FENOC
FirstEnergy Nuclear Operating Company

Withhold from Public Disclosure under 10CFR2.390

When separated from Attachment 1, the remainder of this submittal may be decontrolled.

Beaver Valley Power Station
P.O. Box 4
Shippingport, PA 15077

Paul A. Harden
Site Vice President

724-682-5234
Fax: 724-643-8069

June 1, 2010
L-10-130

10 CFR 2.390 and 50.90

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

SUBJECT:
Beaver Valley Power Station, Unit No. 2
Docket No. 50-412, License No. NPF-73
Remainder of Responses to NRC Staff Request for Additional Information Regarding Unit 2 Spent Fuel Pool Rerack Criticality Analyses (TAC No. ME1079)

A license amendment request to revise the Beaver Valley Power Station Unit 2 Technical Specifications to support installation of high density fuel storage racks in the Unit 2 spent fuel pool was submitted on April 9, 2009 (Accession No. ML091210251), and supplemented on June 15, 2009 (Accession No. ML091680614). With respect to the supporting criticality analysis for the amendment, the Nuclear Regulatory Commission (NRC) staff provided a request for additional information (RAI) by a letter dated February 16, 2010. Responses to a majority of the criticality analysis RAI items were provided in a letter dated March 18, 2010 (Accession No. ML100820165).

Responses to the remaining RAI items are provided in Attachment 1. A portion of the information in the responses is considered proprietary, therefore a nonproprietary version of the responses is provided in Attachment 2. Pursuant to 10 CFR 2.390, an affidavit from Holtec International, the owner of the information that is sought to be withheld from several of the responses, is provided as an enclosure to this letter.

Future correspondence will provide appropriate supplements to the license amendment request, as noted in the attachments.

There are no new regulatory commitments contained in this submittal. If there are any questions or if additional information is required, please contact Mr. Thomas A. Lentz, Manager - Fleet Licensing, at (330) 761-6071.

I declare under penalty of perjury that the foregoing is true and correct. Executed on June 1, 2010.

Sincerely,

Paul A. Harden

A001
NRR

Attachments:

1. Response to RAI on Unit 2 Spent Fuel Pool Rerack Criticality Analysis [PROPRIETARY VERSION OF THE RESPONSE]
2. Response to RAI on Unit 2 Spent Fuel Pool Rerack Criticality Analysis [NONPROPRIETARY VERSION OF THE RESPONSE]

Enclosure: 10 CFR 2.390 Proprietary Affidavit from Holtec International

cc: NRC Region I Administrator
NRC Resident Inspector Office
NRC Project Manager
Director BRP/DEP
Site Representative (BRP/DEP)

Enclosure
L-10-130

10 CFR 2.390 Proprietary Affidavit from Holtec International

Enclosure consists of five pages, exclusive of this cover page

HOLTEC INTERNATIONAL

Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053
Telephone (856) 797-0900
Fax (856) 797-0909

Holtec International Document ID 1702-6aff

AFFIDAVIT PURSUANT TO 10 CFR 2.390

I, Tammy S. Morin, being duly sworn, depose and state as follows:

(1) I have reviewed the information described in paragraph (2) which is sought to be withheld, and am authorized to apply for its withholding.

(2) The information sought to be withheld is information provided in Attachment 1 to FirstEnergy Nuclear Operating Company (FENOC) Letter L-10-130, "Response to RAI on Unit 2 Spent Fuel Pool Re-rack Criticality Analysis". The Holtec proprietary information is in the responses to Request for Additional Information (RAI) items 18, 20, 22, 28, and 33 as marked.

(3) In making this application for withholding of proprietary information of which it is the owner, Holtec International relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4) and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10CFR Part 9.17(a)(4), 2.390(a)(4), and 2.390(b)(1) for "trade secrets and commercial or financial information obtained from a person and privileged or confidential" (Exemption 4). The material for which exemption from disclosure is here sought is all "confidential commercial information", and some portions also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

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

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

c. Information which reveals cost or price information, production, capacities, budget levels, or commercial strategies of Holtec International, its customers, or its suppliers;

d. Information which reveals aspects of past, present, or future Holtec International customer-funded development plans and programs of potential commercial value to Holtec International;

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

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraph 4.b, above.

(5) The information sought to be withheld is being submitted to the NRC in confidence. The information (including that compiled from many sources) is of a sort customarily held in confidence by Holtec International, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by Holtec International. No public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have

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been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within Holtec International is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his designee), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside Holtec International are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information classified as proprietary was developed and compiled by Holtec International at a significant cost to Holtec International. This information is classified as proprietary because it contains detailed descriptions of analytical approaches and methodologies not available elsewhere. This information would provide other parties, including competitors, with information from Holtec International's technical database and the results of evaluations performed by Holtec International. A substantial effort has been expended by Holtec International to develop this information. Release of this information would improve a competitor's position because it would enable Holtec's competitor to copy our technology and offer it for sale in competition with our company, causing us financial injury.

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(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to Holtec International's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of Holtec International's comprehensive spent fuel storage technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology, and includes development of the expertise to determine and apply the appropriate evaluation process.

The research, development, engineering, and analytical costs comprise a substantial investment of time and money by Holtec International.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

Holtec International's competitive advantage will be lost if its competitors are able to use the results of the Holtec International experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to Holtec International would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive Holtec International of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

AFFIDAVIT PURSUANT TO 10 CFR 2.390

STATE OF NEW JERSEY)
) ss:
COUNTY OF BURLINGTON)

Ms. Tammy S. Morin, being duly sworn, deposes and says:

That she has read the foregoing affidavit and the matters stated therein are true and correct to the best of her knowledge, information, and belief.

Executed at Marlton, New Jersey, this 26th day of April, 2010.

Tammy S. Morin
Holtec International

Subscribed and sworn before me this 26th day of April, 2010.

Maria C. Massi

MARIA C. MASSI
NOTARY PUBLIC OF NEW JERSEY
My Commission Expires April 25, 20[illegible]

NONPROPRIETARY VERSION OF THE RESPONSE

The Nuclear Regulatory Commission (NRC) staff provided a request for additional information (RAI) on the FirstEnergy Nuclear Operating Company (FENOC) license amendment request (LAR) for Unit 2 of the Beaver Valley Power Station (BVPS-2), regarding criticality analyses that support a spent fuel pool rerack. The NRC staff requests that were not previously responded to in the FENOC submittal dated March 18, 2010, are presented below in bold type, followed by the FENOC response. Triple brackets denote the start and end of proprietary information.

3. **In Section 3.4, on page 3-7, the first bulleted item states, "A decrease of no more than 5% in Boron-10 (B-10), as determined by neutron attenuation, is acceptable. (This is equivalent to a requirement for no loss in boron within the accuracy of the measurement.)" This statement implies that [it] is acceptable to ignore a loss of up to 5% of the B-10 in the Metamic. It is not clear from the text provided in Section 4 that this acceptable loss of B-10 has been considered in the analysis.**

   Amend the analysis to consider the "acceptable" loss of B-10 or provide justification for not doing so.

<u>Response</u>

The 5 percent loss discussed in the RAI question represents the measurement uncertainty associated with the measurement of neutron attenuation (that is, boron-10 blackness) for the Metamic surveillance coupons. To account for this in the criticality analysis, the analysis will be re-performed with an additional uncertainty factor calculated by using a Metamic density that is 5 percent less than the nominal. Thus, the criticality analysis will contain two independent uncertainties associated with the boron-10 areal density in the Metamic poisons: an uncertainty to address manufacturing tolerances in the boron-10 areal density (this was included in the original analysis), and a second uncertainty to address surveillance coupon blackness measurement uncertainty. A future supplement to the LAR will reflect the revised analysis.

14. **Table 4.5.3 provides the core operating parameters used for CASMO depletion calculations. Was the analysis performed to show that these parameters are conservative and bounding? Note that consideration should be given to the full range of parameters experienced by all fuel currently stored and for fuel that will be stored in the future. Consider too that parameters that lead to spectral hardening and increased plutonium production also reduce depletion of thermal neutron**

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absorbing fission products. It should not just be assumed that anything that hardens the spectrum is conservative.

Provide the ranges of operating parameters affecting the CASMO depletion calculations and provide better justification for bounding values selected.

Response

NUREG/CR-6665, "Review and Prioritization of Technical Issues Related to Burnup Credit for LWR Fuel," provides guidance on the selection of operating parameters for spent fuel depletion calculations. The depletion calculations performed with the lattice analysis code CASMO-4 use operating parameters that harden the neutron spectrum. A harder neutron spectrum increases the production of Pu-239 and Pu-241 due to the increase in neutron capture by U-238. The harder neutron spectrum decreases the U-235 utilization due to the increase in the fission of Pu-239. These effects tend to increase the reactivity of the fuel. The following operating parameters for depletion calculations harden the neutron spectrum, with the exception of specific power and operating history, according to the guidance in NUREG/CR 6665:

- Fuel temperature: A higher value increases Doppler broadening in U-238 and therefore increases production of plutonium. The fuel temperature effect is burnup dependent and increases with burnup.
- Moderator temperature: A higher value decreases moderator density slightly, reducing neutron thermalization and increasing neutron energy therefore hardening the neutron spectrum. The moderator temperature effect increases with burnup.
- Soluble boron: A higher cycle average soluble boron concentration absorbs more thermal neutrons therefore hardening the neutron spectrum. The soluble boron effect is burnup dependent and increases with burnup.
- Specific power and operating history: The effect of specific power and operating history does not have a clear trend and is dependent upon the spent fuel isotopic inventory used for burnup credit.

Based on the above conclusions from NUREG/CR 6665, the spent fuel storage rack criticality methodology calculates the spent fuel isotopic compositions with CASMO-4 using a single full power cycle, with a maximum fuel temperature (1516 degrees Fahrenheit (°F), equivalent to 150 percent of average hot full power fuel temperature), a maximum moderator temperature (638.33 °F, approximately 5 °F greater than the highest nodal end-of-cycle exposure-averaged moderator temperature seen to date at BVPS-2), maximum average soluble boron concentration (1050 parts per million (ppm), as discussed in the response to RAI 15 in the submittal dated March 18, 2010), and a typical specific power (40.4 Watts/gram (W/g), that is, thermal power divided by typical fuel mass). The maximum moderator temperature is a new value that will be used in

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the revised criticality analysis; a future supplement to the LAR will reflect the revised analysis. The application of these parameters is conservative since they are applied to all depleted fuel used in the criticality analysis, irrespective of the axial or radial location of the fuel. As committed to in the letter dated March 18, 2010, a process will be established prior to receipt of the next reload batch of BVPS-2 fuel to ensure that the design features and operating parameters of fuel used in the future at BVPS-2 are consistent with the assumptions of the criticality analysis.

Sensitivity calculations were performed to demonstrate that the selected operating parameters were appropriate. The results show that the operating parameters are conservative and bounding. With respect to the possibility that parameters that lead to spectral hardening and increased plutonium production may also reduce depletion of thermal neutron absorbing fission products, the results of the sensitivity calculations show that if this effect is present it does not have a significant impact on the results. The results of these calculations are presented in the table below.

