flow Rates**

5.0 PREVIOUSLY REQUESTED ADDITIONAL INFORMATION FROM THE NRC

The following subsections provide information responsive to applicable requests for additional information by the NRC which supports the introduction of ATRIUM 11 fuel to Browns Ferry.

5.1 *Decay Heat and Station Blackout***5.1.1 Decay Heat**

In general, the decay heat results are [

]

Fuel Design	²³⁵ U Fission Fraction	²³⁸ U Fission Fraction	²³⁹ Pu Fission Fraction
GE14	0.4821 - 0.5363	0.0699 - 0.0997	0.3938 – 0.4182
ATRIUM-10	0.4902 - 0.5367	0.0710 – 0.0961	0.3923 - 0.4137
ATRIUM 10XM	0.4635 - 0.5547	0.0703 - 0.1020	0.3750 - 0.4346
ATRIUM 11	0.4439 – 0.5362	0.0703 – 0.1058	0.3936 – 0.4502

[

]

5.1.2 **Station Blackout**

The licensing basis analysis remains applicable to Framatome fuel since station blackout is solely driven by decay heat. All other criteria are not fuel dependent. As discussed in Section 5.1.1, the decay heat is insignificantly impacted by the introduction of the ATRIUM 11 fuel design. Framatome fuel is designed to perform in a manner similar to and analogous with fuel of current and previous designs.

5.2 ***Event Changes Potentially Impacting Mass and Energy Release***

[

] No other plant design changes are planned during this transition to ATRIUM 11 fuel. Therefore the analysis of record is not impacted by the introduction of ATRIUM 11 fuel. In the future, plant modifications will be dispositioned for their impact on the licensing basis events and analyses will be updated as necessary.

5.3 ***Implementation of Transition Cycle Transient Limitation and Conditions***

Appendix A provides a listing of, and initial compliance with, the limitations and conditions (L&Cs) related to the AURORA-B AOO topical report, Reference 1. As noted in the Appendix, a few L&Cs require plant specific review which will be provided as part of the initial application (first transition licensing reports). The initial application cycle reload report is scheduled to be provided for information at a later date and will contain compliance with the 4 remaining, plant specific L&Cs 7, 11, 16, and 18a. The application of the L&Cs to the Browns Ferry licensing evaluations are discussed below:

Limitation and Condition 7

As discussed in Section 3.6 of this SE, licensees should provide justification for the key plant parameters and initial conditions selected for performing sensitivity analyses on an event-specific basis. Licensees should further justify that the input values ultimately chosen for these key plant parameters and initial

conditions will result in a conservative prediction of FoMs when performing calculations according to the AURORA-B EM described in ANP-10300P.

As part of the initial preparations for licensing Browns Ferry, Framatome will review the plant parameters document for the key parameters associated with the potentially limiting events. Framatome would also look for parameters that have a range of values that may be allowed for operational flexibility. Likewise, for initial conditions, Framatome will examine the range allowed during normal operation. This will include initial conditions such as power, flow, pressure, and inlet subcooling. Sensitivity studies will be performed for all of these key parameters/conditions for all FoM (MCPR, LHGR, and overpressure) and [

]

Limitation and Condition 11

AREVA will provide justification for the uncertainties used for the highly ranked plant specific PIRT parameters C12, R01, R02, and SL02 on a plant-specific basis, as described in Table 3.2 of this SE.

The parameter C12 is the [

]

[

]

Limitation and Condition 16

[] is not sampled as part of the methodology, justification should be provided on a plant-specific basis that a conservative flow rate has been assumed []

The [] is provided by Browns Ferry in the plant parameters document. This flow accounts for []. The AURORA-B model [

]

Limitation and Condition 18a

Plant-specific licensing applications shall describe and provide justification for the method for determining and applying conservative measures in future deterministic analyses for each FoM (e.g. , biasing calculational inputs, postprocessing adjustments to calculated nominal results).