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Operating Parameter Calculations Using CASMO-4

Parameter		Value												
	Moderator T °F	638.33	**620**	**600**	**550**	638.33	638.33	638.33	638.33	638.33	638.33	638.33	638.33	638.33
	Fuel Temperature °F	1516	1516	1516	1516	**1300**	**1000**	1516	1516	1516	1516	1516	1516	1516
	Soluble Boron ppm	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	**900**	**700**
	Power Density	40.4	40.4	40.4	40.4	40.4	40.4	**38**	**35**	**30**	**45**	**50**	40.4	40.4
wt% U-235	Input File	bv-op1-{enr}	bv-op2-{enr}	bv-op3-{enr}	bv-op4-{enr}	bv-op5-{enr}	bv-op6-{enr}	bv-op7-{enr}	bv-op8-{enr}	bv-op9-{enr}	bv-op10-{enr}	bv-op11-{enr}	bv-op13-{enr}	bv-op14-{enr}
	GWD/MTU	kinf	Delta	Delta	Delta	Delta	Delta	Delta	Delta	Delta	Delta	Delta	Delta	Delta kinf
2	10	0.8926	-0.0033	-0.0059	-0.0101	-0.0013	-0.0033	0.0002	0.0005	0.0009	-0.0004	-0.0008	-0.0013	-0.0032
2	20	0.8312	-0.0071	-0.0127	-0.0222	-0.0028	-0.0071	0.0002	0.0004	0.0007	-0.0003	-0.0007	-0.0026	-0.0062
2	30	0.7836	-0.0104	-0.0188	-0.0329	-0.0041	-0.0101	0.0001	0.0002	0.0003	-0.0002	-0.0005	-0.0036	-0.0086
2	40	0.7489	-0.0129	-0.0232	-0.0402	-0.0048	-0.0121	0.0001	0.0001	0.0000	-0.0001	-0.0003	-0.0042	-0.0100
2	50	0.7254	-0.0143	-0.0258	-0.0442	-0.0052	-0.0130	0.0000	0.0000	-0.0001	-0.0001	-0.0002	-0.0045	-0.0108
2	60	0.7103	-0.0152	-0.0271	-0.0461	-0.0053	-0.0133	0.0000	0.0000	-0.0001	0.0000	-0.0002	-0.0046	-0.0109
3	10	0.9940	-0.0017	-0.0031	-0.0052	-0.0007	-0.0018	0.0002	0.0004	0.0008	-0.0003	-0.0007	-0.0006	-0.0013
3	20	0.9242	-0.0045	-0.0082	-0.0143	-0.0018	-0.0046	0.0002	0.0004	0.0009	-0.0004	-0.0008	-0.0014	-0.0032
3	30	0.8641	-0.0077	-0.0141	-0.0250	-0.0031	-0.0076	0.0001	0.0003	0.0006	-0.0003	-0.0006	-0.0022	-0.0053
3	40	0.8135	-0.0110	-0.0200	-0.0356	-0.0041	-0.0104	0.0001	0.0001	0.0002	-0.0002	-0.0004	-0.0031	-0.0072
3	50	0.7731	-0.0136	-0.0248	-0.0439	-0.0050	-0.0124	0.0000	0.0000	-0.0001	-0.0001	-0.0002	-0.0037	-0.0088
3	60	0.7430	-0.0154	-0.0279	-0.0489	-0.0054	-0.0136	0.0000	-0.0001	-0.0003	0.0000	-0.0001	-0.0041	-0.0098
4	10	1.0654	-0.0008	-0.0014	-0.0024	-0.0004	-0.0010	0.0002	0.0004	0.0007	-0.0003	-0.0006	-0.0002	-0.0006
4	20	0.9967	-0.0027	-0.0049	-0.0085	-0.0012	-0.0029	0.0002	0.0005	0.0010	-0.0004	-0.0008	-0.0007	-0.0017
4	30	0.9358	-0.0052	-0.0094	-0.0168	-0.0021	-0.0053	0.0002	0.0004	0.0008	-0.0004	-0.0007	-0.0013	-0.0030
4	40	0.8804	-0.0081	-0.0149	-0.0267	-0.0032	-0.0079	0.0001	0.0003	0.0004	-0.0003	-0.0006	-0.0020	-0.0046
4	50	0.8314	-0.0112	-0.0205	-0.0368	-0.0042	-0.0104	0.0001	0.0001	0.0000	-0.0001	-0.0003	-0.0026	-0.0062
4	60	0.7900	-0.0139	-0.0254	-0.0456	-0.0050	-0.0124	0.0000	0.0000	-0.0002	0.0000	-0.0002	-0.0032	-0.0077
5	10	1.1178	-0.0003	-0.0005	-0.0007	-0.0002	-0.0006	0.0001	0.0003	0.0007	-0.0003	-0.0005	-0.0001	-0.0002
5	20	1.0524	-0.0015	-0.0028	-0.0047	-0.0008	-0.0019	0.0002	0.0005	0.0010	-0.0004	-0.0008	-0.0004	-0.0009
5	30	0.9939	-0.0033	-0.0060	-0.0106	-0.0014	-0.0036	0.0002	0.0005	0.0010	-0.0004	-0.0008	-0.0007	-0.0017
5	40	0.9393	-0.0056	-0.0103	-0.0184	-0.0023	-0.0057	0.0002	0.0004	0.0007	-0.0003	-0.0007	-0.0012	-0.0028
5	50	0.8883	-0.0083	-0.0153	-0.0276	-0.0032	-0.0080	0.0001	0.0002	0.0003	-0.0002	-0.0005	-0.0017	-0.0041
5	60	0.8418	-0.0112	-0.0206	-0.0374	-0.0041	-0.0103	0.0000	0.0000	-0.0001	-0.0001	-0.0003	-0.0023	-0.0055

Table Note: 'Weight percent' is shown as 'wt%' and fuel burnup using 'gigawatt day per metric ton uranium' is shown as 'GWD/MTU' in this submittal

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18. Section 4.2.1, first paragraph - the last sentence states: "This approach has been validated in [4.3] by showing that the cross sections result in the same reactivity in both CASMO-4 and MCNP4a."

This is not "validation". This cross-code comparison utilizing the same cross sections does not tell us anything about the potential composition and cross-section errors and associated biases introduced by the modeling of lumped fission products and use of lumped fission product cross sections.

What is the worth of the lumped fission products in the fuel storage racks? What fission products are included in the lumped fission products?

The "5% of the reactivity decrement" suggested by the Kopp memo does not cover modeling simplifications and approximations such as use of lumped fission products.

Eliminate or provide better justification for the use of lumped fission products. Justification for the use of the "lumped fission product" modeling simplification should include quantification of associated bias and bias uncertainty.

Response

The "validation" discussed in Section 4.2.1 of the Holtec Licensing Report regarding the transfer of nuclide number densities and lumped fission product (LFP) cross sections from CASMO-4 to the Monte Carlo N-Particle (MCNP) code MCNP4a was not intended to be a validation of the depletion capabilities of CASMO-4. Rather, it was intended to show that the data transfer itself was successful and that both codes, when using the same nuclide number densities and lumped fission product cross sections, produced very similar results.

The worth of the LFP is about 1 percent delta k_{eff}.

The lumped fission products used in CASMO-4 represent a limited population of fission products that are either slowly saturating fission products with burnup or never saturate. The slowly saturating lumped fission product's (SSFP) detailed isotopic characterization and the non-saturating lumped fission product's (NSFP) detailed isotopic characterization is presented in the two tables below (data taken from the chart of the nuclides and "Atlas of Neutron Resonances," S.F. Mughabghab, 5th Ed.).

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[[[PROPRIETARY - [redacted]

]]]

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[[[PROPRIETARY -

[redacted]

]]]

The use of the CASMO-4 LFP cross sections in MCNP may introduce an additional uncertainty to the final MCNP calculated reactivity. To account for this additional uncertainty, an analysis of cross section uncertainty data was performed to develop a cross section uncertainty factor that can be applied to the analysis. The LFP uncertainty factor will be applied to the final MCNP calculated reactivity by multiplying the uncertainty factor (that is, percent) by the reactivity decrement calculated from the reactivity difference between the MCNP calculation with LFPs and the MCNP calculation without LFPs.

The information presented in the above tables contains cross section data (including uncertainties) for total, scattering, and/or capture thermal cross sections, resonance cross sections, and U-235 fission product yields for each isotope. The determination

NONPROPRIETARY VERSION OF THE RESPONSE

of the LFP uncertainty factor is performed in two different ways and summarized in the table below:

[[[PROPRIETARY -

- [redacted]
- [redacted]]]]

Summary of LFP Factor Calculation

Description	Method 1		Method 2	
	Cross Section (b)	Cross Section Uncertainty (b)	Cross Section (b)	Cross Section Uncertainty (b)
SSFP	5576.35	221.56	38.33	2.11
NSFP	834.99	75.29	12.79	1.06
Total	6411.33	296.85	51.11	3.17
Factor	4.63%		6.21%	
95/95	9.26%		12.41%	

For both methods the final result is determined at a 95/95 confidence interval. For both methods, the final result is between 9-13 percent. For additional conservatism, the final LFP factor is determined to be 15 percent. A future supplement to the LAR will reflect the revised analysis.

20. The text in Section 4.7.4, "Isotopic Compositions," describes modeling approximations related to calculation and use of burned fuel compositions. Provide additional detail in this section to clearly state the conditions used in the calculation of fuel compositions as a function of initial-enrichment and fuel burnup.

From the text in Section 4.7.4, it appears that assembly average compositions are used rather than pin-by-pin compositions. This minimizes the impact on reactivity of removing WABA rods from an assembly. During depletion, the WABA rods depress power/burnup locally until the WABA rods are removed. Provide additional detail describing and justifying the use of modeling approximations associated

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with modeling burned fuel. Where appropriate, include biases and bias uncertainties associated with the modeling simplifications and approximations.

Response

To perform the criticality evaluation for spent fuel in MCNP4a, the isotopic composition of the fuel is calculated with the depletion code CASMO-4 and then specified as input data into MCNP4a. The depletion calculations are performed using bounding operating parameters as shown in RAI 14. The depletion calculations do not include any integral or non-integral reactivity control devices. The effect of integral or non-integral reactivity control devices is applied as a reactivity bias, which is discussed in RAI item 24. The CASMO-4 calculations to obtain the isotopic compositions for MCNP4a are performed for fuel with an initial enrichment of 2.0 weight percent U-235 to 5.0 weight percent U-235 in increments of 0.5 weight percent U-235. For each enrichment step, the depletion calculations determine the isotopic concentration in burnup steps of 2.5 GWD/MTU or less. The isotopic composition for any given burnup is then determined by linear interpolation. A complete list of the isotopes considered in the spent fuel composition is provided in the table below. The isotopic concentrations are determined at zero hour cooling time, without xenon, and the amount of Np-239 present is added as additional Pu-239 (as described in the response to RAI 25 in the submittal dated March 18, 2010). A future supplement to the LAR will reflect the revised text.

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[[[PROPRIETARY - [redacted]]]]

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With respect to the use of assembly average compositions, their use is appropriate because wet annular burnable absorber (WABA) rods are not included during depletion calculations that determine the isotopes used in the MCNP calculations. Rather, a reactivity bias is determined to account for the potential reactivity effect of the WABA rods, as described in the response to RAI 21 in the submittal dated March 18, 2010, and in RAI 24.

22. As described in Section 4.7 and in other places in the report, CASMO-4 was used to provide rack k_{eff} sensitivity information. Considering that the storage rack is constructed of "fabricated" cells and "developed" cells (see Fig. 2.6.2), it is not obvious what the CASMO model looked like. Did CASMO model simplifications affect the results?

Describe the CASMO model used for fuel storage rack models. Where appropriate, include biases and uncertainties associated with CASMO model simplifications.

Response

As described in Figure 2.6.2 in the Holtec Licensing Report, the storage racks are constructed using developed cells and fabricated cells. Fabricated cells are storage rack cells that have four cell walls with neutron absorber held in place by sheathing on each exterior face of each cell wall. When a storage rack is built, four fabricated cells are connected [[[PROPRIETARY - [redacted]]]]. The location in the center of the four fabricated cells is the developed cell. This level of detail is not possible with the CASMO-4 code model. Rather, the CASMO-4 model uses a simplified geometry. The simplified model does not consider that the racks contain both developed cells and fabricated cells. Rather, the model evenly distributes the thickness of the storage cell wall and sheathing around the neutron absorber. The CASMO-4 model is a reflective model and therefore the reflective boundary is the centerline of the poison. See the figure below for a 2D representation of the CASMO-4 model.

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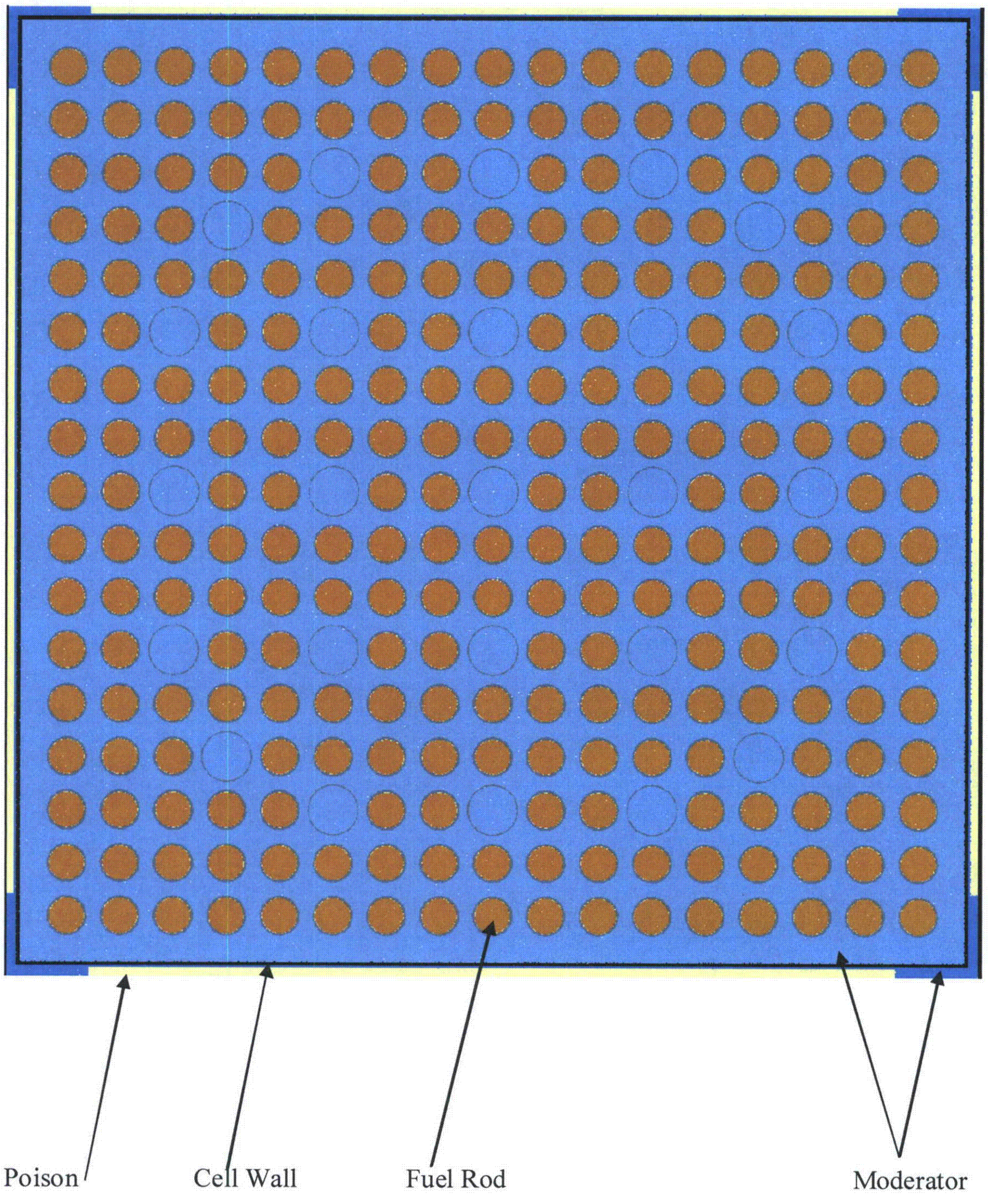

NONPROPRIETARY VERSION OF THE RESPONSE

In order to show that the simplified CASMO-4 storage rack model is acceptable to use for tolerance calculations, sensitivity calculations were performed using both CASMO-4 and MCNP4a for three tolerances: [[[PROPRIETARY - [redacted]]]]. The MCNP4a model does not contain the geometry simplifications inherent in the CASMO-4 model. The results of these calculations are shown in the table below and show that both codes calculate the same result within the uncertainty of the MCNP4a code results. Therefore, the use of the CASMO-4 code with a simplified storage rack model is acceptable to use for tolerance calculations. [[[PROPRIETARY -

[redacted]]]]

NONPROPRIETARY VERSION OF THE RESPONSE

The following information explains why use of a simplified MCNP4a model was also appropriate considering the same issue related to fabricated and developed cells. The MCNP model does not consider that the racks contain both developed cells and fabricated cells. Rather, the MCNP model is a simplified model [[[PROPRIETARY - [redacted]]]]. The simplified MCNP4a model is shown in the first figure below. A MCNP4a model with more detailed geometry was developed and is shown in the second figure below.

[[[PROPRIETARY -

[redacted]

[redacted]

]]]

NONPROPRIETARY VERSION OF THE RESPONSE

Sensitivity studies were performed to demonstrate that the reactivity effect of the MCNP model simplifications is within the uncertainty of the calculations. [[[PROPRIETARY - [redacted]]]] The results are presented in the table below and the small delta k_{calc} values show that the model simplifications are acceptable.

[[[PROPRIETARY -

[redacted]]]]

24. Section 4.7.2 addressed the reactivity effect of fuel assembly reactivity control devices. There are three issues associated with the analysis described in this section:

a. It does not appear that depletion with control rods present was considered. Frequently, second- and third-cycle fuel is placed under control rods, some of which may be used to control reactor power. Thus a realistic fuel depletion scenario could include first cycle depletion with burnable absorbers and second cycle of depletion with partially inserted control rods. Some plants have also included part-length absorbers rods in some peripheral locations to reduce neutron flux to reactor vessel welds. [In] low-leakage loading patterns, these peripheral locations frequently hold fuel that is being used for a third cycle.

Provide justification for modeling reactivity control devices throughout fuel assembly life.

Response: In the letter dated March 18, 2010, sub-item 24.a. was responded to, with the exception of the "part-length absorber rods" discussion. The following new information about part-length absorber rods is provided:

To address the potential impact of part-length absorber rods, sensitivity calculations were performed to determine the reactivity effect of part length integral fuel burnable absorbers (IFBA) and part length WABA rods. The results of the sensitivity studies show that the reactivity effect of cases using full length IFBA and full length WABA rods bound the cases that use part length IFBA and part length WABA rods. A complete description is provided in the response to RAI item 33. With respect to depletion with control rods, the only cycle that used control rods during depletion was Operating Cycle 1. During Cycle 1, control rods were minimally inserted for a short time. The potential reactivity effect due to the

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operation with control rods inserted is offset by the reactivity bias for burnable absorbers applied to all fuel in the analysis. The fuel assemblies that contained the control rods that were inserted during Cycle 1 have never contained burnable absorbers. Since the reactivity bias for burnable absorbers is applied to all fuel, even fuel that physically never contained burnable absorbers, the analysis bounds the case of partial control rod insertion in Cycle 1.

b. **It appears that IFBA and WABA were not modeled during depletion as being present in the same assembly. Does some mechanical feature or technical specification prevent them from being in the same assembly? Provide justification for not modeling both in the same assembly.**

Response: Sub-item 24.b was addressed in the letter dated March 18, 2010.

c. **Some plants have used standard Pyrex glass burnable absorbers. These absorbers deplete more slowly and can result in increased plutonium generation. Confirm that standard Pyrex glass burnable absorbers have not been used at BVPS-2. If they have been used, revise the analysis to address such use.**

Response: Sub-item 24.c was addressed in the letter dated March 18, 2010.

26. **Section 4.7.5 addresses uncertainty in depletion calculations. There is no basis in the Kopp memo to suggest that coverage of changes in fuel geometry during irradiation was intended. Uncertainty in k_{eff} due to random fuel geometry changes should be handled as variations in the parametric ranges of the analysis and included along with the other uncertainties. Variation in k_{eff} due to anticipated geometry changes during irradiation should be handled as a bias.**

    Confirm that the impacts of fuel geometry changes during irradiation are properly handled.

Response

During irradiation in light water reactors the fuel assemblies undergo physical changes associated with irradiation and residence time in an operating reactor. Some of those changes are: fuel pellet densification, crud build up on the outside surface of the fuel rod, and changes to clad geometry due to collapse of the pellet/cladding gas gap in the fuel rod (i.e., clad creep-down) and fuel rod growth. These fuel geometry changes are accounted for in the following way:

- Pellet densification: The spent fuel rack criticality methodology already includes an increase in fuel pellet density that covers both fresh and spent fuel. Therefore no additional calculations are required.
- Crud buildup: Crud buildup on the cladding increases the fuel-to-moderator ratio and therefore reduces reactivity. Thus, no additional calculations are required. Also, there has been no measureable crud-induced power shift

NONPROPRIETARY VERSION OF THE RESPONSE

(CIPS) at BVPS-2 since original startup of the plant, which indicates that crud deposition on the fuel has not been significant.

- Clad geometry: Both fuel rod growth and clad creep-down have the potential to decrease the fuel-to-moderator ratio, thus potentially increasing reactivity. To address clad creep-down, the clad inner diameter (ID) was reduced such that the pellet-clad gap was 0.0001 inch, while simultaneously reducing the clad outer diameter (OD) to preserve overall clad volume. Then, to address clad thinning due to fuel rod growth, the clad OD was further reduced to allow for the maximum possible fuel rod growth. Calculations were performed to determine the reactivity impact of this "creep" model on the magnitude of the fuel tolerance uncertainties. The results are shown in the following six tables. The maximum delta-k value of 0.0075 is essentially equivalent to the results of the fuel tolerance uncertainty calculations without the creep model (maximum delta-k of 0.0074) that was provided in Table 4.7.13 in the original Holtec Licensing Report. A future LAR supplement will reflect the revised analysis.

Region 2 CASMO Calculations for Fuel Tolerance Uncertainties With Creep

Description			Ref Case	Rod Pitch +	Rod Pitch -	Clad OD +	Clad OD -	Clad ID +	Clad ID -	Fuel Pellet OD +	Fuel Pellet OD -	Fuel Pellet Enr +	Stat. Combo
			Input File										
ppm	Burnup GWD/ MTU	Enr	bv-cftn-20-0	bv-cfta-20-0	bv-cftb-20-0	bv-cftc-20-0	bv-cftd-20-0	bv-cfte-20-0	bv-cftf-20-0	bv-cftg-20-0	bv-cfth-20-0	bv-cfti-200	
0	0.0	2	0.9691	0.0006	-0.0077	-0.0012	0.0012	0.0011	-0.0011	0.0001	-0.0001	0.0073	0.0075
0	0.1	2	0.9660	0.0006	-0.0076	-0.0012	0.0012	0.0011	-0.0011	0.0001	-0.0001	0.0073	0.0075
0	2.0	2	0.9517	0.0006	-0.0078	-0.0011	0.0011	0.0010	-0.0010	0.0002	-0.0002	0.0068	0.0070
0	4.0	2	0.9362	0.0006	-0.0079	-0.0011	0.0010	0.0009	-0.0009	0.0002	-0.0002	0.0066	0.0068
0	6.0	2	0.9198	0.0006	-0.0079	-0.0010	0.0009	0.0008	-0.0008	0.0002	-0.0002	0.0064	0.0066
0	8.0	2	0.9038	0.0006	-0.0078	-0.0009	0.0009	0.0008	-0.0008	0.0003	-0.0003	0.0063	0.0064
0	10.0	2	0.8886	0.0006	-0.0078	-0.0008	0.0008	0.0007	-0.0007	0.0003	-0.0003	0.0061	0.0062
0	11.0	2	0.8813	0.0006	-0.0077	-0.0007	0.0007	0.0006	-0.0006	0.0004	-0.0004	0.0060	0.0061
0	12.5	2	0.8707	0.0006	-0.0077	-0.0007	0.0006	0.0006	-0.0006	0.0004	-0.0004	0.0059	0.0060
0	15.0	2	0.8538	0.0005	-0.0076	-0.0005	0.0005	0.0005	-0.0005	0.0005	-0.0005	0.0057	0.0058
0	17.5	2	0.8377	0.0005	-0.0074	-0.0004	0.0004	0.0004	-0.0004	0.0006	-0.0006	0.0055	0.0056
0	20.0	2	0.8225	0.0005	-0.0073	-0.0003	0.0003	0.0003	-0.0003	0.0006	-0.0006	0.0052	0.0053
0	22.5	2	0.8082	0.0005	-0.0072	-0.0002	0.0002	0.0002	-0.0002	0.0007	-0.0007	0.0050	0.0051
0	25.0	2	0.7948	0.0005	-0.0071	-0.0001	0.0001	0.0001	-0.0001	0.0008	-0.0008	0.0047	0.0048
0	27.5	2	0.7823	0.0005	-0.0070	0.0000	0.0000	0.0000	0.0000	0.0009	-0.0009	0.0044	0.0045
0	30.0	2	0.7707	0.0005	-0.0070	0.0001	-0.0001	-0.0001	0.0001	0.0009	-0.0009	0.0041	0.0043
0	32.5	2	0.7599	0.0005	-0.0069	0.0002	-0.0002	-0.0002	0.0002	0.0010	-0.0010	0.0038	0.0040
0	35.0	2	0.7501	0.0005	-0.0069	0.0003	-0.0003	-0.0002	0.0002	0.0010	-0.0010	0.0035	0.0037
0	37.5	2	0.7411	0.0004	-0.0069	0.0003	-0.0003	-0.0003	0.0003	0.0011	-0.0011	0.0032	0.0035
0	42.5	2	0.7255	0.0005	-0.0068	0.0005	-0.0004	-0.0004	0.0004	0.0011	-0.0012	0.0027	0.0030
0	45.0	2	0.7189	0.0004	-0.0068	0.0005	-0.0005	-0.0004	0.0004	0.0012	-0.0012	0.0024	0.0028
0	47.5	2	0.7129	0.0004	-0.0069	0.0005	-0.0005	-0.0005	0.0005	0.0012	-0.0012	0.0021	0.0026
0	50.0	2	0.7075	0.0005	-0.0069	0.0006	-0.0006	-0.0005	0.0005	0.0012	-0.0012	0.0019	0.0024
0	52.5	2	0.7028	0.0004	-0.0069	0.0006	-0.0006	-0.0005	0.0005	0.0012	-0.0012	0.0017	0.0023
0	55.0	2	0.6985	0.0005	-0.0069	0.0006	-0.0006	-0.0005	0.0006	0.0013	-0.0013	0.0015	0.0022
0	57.5	2	0.6948	0.0005	-0.0070	0.0006	-0.0006	-0.0006	0.0006	0.0013	-0.0013	0.0013	0.0021
0	60.0	2	0.6915	0.0005	-0.0070	0.0007	-0.0007	-0.0006	0.0006	0.0013	-0.0013	0.0011	0.0020