For licensing calculations at Browns Ferry, [

]

For the LHGRFACp evaluations [

]

6.0 REFERENCES

1. ANP-10300P-A Revision 1, *AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios*, Framatome Inc., January 2018.
2. ANP-10335P-A Revision 0, *ACE/ATRIUM 11 Critical Power Correlation*, Framatome Inc., May 2018.
3. ANP-3854P Revision 1, *Browns Ferry ATRIUM 11 Equilibrium Cycle Fuel Cycle Design Report*, Framatome Inc., June 2020.
4. ANP-3908P Revision 3, *Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel*, Framatome Inc., July 2021.
5. ANP-3905P Revision 1, *Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel*, Framatome Inc., July 2021.

Appendix A LIMITATIONS FROM THE SAFETY EVALUATION FOR LTR ANP-10300P-A REVISION 1

Compliance to the limitations and conditions from Section 5 of the safety evaluation in ANP-10300P-A Revision 1, "AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios" (Reference 1) is discussed in the following table.

Appendix A (Continued)

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
1	AURORA-B may not be used to perform analyses that result in one or more of its CCDs (S-RELAP5, MB2-K, MICROBURN-B2, RODEX4) operating outside the limits of approval specified in their respective TRs, SEs, and plant-specific LARs. In the case of MB2-K, MB2-K is subject to the same limitations and conditions as MICROBURN-B2.	All methods are used within their limits of approval.
2	The regulatory limit contained in 10 CFR 50.46(b)(2) , requiring cladding oxidation not to exceed 17 percent of the initial cladding thickness prior to oxidation, is based on the use of the Baker-Just oxidation correlation. Because AURORA-B makes use of the Cathcart-Pawel oxidation correlation, this limit shall be reduced to 13 percent, inclusive of pre-transient oxide layer thickness (See Section 3.4.3.1). Should the NRC staff position regarding the appropriate acceptance criterion for the Cathcart-Pawel correlation change, the NRC will notify AREVA with a letter either revising this limitation or stating that it is removed.	[]

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
3	Parameter uncertainty distributions and their characterizing upper and lower 2σ levels are presented in Table 3.6 and discussed in Section 3.6 of this SE. The distribution types will not be changed and the characterizing upper and lower 2σ uncertainties will not be reduced without prior NRC approval. In the cases of the parameters [], the respective methodologies discussed in Section 3.6.4.10 and Section 3.6.4.17 shall be used when determining the associated upper and lower 2σ levels. The [] is subject to Limitation and Condition No. 4, below.	[]
4	As discussed in Section 3.3.1.2, before new fuel designs (i.e., designs other than ATRIUM-10 and ATRIUM-10XM) are modeled in licensing analyses using AURORA-B, AREVA must justify that the AURORA-B EM can acceptably predict void fraction results for the new fuel designs within the [] prediction uncertainty bands. Otherwise, the prediction uncertainty bands should be appropriately expanded, and the [] should be appropriately updated utilizing the methodology discussed in Section O of this SE.	Justification of void fraction application to ATRIUM 11 fuel is provided in Section 5.1 of Reference 4.
5	As discussed in Section 3.3.2.4.4, before new fuel designs (i.e., designs other than ATRIUM-10 and ATRIUM-10XM) are included in licensing analyses performed using the AURORA-B EF, AREVA must justify that the [] void-quality correlation within MICROBURN-B2 is valid for the new fuel designs at EPU and EFW conditions.	Justification of void fraction application to ATRIUM 11 fuel is provided in Section 5.1 of Reference 4.

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
6	The 2σ ranges [] until AREVA supplies additional justification (e.g., as part of a first-time application analysis) demonstrating an acceptable alternative for NRC review and approval. For [] will be utilized when performing licensing analyses to determine peak cladding temperature and maximum local oxidation. Should the NRC staff position regarding these uncertainties change as a result of additional justification, the NRC will notify AREVA with a letter either revising this limitation or stating that it is removed.	[]
7	As discussed in Section 3.6 of this SE, licensees should provide justification for the key plant parameters and initial conditions selected for performing sensitivity analyses on an event-specific basis. Licensees should further justify that the input values ultimately chosen for these key plant parameters and initial conditions will result in a conservative prediction of FoMs when performing calculations according to the AURORA-B EM described in ANP-10300P.	See Section 5.3 for further discussion of this L&C. The justification for the key plant parameters and initial conditions will be thoroughly explored for the first application cycle for Browns Ferry.
8	The sampling ranges for uncertainty distributions used in the non-parametric order statistics analyses will be truncated at no less than $\pm 6\sigma$ []	[]