Table Note: Enrichment is shown as 'Enr' in this submittal

NONPROPRIETARY VERSION OF THE RESPONSE

Region 2 CASMO Calculations for Fuel Tolerance Uncertainties With Creep

Description			Ref Case	Rod Pitch +	Rod Pitch -	Clad OD +	Clad OD -	Clad ID +	Clad ID -	Fuel Pellet OD +	Fuel Pellet OD -	Fuel Pellet Enr +	Stat. Combo
			Input File										
ppm	Burnup GWD/ MTU	Enr	bv-cftn-35-0	bv-cfta-35-0	bv-cftb-35-0	bv-cftc-35-0	bv-cftd-35-0	bv-cfte-35-0	bv-cftf-35-0	bv-cftg-35-0	bv-cfth-35-0	bv-cfti-35-0	
0	0.0	3.5	1.1205	0.0009	-0.0121	-0.0014	0.0014	0.0012	-0.0012	0.0000	0.0001	0.0034	0.0040
0	0.1	3.5	1.1182	0.0009	-0.0120	-0.0014	0.0013	0.0012	-0.0012	-0.0001	0.0000	0.0034	0.0040
0	2.0	3.5	1.0979	0.0009	-0.0120	-0.0013	0.0013	0.0012	-0.0012	-0.0001	0.0000	0.0034	0.0039
0	4.0	3.5	1.0811	0.0009	-0.0119	-0.0013	0.0013	0.0011	-0.0011	-0.0001	0.0000	0.0034	0.0040
0	6.0	3.5	1.0640	0.0008	-0.0118	-0.0013	0.0013	0.0011	-0.0011	0.0000	0.0000	0.0035	0.0040
0	8.0	3.5	1.0473	0.0008	-0.0118	-0.0012	0.0012	0.0011	-0.0011	0.0000	0.0000	0.0035	0.0040
0	10.0	3.5	1.0312	0.0008	-0.0116	-0.0012	0.0012	0.0010	-0.0011	0.0000	0.0000	0.0036	0.0040
0	11.0	3.5	1.0234	0.0008	-0.0116	-0.0012	0.0012	0.0010	-0.0010	0.0000	0.0000	0.0036	0.0040
0	12.5	3.5	1.0120	0.0008	-0.0115	-0.0011	0.0011	0.0010	-0.0010	0.0000	0.0000	0.0036	0.0040
0	15.0	3.5	0.9937	0.0008	-0.0113	-0.0011	0.0011	0.0009	-0.0009	0.0001	-0.0001	0.0036	0.0040
0	17.5	3.5	0.9759	0.0008	-0.0111	-0.0010	0.0010	0.0009	-0.0009	0.0001	-0.0001	0.0037	0.0040
0	20.0	3.5	0.9586	0.0007	-0.0109	-0.0009	0.0009	0.0008	-0.0008	0.0001	-0.0002	0.0037	0.0039
0	22.5	3.5	0.9417	0.0007	-0.0107	-0.0008	0.0008	0.0007	-0.0007	0.0002	-0.0002	0.0037	0.0039
0	25.0	3.5	0.9253	0.0007	-0.0105	-0.0007	0.0007	0.0006	-0.0006	0.0003	-0.0003	0.0037	0.0039
0	27.5	3.5	0.9093	0.0007	-0.0102	-0.0006	0.0006	0.0005	-0.0006	0.0003	-0.0004	0.0037	0.0039
0	30.0	3.5	0.8937	0.0007	-0.0100	-0.0005	0.0005	0.0005	-0.0005	0.0004	-0.0004	0.0037	0.0039
0	32.5	3.5	0.8785	0.0007	-0.0098	-0.0005	0.0004	0.0004	-0.0004	0.0005	-0.0005	0.0037	0.0038
0	35.0	3.5	0.8638	0.0006	-0.0096	-0.0004	0.0003	0.0003	-0.0003	0.0005	-0.0006	0.0037	0.0038
0	37.5	3.5	0.8495	0.0006	-0.0093	-0.0002	0.0002	0.0002	-0.0002	0.0006	-0.0006	0.0036	0.0037
0	42.5	3.5	0.8225	0.0006	-0.0090	-0.0001	0.0000	0.0000	0.0000	0.0008	-0.0008	0.0035	0.0036
0	45.0	3.5	0.8099	0.0006	-0.0088	0.0000	0.0000	0.0000	0.0000	0.0008	-0.0008	0.0033	0.0035
0	47.5	3.5	0.7978	0.0006	-0.0086	0.0001	-0.0001	-0.0001	0.0001	0.0009	-0.0009	0.0032	0.0034
0	50.0	3.5	0.7863	0.0005	-0.0084	0.0002	-0.0002	-0.0002	0.0002	0.0010	-0.0010	0.0031	0.0033
0	52.5	3.5	0.7755	0.0005	-0.0083	0.0003	-0.0003	-0.0003	0.0003	0.0010	-0.0010	0.0030	0.0032
0	55.0	3.5	0.7653	0.0005	-0.0082	0.0004	-0.0004	-0.0003	0.0003	0.0011	-0.0011	0.0028	0.0031
0	57.5	3.5	0.7558	0.0005	-0.0081	0.0004	-0.0004	-0.0004	0.0004	0.0011	-0.0011	0.0027	0.0030
0	60.0	3.5	0.7469	0.0005	-0.0080	0.0005	-0.0005	-0.0004	0.0004	0.0012	-0.0012	0.0025	0.0029

NONPROPRIETARY VERSION OF THE RESPONSE

Region 2 CASMO Calculations for Fuel Tolerance Uncertainties With Creep

Description			Ref Case	Rod Pitch +	Rod Pitch -	Clad OD +	Clad OD -	Clad ID +	Clad ID -	Fuel Pellet OD +	Fuel Pellet OD -	Fuel Pellet Enr +	Stat. Combo
			Input File										
ppm	Burnup GWD/ MTU	Enr	bv-cftn-50-0	bv-cfta-50-0	bv-cftb-50-0	bv-cftc-50-0	bv-cftd-50-0	bv-cfte-50-0	bv-cftf-50-0	bv-cftg-50-0	bv-cfth-50-0	bv-cfti-500	
0	0.0	5	1.2003	0.0010	-0.0146	-0.0014	0.0014	0.0013	-0.0012	-0.0001	0.0002	0.0021	0.0030
0	0.1	5	1.1985	0.0010	-0.0146	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0021	0.0030
0	2.0	5	1.1775	0.0010	-0.0145	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0021	0.0030
0	4.0	5	1.1624	0.0010	-0.0144	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0021	0.0030
0	6.0	5	1.1471	0.0010	-0.0143	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0022	0.0030
0	8.0	5	1.1320	0.0010	-0.0142	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0022	0.0030
0	10.0	5	1.1173	0.0010	-0.0141	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0023	0.0031
0	11.0	5	1.1102	0.0010	-0.0140	-0.0014	0.0013	0.0012	-0.0012	-0.0002	0.0002	0.0023	0.0031
0	12.5	5	1.0997	0.0010	-0.0139	-0.0013	0.0013	0.0012	-0.0012	-0.0002	0.0002	0.0023	0.0031
0	15.0	5	1.0828	0.0009	-0.0138	-0.0013	0.0013	0.0011	-0.0011	-0.0001	0.0002	0.0024	0.0031
0	17.5	5	1.0664	0.0009	-0.0136	-0.0013	0.0012	0.0011	-0.0011	-0.0001	0.0001	0.0024	0.0031
0	20.0	5	1.0504	0.0009	-0.0135	-0.0012	0.0012	0.0011	-0.0011	-0.0001	0.0001	0.0025	0.0031
0	22.5	5	1.0348	0.0009	-0.0133	-0.0012	0.0011	0.0010	-0.0010	-0.0001	0.0001	0.0025	0.0031
0	25.0	5	1.0196	0.0009	-0.0131	-0.0011	0.0011	0.0010	-0.0010	-0.0001	0.0000	0.0026	0.0031
0	27.5	5	1.0046	0.0009	-0.0129	-0.0011	0.0010	0.0009	-0.0009	0.0000	0.0000	0.0026	0.0031
0	30.0	5	0.9898	0.0008	-0.0127	-0.0010	0.0010	0.0009	-0.0009	0.0000	0.0000	0.0027	0.0031
0	32.5	5	0.9751	0.0008	-0.0125	-0.0009	0.0009	0.0008	-0.0008	0.0001	-0.0001	0.0027	0.0031
0	35.0	5	0.9607	0.0008	-0.0123	-0.0009	0.0008	0.0008	-0.0008	0.0001	-0.0001	0.0028	0.0031
0	37.5	5	0.9464	0.0008	-0.0121	-0.0008	0.0008	0.0007	-0.0007	0.0002	-0.0002	0.0028	0.0031
0	42.5	5	0.9184	0.0008	-0.0116	-0.0006	0.0006	0.0006	-0.0005	0.0003	-0.0003	0.0028	0.0031
0	45.0	5	0.9047	0.0007	-0.0114	-0.0005	0.0005	0.0005	-0.0005	0.0003	-0.0003	0.0029	0.0030
0	47.5	5	0.8912	0.0007	-0.0111	-0.0005	0.0005	0.0004	-0.0004	0.0004	-0.0004	0.0029	0.0030
0	50.0	5	0.8779	0.0007	-0.0109	-0.0004	0.0004	0.0003	-0.0003	0.0005	-0.0005	0.0028	0.0030
0	52.5	5	0.8650	0.0007	-0.0107	-0.0003	0.0003	0.0003	-0.0002	0.0005	-0.0005	0.0029	0.0030
0	55.0	5	0.8523	0.0007	-0.0105	-0.0002	0.0002	0.0002	-0.0002	0.0006	-0.0006	0.0028	0.0030
0	57.5	5	0.8400	0.0006	-0.0102	-0.0001	0.0001	0.0001	-0.0001	0.0007	-0.0007	0.0028	0.0029
0	60.0	5	0.8280	0.0006	-0.0100	0.0000	0.0000	0.0000	0.0000	0.0007	-0.0008	0.0027	0.0029

NONPROPRIETARY VERSION OF THE RESPONSE

Region 2 CASMO Calculations for Fuel Tolerance Uncertainties With Creep

Description			Ref Case	Rod Pitch +	Rod Pitch -	Clad OD +	Clad OD -	Clad ID +	Clad ID -	Fuel Pellet OD +	Fuel Pellet OD -	Fuel Pellet Enr +	Stat. Combo
			Input File										
ppm	Burnup GWD/MTU	Enr	bv-cftn-20-0	bv-cfta-20-2000	bv-cftb-20-2000	bv-cftc-20-2000	bv-cftd-20-2000	bv-cfte-20-2000	bv-cftf-20-2000	bv-cftg-20-2000	bv-cfth-20-2000	bv-cfti-20 2000	
2000	0.0	2	0.9691	0.0006	-0.0077	-0.0012	0.0012	0.0011	-0.0011	0.0001	-0.0001	0.0073	0.0075
2000	0.1	2	0.9660	0.0006	-0.0076	-0.0012	0.0012	0.0011	-0.0011	0.0001	-0.0001	0.0073	0.0075
2000	2.0	2	0.9517	0.0006	-0.0078	-0.0011	0.0011	0.0010	-0.0010	0.0002	-0.0002	0.0068	0.0070
2000	4.0	2	0.9362	0.0006	-0.0079	-0.0011	0.0010	0.0009	-0.0009	0.0002	-0.0002	0.0066	0.0068
2000	6.0	2	0.9198	0.0006	-0.0079	-0.0010	0.0009	0.0008	-0.0008	0.0002	-0.0002	0.0064	0.0066
2000	8.0	2	0.9038	0.0006	-0.0078	-0.0009	0.0009	0.0008	-0.0008	0.0003	-0.0003	0.0063	0.0064
2000	10.0	2	0.8886	0.0006	-0.0078	-0.0008	0.0008	0.0007	-0.0007	0.0003	-0.0003	0.0061	0.0062
2000	11.0	2	0.8813	0.0006	-0.0077	-0.0007	0.0007	0.0006	-0.0006	0.0004	-0.0004	0.0060	0.0061
2000	12.5	2	0.8707	0.0006	-0.0077	-0.0007	0.0006	0.0006	-0.0006	0.0004	-0.0004	0.0059	0.0060
2000	15.0	2	0.8538	0.0005	-0.0076	-0.0005	0.0005	0.0005	-0.0005	0.0005	-0.0005	0.0057	0.0058
2000	17.5	2	0.8377	0.0005	-0.0074	-0.0004	0.0004	0.0004	-0.0004	0.0006	-0.0006	0.0055	0.0056
2000	20.0	2	0.8225	0.0005	-0.0073	-0.0003	0.0003	0.0003	-0.0003	0.0006	-0.0006	0.0052	0.0053
2000	22.5	2	0.8082	0.0005	-0.0072	-0.0002	0.0002	0.0002	-0.0002	0.0007	-0.0007	0.0050	0.0051
2000	25.0	2	0.7948	0.0005	-0.0071	-0.0001	0.0001	0.0001	-0.0001	0.0008	-0.0008	0.0047	0.0048
2000	27.5	2	0.7823	0.0005	-0.0070	0.0000	0.0000	0.0000	0.0000	0.0009	-0.0009	0.0044	0.0045
2000	30.0	2	0.7707	0.0005	-0.0070	0.0001	-0.0001	-0.0001	0.0001	0.0009	-0.0009	0.0041	0.0043
2000	32.5	2	0.7599	0.0005	-0.0069	0.0002	-0.0002	-0.0002	0.0002	0.0010	-0.0010	0.0038	0.0040
2000	35.0	2	0.7501	0.0005	-0.0069	0.0003	-0.0003	-0.0002	0.0002	0.0010	-0.0010	0.0035	0.0037
2000	37.5	2	0.7411	0.0004	-0.0069	0.0003	-0.0003	-0.0003	0.0003	0.0011	-0.0011	0.0032	0.0035
2000	42.5	2	0.7255	0.0005	-0.0068	0.0005	-0.0004	-0.0004	0.0004	0.0011	-0.0012	0.0027	0.0030
2000	45.0	2	0.7189	0.0004	-0.0068	0.0005	-0.0005	-0.0004	0.0004	0.0012	-0.0012	0.0024	0.0028
2000	47.5	2	0.7129	0.0004	-0.0069	0.0005	-0.0005	-0.0005	0.0005	0.0012	-0.0012	0.0021	0.0026
2000	50.0	2	0.7075	0.0005	-0.0069	0.0006	-0.0006	-0.0005	0.0005	0.0012	-0.0012	0.0019	0.0024
2000	52.5	2	0.7028	0.0004	-0.0069	0.0006	-0.0006	-0.0005	0.0005	0.0012	-0.0012	0.0017	0.0023
2000	55.0	2	0.6985	0.0005	-0.0069	0.0006	-0.0006	-0.0005	0.0006	0.0013	-0.0013	0.0015	0.0022
2000	57.5	2	0.6948	0.0005	-0.0070	0.0006	-0.0006	-0.0006	0.0006	0.0013	-0.0013	0.0013	0.0021
2000	60.0	2	0.6915	0.0005	-0.0070	0.0007	-0.0007	-0.0006	0.0006	0.0013	-0.0013	0.0011	0.0020

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Region 2 CASMO Calculations for Fuel Tolerance Uncertainties With Creep

Description			Ref Case	Rod Pitch +	Rod Pitch -	Clad OD +	Clad OD -	Clad ID +	Clad ID -	Fuel Pellet OD +	Fuel Pellet OD -	Fuel Pellet Enr +	Stat. Combo
			Input File										
ppm	Burnup GWD/ MTU	Enr	bv-cftn-35-0	bv-cfta-35-2000	bv-cftb-35-2000	bv-cftc-35-2000	bv-cftd-35-2000	bv-cfte-35-2000	bv-cftf-35-2000	bv-cftg-35-2000	bv-cfth-35-2000	bv-cfti-35 2000	
2000	0.0	3.5	1.1205	0.0009	-0.0121	-0.0014	0.0014	0.0012	-0.0012	0.0000	0.0001	0.0034	0.0040
2000	0.1	3.5	1.1182	0.0009	-0.0120	-0.0014	0.0013	0.0012	-0.0012	-0.0001	0.0000	0.0034	0.0040
2000	2.0	3.5	1.0979	0.0009	-0.0120	-0.0013	0.0013	0.0012	-0.0012	-0.0001	0.0000	0.0034	0.0039
2000	4.0	3.5	1.0811	0.0009	-0.0119	-0.0013	0.0013	0.0011	-0.0011	-0.0001	0.0000	0.0034	0.0040
2000	6.0	3.5	1.0640	0.0008	-0.0118	-0.0013	0.0013	0.0011	-0.0011	0.0000	0.0000	0.0035	0.0040
2000	8.0	3.5	1.0473	0.0008	-0.0118	-0.0012	0.0012	0.0011	-0.0011	0.0000	0.0000	0.0035	0.0040
2000	10.0	3.5	1.0312	0.0008	-0.0116	-0.0012	0.0012	0.0010	-0.0011	0.0000	0.0000	0.0036	0.0040
2000	11.0	3.5	1.0234	0.0008	-0.0116	-0.0012	0.0012	0.0010	-0.0010	0.0000	0.0000	0.0036	0.0040
2000	12.5	3.5	1.0120	0.0008	-0.0115	-0.0011	0.0011	0.0010	-0.0010	0.0000	0.0000	0.0036	0.0040
2000	15.0	3.5	0.9937	0.0008	-0.0113	-0.0011	0.0011	0.0009	-0.0009	0.0001	-0.0001	0.0036	0.0040
2000	17.5	3.5	0.9759	0.0008	-0.0111	-0.0010	0.0010	0.0009	-0.0009	0.0001	-0.0001	0.0037	0.0040
2000	20.0	3.5	0.9586	0.0007	-0.0109	-0.0009	0.0009	0.0008	-0.0008	0.0001	-0.0002	0.0037	0.0039
2000	22.5	3.5	0.9417	0.0007	-0.0107	-0.0008	0.0008	0.0007	-0.0007	0.0002	-0.0002	0.0037	0.0039
2000	25.0	3.5	0.9253	0.0007	-0.0105	-0.0007	0.0007	0.0006	-0.0006	0.0003	-0.0003	0.0037	0.0039
2000	27.5	3.5	0.9093	0.0007	-0.0102	-0.0006	0.0006	0.0005	-0.0006	0.0003	-0.0004	0.0037	0.0039
2000	30.0	3.5	0.8937	0.0007	-0.0100	-0.0005	0.0005	0.0005	-0.0005	0.0004	-0.0004	0.0037	0.0039
2000	32.5	3.5	0.8785	0.0007	-0.0098	-0.0005	0.0004	0.0004	-0.0004	0.0005	-0.0005	0.0037	0.0038
2000	35.0	3.5	0.8638	0.0006	-0.0096	-0.0004	0.0003	0.0003	-0.0003	0.0005	-0.0006	0.0037	0.0038
2000	37.5	3.5	0.8495	0.0006	-0.0093	-0.0002	0.0002	0.0002	-0.0002	0.0006	-0.0006	0.0036	0.0037
2000	42.5	3.5	0.8225	0.0006	-0.0090	-0.0001	0.0000	0.0000	0.0000	0.0008	-0.0008	0.0035	0.0036
2000	45.0	3.5	0.8099	0.0006	-0.0088	0.0000	0.0000	0.0000	0.0000	0.0008	-0.0008	0.0033	0.0035
2000	47.5	3.5	0.7978	0.0006	-0.0086	0.0001	-0.0001	-0.0001	0.0001	0.0009	-0.0009	0.0032	0.0034
2000	50.0	3.5	0.7863	0.0005	-0.0084	0.0002	-0.0002	-0.0002	0.0002	0.0010	-0.0010	0.0031	0.0033
2000	52.5	3.5	0.7755	0.0005	-0.0083	0.0003	-0.0003	-0.0003	0.0003	0.0010	-0.0010	0.0030	0.0032
2000	55.0	3.5	0.7653	0.0005	-0.0082	0.0004	-0.0004	-0.0003	0.0003	0.0011	-0.0011	0.0028	0.0031
2000	57.5	3.5	0.7558	0.0005	-0.0081	0.0004	-0.0004	-0.0004	0.0004	0.0011	-0.0011	0.0027	0.0030
2000	60.0	3.5	0.7469	0.0005	-0.0080	0.0005	-0.0005	-0.0004	0.0004	0.0012	-0.0012	0.0025	0.0029

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Region 2 CASMO Calculations for Fuel Tolerance Uncertainties With Creep

Description			Ref Case	Rod Pitch +	Rod Pitch -	Clad OD +	Clad OD -	Clad ID +	Clad ID -	Fuel Pellet OD +	Fuel Pellet OD -	Fuel Pellet Enr +	Stat. Combo
			Input File										
ppm	Burnup GWD/ MTU	Enr	bv-cftn-50-0	bv-cfta-50-2000	bv-cftb-50-2000	bv-cftc-50-2000	bv-cftd-50-2000	bv-cfte-50-2000	bv-cftf-50-2000	bv-cftg-50-2000	bv-cfth-50-2000	bv-cfti-50 2000	
2000	0.0	5	1.2003	0.0010	-0.0146	-0.0014	0.0014	0.0013	-0.0012	-0.0001	0.0002	0.0021	0.0030
2000	0.1	5	1.1985	0.0010	-0.0146	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0021	0.0030
2000	2.0	5	1.1775	0.0010	-0.0145	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0021	0.0030
2000	4.0	5	1.1624	0.0010	-0.0144	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0021	0.0030
2000	6.0	5	1.1471	0.0010	-0.0143	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0022	0.0030
2000	8.0	5	1.1320	0.0010	-0.0142	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0022	0.0030
2000	10.0	5	1.1173	0.0010	-0.0141	-0.0014	0.0014	0.0012	-0.0012	-0.0002	0.0002	0.0023	0.0031
2000	11.0	5	1.1102	0.0010	-0.0140	-0.0014	0.0013	0.0012	-0.0012	-0.0002	0.0002	0.0023	0.0031
2000	12.5	5	1.0997	0.0010	-0.0139	-0.0013	0.0013	0.0012	-0.0012	-0.0002	0.0002	0.0023	0.0031
2000	15.0	5	1.0828	0.0009	-0.0138	-0.0013	0.0013	0.0011	-0.0011	-0.0001	0.0002	0.0024	0.0031
2000	17.5	5	1.0664	0.0009	-0.0136	-0.0013	0.0012	0.0011	-0.0011	-0.0001	0.0001	0.0024	0.0031
2000	20.0	5	1.0504	0.0009	-0.0135	-0.0012	0.0012	0.0011	-0.0011	-0.0001	0.0001	0.0025	0.0031
2000	22.5	5	1.0348	0.0009	-0.0133	-0.0012	0.0011	0.0010	-0.0010	-0.0001	0.0001	0.0025	0.0031
2000	25.0	5	1.0196	0.0009	-0.0131	-0.0011	0.0011	0.0010	-0.0010	-0.0001	0.0000	0.0026	0.0031
2000	27.5	5	1.0046	0.0009	-0.0129	-0.0011	0.0010	0.0009	-0.0009	0.0000	0.0000	0.0026	0.0031
2000	30.0	5	0.9898	0.0008	-0.0127	-0.0010	0.0010	0.0009	-0.0009	0.0000	0.0000	0.0027	0.0031
2000	32.5	5	0.9751	0.0008	-0.0125	-0.0009	0.0009	0.0008	-0.0008	0.0001	-0.0001	0.0027	0.0031
2000	35.0	5	0.9607	0.0008	-0.0123	-0.0009	0.0008	0.0008	-0.0008	0.0001	-0.0001	0.0028	0.0031
2000	37.5	5	0.9464	0.0008	-0.0121	-0.0008	0.0008	0.0007	-0.0007	0.0002	-0.0002	0.0028	0.0031
2000	42.5	5	0.9184	0.0008	-0.0116	-0.0006	0.0006	0.0006	-0.0005	0.0003	-0.0003	0.0028	0.0031
2000	45.0	5	0.9047	0.0007	-0.0114	-0.0005	0.0005	0.0005	-0.0005	0.0003	-0.0003	0.0029	0.0030
2000	47.5	5	0.8912	0.0007	-0.0111	-0.0005	0.0005	0.0004	-0.0004	0.0004	-0.0004	0.0029	0.0030
2000	50.0	5	0.8779	0.0007	-0.0109	-0.0004	0.0004	0.0003	-0.0003	0.0005	-0.0005	0.0028	0.0030
2000	52.5	5	0.8650	0.0007	-0.0107	-0.0003	0.0003	0.0003	-0.0002	0.0005	-0.0005	0.0029	0.0030
2000	55.0	5	0.8523	0.0007	-0.0105	-0.0002	0.0002	0.0002	-0.0002	0.0006	-0.0006	0.0028	0.0030
2000	57.5	5	0.8400	0.0006	-0.0102	-0.0001	0.0001	0.0001	-0.0001	0.0007	-0.0007	0.0028	0.0029
2000	60.0	5	0.8280	0.0006	-0.0100	0.0000	0.0000	0.0000	0.0000	0.0007	-0.0008	0.0027	0.0029

28. Section 4.7.8 discussed temperature and water density effects. Clarify the source of the bias, the method by which the bias is calculated, and the justification for using CASMO to estimate the bias. Confirm that the calculational results shown in Table 4.7.15 reflect changes in both water density and temperature. Discuss how the temperature bias changes with the presence of soluble boron. If appropriate, include a revised temperature bias for soluble boron crediting.