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
9	For any highly ranked PIRT phenomena whose uncertainties are not addressed in a given non-parametric order statistics analysis via sampling , AREVA will address the associated uncertainties by modeling the phenomena as described in Table 3.2 of this SE. For any pertinent medium ranked PIRT phenomena whose uncertainties are not addressed in a given non-parametric order statistics analysis via sampling, AREVA will address the associated uncertainties by modeling the phenomena as described in Table 3.4 of this SE.	Framatome analyses comply with the requirements of Tables 3.2 and 3.4 of the SE.
10	The assumptions of [] will be used in the AURORA-B EM to ensure the uncertainty in SL03: [] is conservatively accounted for.	[]
11	AREVA will provide justification for the uncertainties used for the highly ranked plant-specific PIRT parameters C12, R01, R02, and SL02 on a plant-specific basis, as described in Table 3.2 of this SE.	See Section 5.3 for further discussion of this L&C. []
12	When applying the AURORA-B EM to the [] , any changes to AURORA-B to enhance [] on a plant-specific basis without prior NRG review and approval are not approved as part of this SE, as described in Table 3.2 of this SE.	[]

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
13	The AURORA-B uncertainty methodology discussed in Section 3.6 of this SE may be used in licensing applications for the events listed in Section 3.1 of this SE, with the exception of three specific events identified in Section 3.6.2 of this SE : []. These events are generally expected to be benign and hence nonlimiting. While the NRC staff's review concluded that the AURORA-B EM contains code models and correlations sufficient for simulating these events, the uncertainty methodology developed in the TR did not address certain important phenomena or conditions associated therewith. Therefore, while licensing applications may rely on nominal calculations with the AURORA-B EM for these events in the course of demonstrating that all regulatory limits are satisfied with significant margin, the existing uncertainty methodology may not be applied directly to these specific events.	[]
14	The scope of the NRC staff's approval for AURORA-B does not include the ABWR design.	Not applicable to TVA. Browns Ferry is not an ABWR design.
15	For application to BWR/2s at EPU or EFW conditions, plant-specific justification should be provided for the applicability of AURORA-B, as discussed in Section 3.1 of this SE.	Not applicable to TVA. Browns Ferry is not a BWR/2
16	[] is not sampled as part of the methodology. justification should be provided on a plant-specific basis that a conservative flow rate has been assumed [].	See Section 5.3 for further discussion of this L&C. [] will be conservatively modeled for the first application cycle for Brown Ferry.

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
17	If the AURORA-B EM calculates that the film boiling regime is entered during a transient or accident, AREVA must justify that the uncertainty associated with heat transfer predictions in the film boiling regime is adequately addressed.	[]
18	As discussed in Section 3.6.5 of this SE regarding conservative measures : a. Plant-specific licensing applications shall describe and provide justification for the method for determining and applying conservative measures in future deterministic analyses for each FoM (e.g., biasing calculational inputs, post-processing adjustments to calculated nominal results), and b. If the 95/95 FoM for a given parameter calculated according to the defined conservative measures during a deterministic analysis shows a difference in magnitude exceeding 1σ from the corresponding value calculated in the most recent baseline full statistical analysis, AREVA must re-perform the full statistical analysis for the affected scenario and determine new conservative measures.	See Section 5.3 for further discussion of this L&C. Compliance with this item will be demonstrated for the first application cycle for Browns Ferry.
19	As discussed in Section 3.6.5 of this SE, the following stipulations are necessary to ensure that the FoMs calculated by AREVA in accordance with ANP-10300P would satisfy the 95/95 criterion: a. AREVA will use multivariate order statistics when multiple FoMs are drawn from a single set of statistical calculations, b. AREVA will choose the sample size prior to initiating statistical calculations,	[] Framatome calculations will utilize the multivariate order statistics when a single transient is used to determine multiple figures of merits.
		Framatome will choose the sample size prior to initiating statistical calculations.