Response

The source of the bias is related to the temperature at which the cross sections are evaluated in MCNP4a and the temperature at which the analysis is performed in MCNP4a. CASMO-4 is used to estimate the bias because the moderator temperature is easily changed in CASMO-4 (thus making it useful for parametric studies), and the water density is calculated by the CASMO-4 code for the given water temperature. The CASMO-4 benchmark that was provided as Enclosure A to the letter dated June 15, 2009, includes experiments at various temperatures,

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demonstrating that CASMO-4 adequately models the effects of changing moderator temperature. Additional explanation is provided below. With respect to the results of the moderator temperature coefficient calculations presented in Table 4.7.15 of the Holtec Licensing Report, those results reflect both changes in moderator density and temperature. These results are used to determine the most reactive moderator density for use in MCNP k_{eff} calculations.

The effect of soluble boron on the temperature bias is shown in the table below. The results show that the temperature bias decreases with borated water, and therefore pure water bounds that for borated water. The results presented in the table below were calculated using the methodology explained in greater detail below.

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Calculation of the Temperature Bias CASMO-4						
parameter			T = 39.2 F		T = 80.33 F	
wt% U235	ppm	gwd/mtu	input file	kinf	input file	delta kinf
2	0	0.0	bv-pftb2-20-0	0.9688	bv-pftb3-20-0	-0.0043
2	0	10.0	bv-pftb2-20-0	0.8926	bv-pftb3-20-0	-0.0027
2	0	20.0	bv-pftb2-20-0	0.8312	bv-pftb3-20-0	-0.0017
2	0	30.0	bv-pftb2-20-0	0.7836	bv-pftb3-20-0	-0.0009
3	0	0.0	bv-pftb2-30-0	1.0818	bv-pftb3-30-0	-0.0035
3	0	10.0	bv-pftb2-30-0	0.9940	bv-pftb3-30-0	-0.0028
3	0	20.0	bv-pftb2-30-0	0.9242	bv-pftb3-30-0	-0.0022
3	0	30.0	bv-pftb2-30-0	0.8641	bv-pftb3-30-0	-0.0015
3	0	40.0	bv-pftb2-30-0	0.8135	bv-pftb3-30-0	-0.0010
4	0	0.0	bv-pftb2-40-0	1.1519	bv-pftb3-40-0	-0.0029
4	0	10.0	bv-pftb2-40-0	1.0654	bv-pftb3-40-0	-0.0027
4	0	20.0	bv-pftb2-40-0	0.9967	bv-pftb3-40-0	-0.0023
4	0	30.0	bv-pftb2-40-0	0.9358	bv-pftb3-40-0	-0.0019
4	0	40.0	bv-pftb2-40-0	0.8804	bv-pftb3-40-0	-0.0014
5	0	0.0	bv-pftb2-50-0	1.2004	bv-pftb3-50-0	-0.0025
5	0	10.0	bv-pftb2-50-0	1.1178	bv-pftb3-50-0	-0.0025
5	0	20.0	bv-pftb2-50-0	1.0524	bv-pftb3-50-0	-0.0023
5	0	30.0	bv-pftb2-50-0	0.9939	bv-pftb3-50-0	-0.0020
5	0	40.0	bv-pftb2-50-0	0.9393	bv-pftb3-50-0	-0.0017
5	0	50.0	bv-pftb2-50-0	0.8883	bv-pftb3-50-0	-0.0013
5	0	60.0	bv-pftb2-50-0	0.8418	bv-pftb3-50-0	-0.0010
2	2000	0.0	bv-pftb2-20-2000	0.7044	bv-pftb3-20-2000	-0.0020
2	2000	10.0	bv-pftb2-20-2000	0.6744	bv-pftb3-20-2000	-0.0005
2	2000	20.0	bv-pftb2-20-2000	0.6360	bv-pftb3-20-2000	0.0003
2	2000	30.0	bv-pftb2-20-2000	0.6044	bv-pftb3-20-2000	0.0007
3	2000	0.0	bv-pftb2-30-2000	0.8340	bv-pftb3-30-2000	-0.0016
3	2000	10.0	bv-pftb2-30-2000	0.7807	bv-pftb3-30-2000	-0.0008
3	2000	20.0	bv-pftb2-30-2000	0.7291	bv-pftb3-30-2000	-0.0002
3	2000	30.0	bv-pftb2-30-2000	0.6828	bv-pftb3-30-2000	0.0002
3	2000	40.0	bv-pftb2-30-2000	0.6436	bv-pftb3-30-2000	0.0006
4	2000	0.0	bv-pftb2-40-2000	0.9228	bv-pftb3-40-2000	-0.0013
4	2000	10.0	bv-pftb2-40-2000	0.8626	bv-pftb3-40-2000	-0.0009
4	2000	20.0	bv-pftb2-40-2000	0.8079	bv-pftb3-40-2000	-0.0005
4	2000	30.0	bv-pftb2-40-2000	0.7576	bv-pftb3-40-2000	-0.0002
4	2000	40.0	bv-pftb2-40-2000	0.7114	bv-pftb3-40-2000	0.0002
5	2000	0.0	bv-pftb2-50-2000	0.9880	bv-pftb3-50-2000	-0.0010
5	2000	10.0	bv-pftb2-50-2000	0.9265	bv-pftb3-50-2000	-0.0009
5	2000	20.0	bv-pftb2-50-2000	0.8721	bv-pftb3-50-2000	-0.0006
5	2000	30.0	bv-pftb2-50-2000	0.8218	bv-pftb3-50-2000	-0.0004
5	2000	40.0	bv-pftb2-50-2000	0.7742	bv-pftb3-50-2000	-0.0001
5	2000	50.0	bv-pftb2-50-2000	0.7297	bv-pftb3-50-2000	0.0002
5	2000	60.0	bv-pftb2-50-2000	0.6895	bv-pftb3-50-2000	0.0004

min -0.0043

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The cases and calculations presented above allow the following conclusions:

- [[[PROPRIETARY - [redacted]]]]
- The temperature bias determined with CASMO-4 for a low temperature essentially bounds that determined with MCNP.
- [[[PROPRIETARY - [redacted]]]]

Additional sensitivity calculations were performed to calculate the temperature bias using CASMO-4. The results are presented in the table on page 24 entitled "Calculation of the Temperature Bias CASMO-4," and show that the temperature bias

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is 0.0043. This new temperature bias uses the above discussed methodology and is larger than the temperature bias in the LAR because the new calculations fix the moderator density to match that used in MCNP4a calculations and include calculations that cover the range of initial enrichment and burnup combinations.

This revised bias will be included in the determination of the final burnup versus enrichment values in a future supplement to the LAR.

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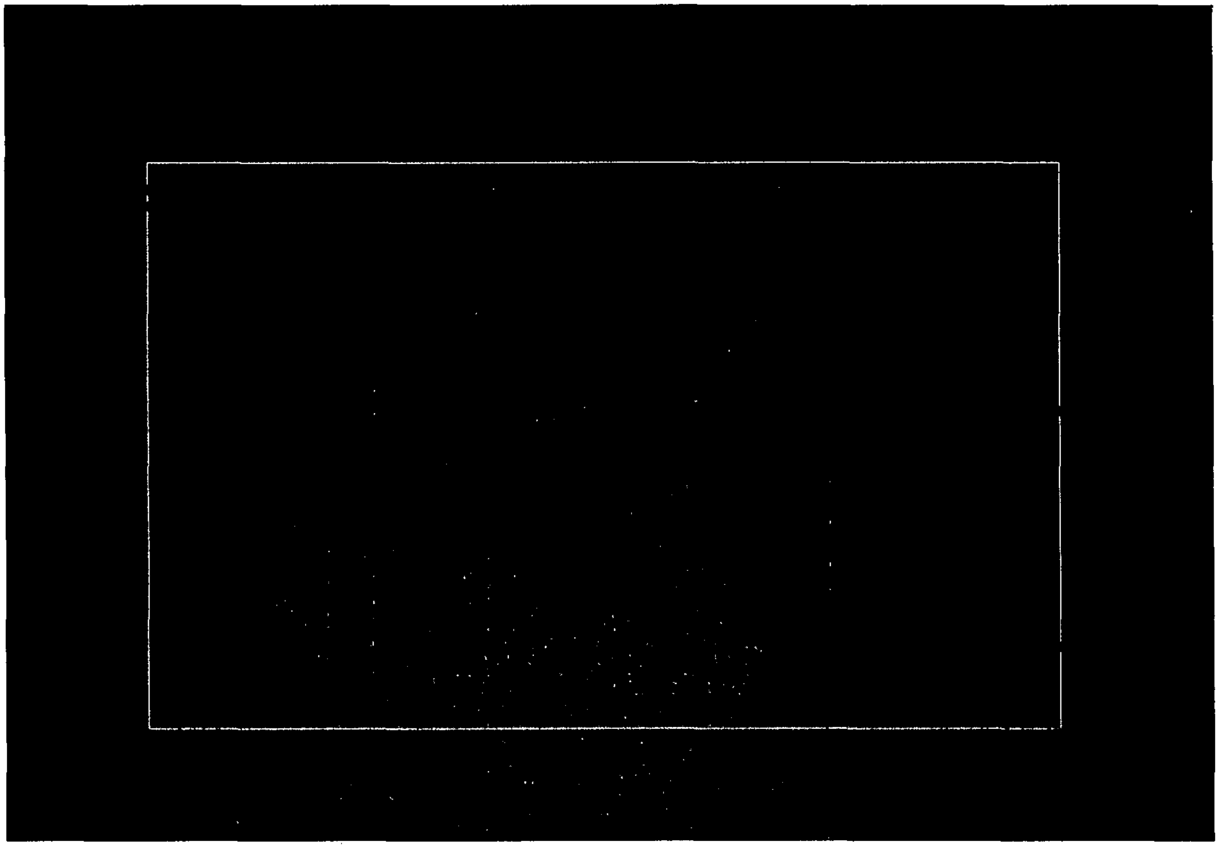

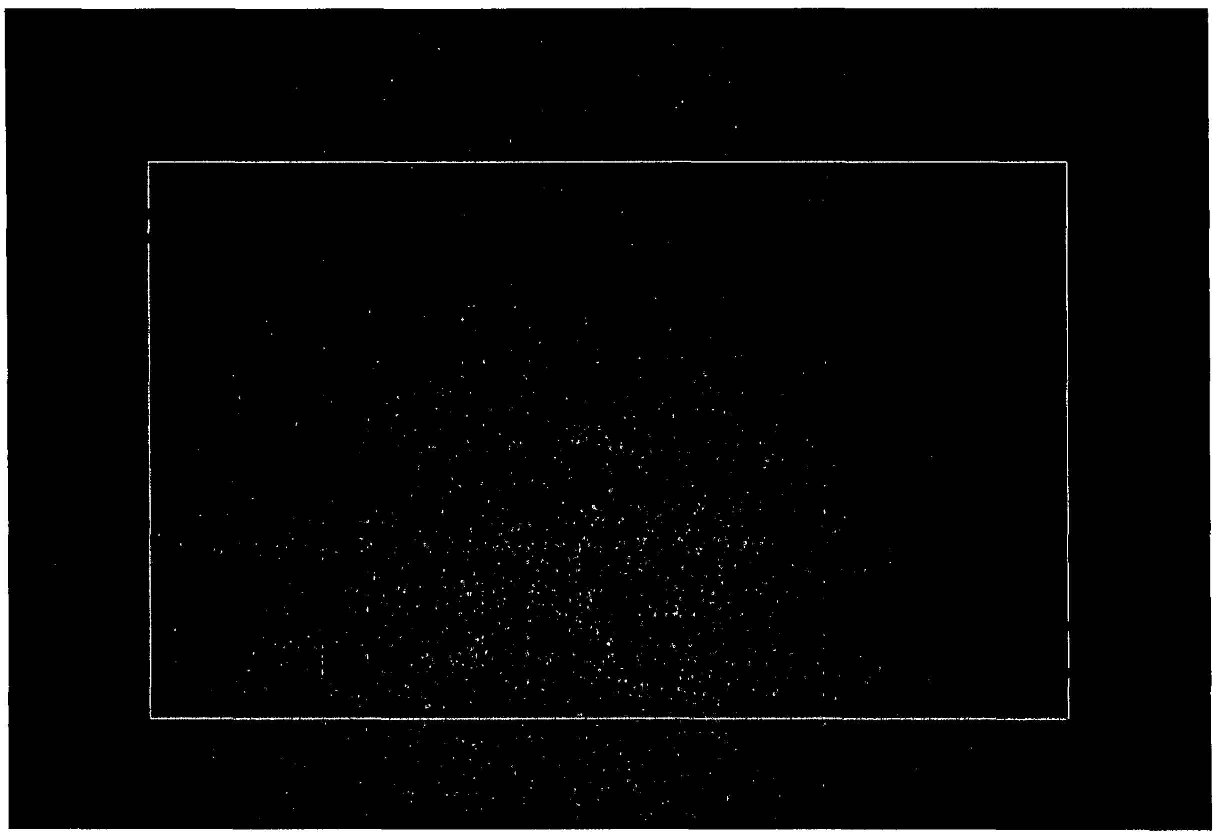

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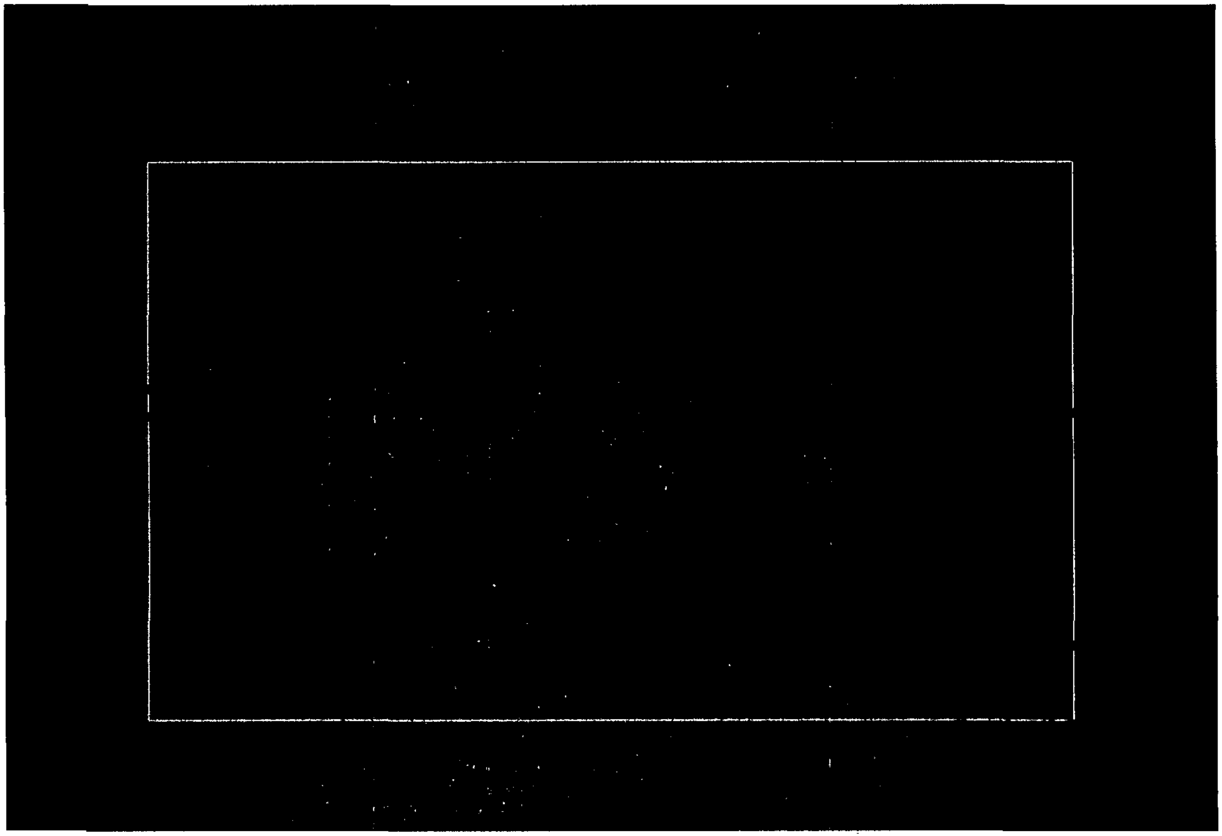

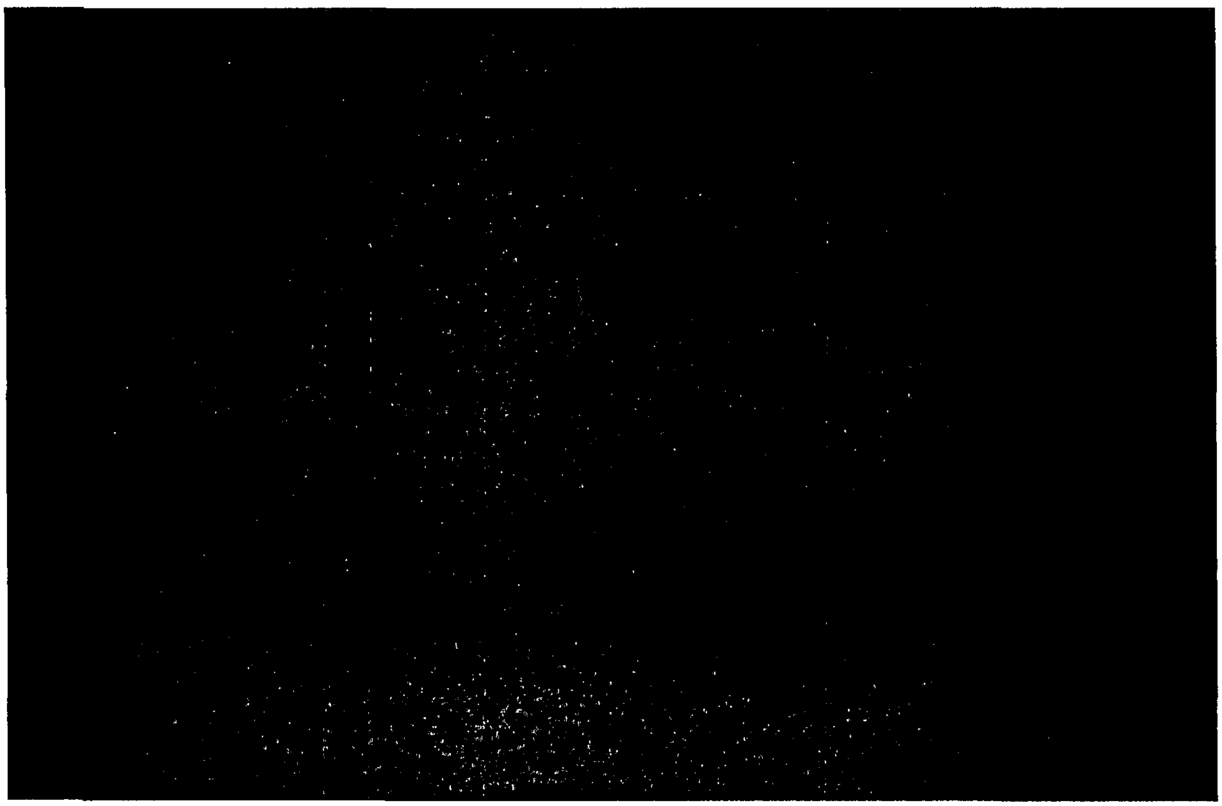

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33. It appears that the purpose of Tables 4.7.8 and 4.7.10 is to produce an estimate for the bias introduced by not modeling the IFBA and the IFBAs with WDRs during the depletion calculations. Since the storage racks do not take credit for the presence of IFBA, it would seem that this table should show only the impact of the presence of IFBA during the depletion calculations. All of the results should have been restarts in the rack geometry with IFBA B-10 and WDRs removed. Consequently all "Ref." values and associated k_∞ values at zero burnup should have been the same.

It also appears that the columns for IFBA with four and eight WDRs includes the IFBA B-10. This creates large negative Δk values in the last column. So this approach uses the IFBA B-10 to reduce the Δk values, thus indirectly taking credit for IFBA B-10. This is probably not appropriate without further justification. Justify crediting the residual IFBA B-10 in the calculation of the depletion bias.

The calculations were done only with fuel having initial enrichment of 3.4 wt%. Justify not performing the calculations for the range of initial enrichments and IFBA loadings permitted.

Response

This response is applicable to both RAI item 33 and RAI item 34.

Tables 4.7.8 through 4.7.10 in the Holtec Licensing Report calculate the reactivity bias associated with the use of integral and non-integral absorbers or reactivity control devices. The calculations shown in Table 4.7.8 through 4.7.10 are not used for any other purpose other than to determine the reactivity bias that is applied to the final k_{eff}. No credit is taken for the presence of either integral or non-integral absorbers in calculations to determine k_{eff} in the spent fuel storage rack calculations. Instead, the maximum positive difference from the results of the calculations shown in Tables 4.7.8 through 4.7.10 is applied as a reactivity bias to k_{eff}. Therefore, the restarts in the storage rack geometry are only applicable to the determination of the bias.

Non-integral reactivity devices (WABA) are separate rods that can be inserted and removed from the fuel, and, therefore, may not be physically present in the storage rack geometry. However, integral absorbers (IFBA) are by definition part of the fuel pellet. The peak reactivity effect is expected after the removal of WABA rods and after the depletion of the initial IFBA B-10 content. Therefore, the IFBA cases were calculated with the IFBA included in the composition within the rack geometry as it is physically impossible to remove. However, additional sensitivity calculations are presented here to demonstrate that removing the IFBA for the restart calculation has no impact (in CASMO-4 this is done by setting the B-10 concentration for the IFBA layer to zero). However, IFBA is not credited because the results are used to

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determine a reactivity bias that is applied as a penalty to the final k_{eff}, not in the determination of a k_{calc} or isotopic compositions.

Additional calculations were also performed and the results are presented below for the IFBA case to demonstrate that the calculations that were presented in Table 4.7.8 of the Holtec Licensing Report were the bounding configuration.