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
	c. AREVA will not arbitrarily discard undesirable statistical results, and	Framatome will not arbitrarily discard undesirable statistical results.
	d. AREVA will maintain an auditable record to demonstrate that its process for performing statistical licensing calculations has been executed in an unbiased manner.	Framatome will maintain an auditable record to demonstrate the process for performing statistical licensing calculations is being executed in an unbiased manner.
20	The implementation of any new methodology within the AURORA-B EM (i.e., replacement of an existing CCD) is not acceptable unless the AURORA-B EM with the new methodology incorporated into it has received NRC review and approval. An existing NRC-approved methodology cannot be implemented within the AURORA-B EM without NRC review of the updated EM.	The evaluation model is implemented as described in Reference 1. No CCD as described in Reference 1 is replaced.
21	NRC-approved changes that revise or extend the capabilities of the individual CCDs comprising the AURORA-B EM may not be incorporated into the EM without prior NRC approval.	Framatome regulatory procedures require use of NRC approved methodologies within the applicability defined for that methodology.
22	As discussed in Section 3.3.1.5 and Section 4.0 of this SE, the SPCB and ACE CPR correlations for the ATRIUM-10 and ATRIUM-10XM fuels, respectively, are approved for use with the AURORA-B EF. Other CPR correlations (existing and new) that would be used with the AURORA-B EM must be reviewed and approved by the NRC or must be developed with an NRC-approved approach such as that described in EMF-2245(P)(A), Revision 0, "Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel" (Reference 50). Furthermore, if transient thermal-hydraulic simulations are performed in the process of applying AREVA CPR correlations to co-resident fuel, these calculations should use the AURORA-B methodology.	Framatome regulatory procedures require use of NRC approved methodologies. The applicability of the ACE/TRIUM 11 correlation for use in the AURORA-B AOO methodology is described in Reference 2.

Limitation and Condition Number	Limitation and Condition Description	Disposition/Discussion
23	Except when prohibited elsewhere, the AURORA-B EM may be used with new or revised fuel designs without prior NRC approval provided that the new or revised fuel designs are substantially similar to those fuel designs already approved for use in the AURORA-B EM (i.e., thermal energy is conducted through a cylindrical ceramic fuel pellet surrounded by metal cladding, flow in the fuel channels develops into a predominantly vertical annular flow regime, etc.). New fuel designs exhibiting a large deviation from these behaviors will require NRC review and approval prior to their implementation in AURORA-B.	Framatome has no fuel designs that exhibit a large deviation from the behaviors described in this limitation and condition. If a fuel design is developed that is significantly different, this fuel design will be submitted to the NRC for approval.
24	Changes may be made to the AURORA-B EM in the [] areas discussed in Section 4.0 of this SE without prior NRC approval.	[]
25	The parallelization of individual CCDs may be performed without prior NRC approval as discussed in Section 4.0 of this SE.	[]
26	AREVA must continue to use existing regulatory processes for any code modifications made in the [] areas discussed in Section 4.0 of this SE.	[]

ATTACHMENT 17

**Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3**

Technical Specifications (TS) Change 535

**Request for License Amendment Regarding Application of Advanced Framatome
Methodologies, and Adoption of TSTF-564 Revision 2 for Browns Ferry 1, 2, & 3, in
Support of ATRIUM 11 Fuel Use at Browns Ferry**

Affidavits

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the report ANP-3857P, Revision 2 "Design Limits for Framatome Critical Power Correlations," dated July 2020 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome 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 Framatome 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 Framatome to determine whether information should be classified as proprietary:

- (a) The information reveals details of Framatome'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 Framatome.
- (d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for Framatome in product optimization or marketability.
- (e) The information is vital to a competitive advantage held by Framatome, would be helpful to competitors to Framatome, and would likely cause substantial harm to the competitive position of Framatome.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b), 6(d) and 6(e) above.

7. In accordance with Framatome's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside Framatome only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. Framatome 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.

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

Executed on: July 23, 2020


Alan Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the report ANP-3854P, Revision 1 "Browns Ferry ATRIUM 11 Equilibrium Cycle, Fuel Cycle Design Report," dated June 2020 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome 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 Framatome 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.

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8. Framatome 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.

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

Executed on: June 24, 2020


Alan Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the report ANP-3850P, Revision 0, "Browns Ferry ATRIUM 11 Equilibrium Cycle Nuclear Fuel Design Report," dated May 2020 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome 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 Framatome 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.

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- (e) The information is vital to a competitive advantage held by Framatome, would be helpful to competitors to Framatome, and would likely cause substantial harm to the competitive position of Framatome.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(e) above.

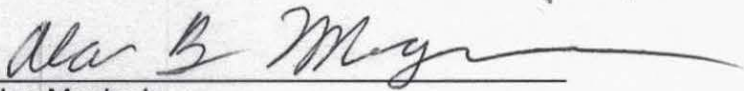
7. In accordance with Framatome's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside Framatome only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. Framatome 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.

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

Executed on: May 26, 2020


Alan Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.
2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.
3. I am familiar with the Framatome information contained in the report ANP-3860P, Revision 0, "Mechanical Design Report for Browns Ferry ATRIUM 11 Fuel Assemblies," dated April 2021 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome 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 Framatome 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.
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- (d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for Framatome in product optimization or marketability.
- (e) The information is vital to a competitive advantage held by Framatome, would be helpful to competitors to Framatome, and would likely cause substantial harm to the competitive position of Framatome.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b), 6(d) and 6(e) above.

7. In accordance with Framatome's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside Framatome only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. Framatome 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.

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

Executed on: April 9, 2021


Alan Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.
2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.
3. I am familiar with the Framatome information contained in the report ANP-3866P, Revision 0, "ATRIUM 11 Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry LAR," dated October 2020 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome 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 Framatome 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 Framatome to determine whether information should be classified as proprietary:

- (a) The information reveals details of Framatome's research and development plans and programs or their results.
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- (e) The information is vital to a competitive advantage held by Framatome, would be helpful to competitors to Framatome, and would likely cause substantial harm to the competitive position of Framatome.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b), 6(d) and 6(e) above.

7. In accordance with Framatome's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside Framatome only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. Framatome 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.

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

Executed on: October 1, 2020


Alan Meginnis

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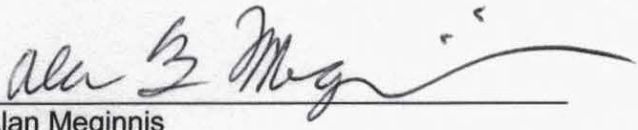
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I declare under penalty of perjury that the foregoing is true and correct.

Executed on: September 22, 2020


Alan Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the report ANP-3908P, Revision 3, "Applicability of Framatome BWR Methods to Browns Ferry with ATRIUM 11 Fuel," dated July 2021 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome for the control and protection of proprietary and confidential information.

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9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

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

Executed on: July 19, 2021


Alan B. Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the report ANP-3905P, Revision 1, "Browns Ferry Units 1, 2, and 3 LOCA Analysis for ATRIUM 11 Fuel," dated July 2021 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome for the control and protection of proprietary and confidential information.

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9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

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

Executed on: July 6, 2021


Alan B. Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the report ANP-3907P, Revision 0, "Application of BEO-III Methodology with the Confirmation Density Algorithm at Browns Ferry," dated April 2021 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome for the control and protection of proprietary and confidential information.

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9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

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

Executed on: April 21, 2021


Alan Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the report ANP-3906P, Revision 0, "Browns Ferry ATWS-I Evaluation for ATRIUM 11 Fuel," dated April 2021 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome for the control and protection of proprietary and confidential information.

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9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

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

Executed on: April 14, 2021


Alan Meginnis

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.
2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.
3. I am familiar with the Framatome information contained in the report ANP-3874P, Revision 2 "Browns Ferry ATRIUM 11 Control Rod Drop Accident Analysis with the AURORA-B CRDA Methodology," dated March 2021 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome for the control and protection of proprietary and confidential information.
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I declare under penalty of perjury that the foregoing is true and correct.

Executed on: March 17, 2021


Alan Meginnis

A F F I D A V I T

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3. I am familiar with the Framatome information contained in the report ANP-3904P, Revision 4, "Browns Ferry ATRIUM 11 Transient Demonstration," dated July 2021 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome for the control and protection of proprietary and confidential information.

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