CASMO-4 Results for Reactivity Comparison of Calculations with and without IFBA

		Reference Case (no IFBA)		IFBA (IFBA B-10 removed in storage rack				IFBA			
gwd/mtu	wt%	Input File	kinf	# IFBA	Input File	kinf	Delta kinf (IFBA - no IFBA)	# IFBA	Input File	kinf	Delta kinf (IFBA - no IFBA)
10	3	bv-dep-30-0-rack-creep	0.9940	100	bv-ifba100-out-30-0	0.9955	0.0015	100	bv-ifba100-30-0-rack-creep	0.9670	-0.0271
15	3	bv-dep-30-0-rack-creep	0.9577	100	bv-ifba100-out-30-0	0.9598	0.0020	100	bv-ifba100-30-0-rack-creep	0.9499	-0.0079
20	3	bv-dep-30-0-rack-creep	0.9242	100	bv-ifba100-out-30-0	0.9263	0.0021	100	bv-ifba100-30-0-rack-creep	0.9231	-0.0011
25	3	bv-dep-30-0-rack-creep	0.8930	100	bv-ifba100-out-30-0	0.8951	0.0021	100	bv-ifba100-30-0-rack-creep	0.8941	0.0011
30	3	bv-dep-30-0-rack-creep	0.8641	100	bv-ifba100-out-30-0	0.8661	0.0020	100	bv-ifba100-30-0-rack-creep	0.8658	0.0017
45	3	bv-dep-30-0-rack-creep	0.7920	100	bv-ifba100-out-30-0	0.7935	0.0015	100	bv-ifba100-30-0-rack-creep	0.7935	0.0015
60	3	bv-dep-30-0-rack-creep	0.7430	100	bv-ifba100-out-30-0	0.7438	0.0008	100	bv-ifba100-30-0-rack-creep	0.7438	0.0008
10	4	bv-dep-40-0-rack-creep	1.0655	100	bv-ifba100-out-40-0	1.0650	-0.0004	100	bv-ifba100-40-0-rack-creep	1.0258	-0.0396
15	4	bv-dep-40-0-rack-creep	1.0298	100	bv-ifba100-out-40-0	1.0301	0.0002	100	bv-ifba100-40-0-rack-creep	1.0126	-0.0173
20	4	bv-dep-40-0-rack-creep	0.9967	100	bv-ifba100-out-40-0	0.9973	0.0006	100	bv-ifba100-40-0-rack-creep	0.9899	-0.0068
25	4	bv-dep-40-0-rack-creep	0.9655	100	bv-ifba100-out-40-0	0.9663	0.0008	100	bv-ifba100-40-0-rack-creep	0.9633	-0.0022
30	4	bv-dep-40-0-rack-creep	0.9358	100	bv-ifba100-out-40-0	0.9367	0.0009	100	bv-ifba100-40-0-rack-creep	0.9355	-0.0003
45	4	bv-dep-40-0-rack-creep	0.8550	100	bv-ifba100-out-40-0	0.8561	0.0011	100	bv-ifba100-40-0-rack-creep	0.8560	0.0010
60	4	bv-dep-40-0-rack-creep	0.7900	100	bv-ifba100-out-40-0	0.7910	0.0009	100	bv-ifba100-40-0-rack-creep	0.7910	0.0009
10	5	bv-dep-50-0-rack-creep	1.1178	100	bv-ifba100-out-50-0	1.1163	-0.0015	100	bv-ifba100-50-0-rack-creep	1.0701	-0.0477
15	5	bv-dep-50-0-rack-creep	1.0840	100	bv-ifba100-out-50-0	1.0830	-0.0010	100	bv-ifba100-50-0-rack-creep	1.0589	-0.0251
20	5	bv-dep-50-0-rack-creep	1.0524	100	bv-ifba100-out-50-0	1.0518	-0.0006	100	bv-ifba100-50-0-rack-creep	1.0398	-0.0126
25	5	bv-dep-50-0-rack-creep	1.0226	100	bv-ifba100-out-50-0	1.0223	-0.0003	100	bv-ifba100-50-0-rack-creep	1.0165	-0.0061
30	5	bv-dep-50-0-rack-creep	0.9940	100	bv-ifba100-out-50-0	0.9939	-0.0001	100	bv-ifba100-50-0-rack-creep	0.9911	-0.0028
45	5	bv-dep-50-0-rack-creep	0.9133	100	bv-ifba100-out-50-0	0.9137	0.0004	100	bv-ifba100-50-0-rack-creep	0.9134	0.0001
60	5	bv-dep-50-0-rack-creep	0.8419	100	bv-ifba100-out-50-0	0.8424	0.0005	100	bv-ifba100-50-0-rack-creep	0.8424	0.0005
10	3.8	bv-dep-38-0-rack-creep	1.0530	200	bv-ifba200-out-38-0	1.0534	0.0005	200	bv-ifba200-38-0-rack-creep	0.9878	-0.0652
15	3.8	bv-dep-38-0-rack-creep	1.0171	200	bv-ifba200-out-38-0	1.0188	0.0017	200	bv-ifba200-38-0-rack-creep	0.9907	-0.0263
20	3.8	bv-dep-38-0-rack-creep	0.9837	200	bv-ifba200-out-38-0	0.9861	0.0023	200	bv-ifba200-38-0-rack-creep	0.9747	-0.0091
25	3.8	bv-dep-38-0-rack-creep	0.9524	200	bv-ifba200-out-38-0	0.9550	0.0026	200	bv-ifba200-38-0-rack-creep	0.9506	-0.0018
30	3.8	bv-dep-38-0-rack-creep	0.9226	200	bv-ifba200-out-38-0	0.9254	0.0028	200	bv-ifba200-38-0-rack-creep	0.9237	0.0011
45	3.8	bv-dep-38-0-rack-creep	0.8426	200	bv-ifba200-out-38-0	0.8455	0.0029	200	bv-ifba200-38-0-rack-creep	0.8454	0.0028
60	3.8	bv-dep-38-0-rack-creep	0.7800	200	bv-ifba200-out-38-0	0.7823	0.0023	200	bv-ifba200-38-0-rack-creep	0.7823	0.0023
10	4.5	bv-dep-45-0-rack-creep	1.0935	200	bv-ifba200-out-45-0	1.0922	-0.0013	200	bv-ifba200-45-0-rack-creep	1.0161	-0.0775
15	4.5	bv-dep-45-0-rack-creep	1.0587	200	bv-ifba200-out-45-0	1.0586	-0.0001	200	bv-ifba200-45-0-rack-creep	1.0218	-0.0370
20	4.5	bv-dep-45-0-rack-creep	1.0263	200	bv-ifba200-out-45-0	1.0270	0.0006	200	bv-ifba200-45-0-rack-creep	1.0100	-0.0164
25	4.5	bv-dep-45-0-rack-creep	0.9958	200	bv-ifba200-out-45-0	0.9969	0.0011	200	bv-ifba200-45-0-rack-creep	0.9893	-0.0065
30	4.5	bv-dep-45-0-rack-creep	0.9665	200	bv-ifba200-out-45-0	0.9679	0.0014	200	bv-ifba200-45-0-rack-creep	0.9646	-0.0018
45	4.5	bv-dep-45-0-rack-creep	0.8851	200	bv-ifba200-out-45-0	0.8871	0.0020	200	bv-ifba200-45-0-rack-creep	0.8869	0.0018
60	4.5	bv-dep-45-0-rack-creep	0.8159	200	bv-ifba200-out-45-0	0.8180	0.0021	200	bv-ifba200-45-0-rack-creep	0.8179	0.0020
10	4.5	bv-dep-45-0-rack-creep	1.0935	200	bv-ifba200-out-45-0	1.0922	-0.0013	200	bv-ifba200-45-0-rack-creep	1.0161	-0.0775
15	4.5	bv-dep-45-0-rack-creep	1.0587	200	bv-ifba200-out-45-0	1.0586	-0.0001	200	bv-ifba200-45-0-rack-creep	1.0218	-0.0370
20	4.5	bv-dep-45-0-rack-creep	1.0263	200	bv-ifba200-out-45-0	1.0270	0.0006	200	bv-ifba200-45-0-rack-creep	1.0100	-0.0164
25	4.5	bv-dep-45-0-rack-creep	0.9958	200	bv-ifba200-out-45-0	0.9969	0.0011	200	bv-ifba200-45-0-rack-creep	0.9893	-0.0065
30	4.5	bv-dep-45-0-rack-creep	0.9665	200	bv-ifba200-out-45-0	0.9679	0.0014	200	bv-ifba200-45-0-rack-creep	0.9646	-0.0018
45	4.5	bv-dep-45-0-rack-creep	0.8851	200	bv-ifba200-out-45-0	0.8871	0.0020	200	bv-ifba200-45-0-rack-creep	0.8869	0.0018
60	4.5	bv-dep-45-0-rack-creep	0.8159	200	bv-ifba200-out-45-0	0.8180	0.0021	200	bv-ifba200-45-0-rack-creep	0.8179	0.0020
						max	0.0029			max	0.0028

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Results of the CASMO-4 Calculations of the IFBA Bias

IFBA Pins	0	0	0	100		100		128		128		200		200		
wt% U-235 * 10	30	38	50	30		50		30		50		38		50		
input file / gwd/mtu	bvdba5-30	bvdba5-38	bvdba5-50	bvifba100-30-rai	delta kinf	bvifba100-50-rai	delta kinf	bvifba128-30-rai	delta kinf	bvifba128-50-rai	delta kinf	bvifba200-38-rai	delta kinf	bvifba200-50-rai	delta kinf	max delta kinf
0.0	1.0779	1.1358	1.1958	0.8918	-0.1860	1.0450	-0.1508	0.8433	-0.2346	1.0006	-0.1952	0.8405	-0.2953	0.9276	-0.2682	-0.1508
0.1	1.0754	1.1336	1.1940	0.8924	-0.1830	1.0448	-0.1492	0.8447	-0.2306	1.0010	-0.1931	0.8423	-0.2913	0.9287	-0.2653	-0.1492
2.0	1.0560	1.1131	1.1732	0.9255	-0.1304	1.0534	-0.1197	0.8924	-0.1635	1.0190	-0.1542	0.8912	-0.2219	0.9598	-0.2134	-0.1197
4.0	1.0389	1.0967	1.1581	0.9491	-0.0899	1.0629	-0.0952	0.9272	-0.1117	1.0364	-0.1217	0.9313	-0.1654	0.9884	-0.1697	-0.0899
6.0	1.0215	1.0799	1.1427	0.9613	-0.0603	1.0678	-0.0749	0.9474	-0.0741	1.0477	-0.0950	0.9589	-0.1211	1.0092	-0.1336	-0.0603
8.0	1.0046	1.0636	1.1277	0.9654	-0.0392	1.0692	-0.0584	0.9571	-0.0475	1.0543	-0.0734	0.9767	-0.0869	1.0237	-0.1040	-0.0392
10.0	0.9885	1.0478	1.1130	0.9638	-0.0247	1.0679	-0.0451	0.9591	-0.0294	1.0570	-0.0560	0.9868	-0.0611	1.0330	-0.0800	-0.0247
11.0	0.9806	1.0402	1.1059	0.9614	-0.0192	1.0665	-0.0395	0.9580	-0.0226	1.0572	-0.0487	0.9895	-0.0508	1.0360	-0.0699	-0.0192
12.5	0.9692	1.0290	1.0955	0.9564	-0.0128	1.0633	-0.0321	0.9544	-0.0148	1.0561	-0.0393	0.9911	-0.0380	1.0387	-0.0567	-0.0128
15.0	0.9509	1.0111	1.0787	0.9452	-0.0057	1.0562	-0.0225	0.9447	-0.0062	1.0516	-0.0270	0.9888	-0.0223	1.0393	-0.0394	-0.0057
17.5	0.9331	0.9936	1.0623	0.9316	-0.0015	1.0470	-0.0153	0.9319	-0.0012	1.0443	-0.0181	0.9816	-0.0120	1.0358	-0.0266	-0.0012
20.0	0.9160	0.9767	1.0465	0.9168	0.0009	1.0363	-0.0101	0.9175	0.0016	1.0348	-0.0117	0.9714	-0.0053	1.0291	-0.0173	0.0016
22.5	0.8993	0.9602	1.0310	0.9015	0.0022	1.0246	-0.0064	0.9024	0.0031	1.0239	-0.0071	0.9592	-0.0010	1.0203	-0.0107	0.0031
25.0	0.8833	0.9441	1.0159	0.8862	0.0029	1.0121	-0.0038	0.8871	0.0039	1.0119	-0.0040	0.9458	0.0017	1.0098	-0.0061	0.0039
27.5	0.8677	0.9284	1.0010	0.8710	0.0033	0.9991	-0.0019	0.8720	0.0043	0.9993	-0.0018	0.9317	0.0033	0.9982	-0.0028	0.0043
30.0	0.8528	0.9130	0.9863	0.8562	0.0034	0.9858	-0.0006	0.8572	0.0045	0.9861	-0.0003	0.9174	0.0044	0.9858	-0.0005	0.0045
32.5	0.8384	0.8980	0.9719	0.8419	0.0035	0.9722	0.0003	0.8429	0.0045	0.9727	0.0008	0.9030	0.0050	0.9729	0.0011	0.0050
35.0	0.8247	0.8833	0.9576	0.8281	0.0035	0.9585	0.0010	0.8291	0.0044	0.9591	0.0015	0.8887	0.0054	0.9598	0.0022	0.0054
37.5	0.8116	0.8690	0.9435	0.8150	0.0034	0.9449	0.0014	0.8159	0.0044	0.9455	0.0020	0.8746	0.0056	0.9465	0.0030	0.0056
40.0	0.7991	0.8551	0.9296	0.8024	0.0033	0.9313	0.0017	0.8034	0.0042	0.9319	0.0024	0.8608	0.0057	0.9331	0.0035	0.0057
42.5	0.7873	0.8417	0.9158	0.7906	0.0032	0.9178	0.0020	0.7914	0.0041	0.9184	0.0026	0.8474	0.0058	0.9197	0.0039	0.0058
45.0	0.7763	0.8287	0.9023	0.7794	0.0031	0.9044	0.0021	0.7802	0.0039	0.9051	0.0028	0.8344	0.0057	0.9065	0.0042	0.0057
47.5	0.7659	0.8162	0.8890	0.7688	0.0030	0.8912	0.0022	0.7696	0.0038	0.8919	0.0029	0.8219	0.0057	0.8934	0.0044	0.0057
50.0	0.7562	0.8043	0.8760	0.7590	0.0028	0.8783	0.0023	0.7598	0.0035	0.8789	0.0030	0.8098	0.0056	0.8805	0.0045	0.0056
52.5	0.7473	0.7929	0.8632	0.7499	0.0027	0.8655	0.0023	0.7506	0.0034	0.8662	0.0030	0.7983	0.0055	0.8678	0.0046	0.0055
55.0	0.7390	0.7821	0.8507	0.7415	0.0025	0.8531	0.0024	0.7421	0.0032	0.8538	0.0031	0.7873	0.0053	0.8554	0.0046	0.0053
57.5	0.7314	0.7718	0.8386	0.7337	0.0023	0.8410	0.0024	0.7343	0.0030	0.8417	0.0031	0.7770	0.0051	0.8433	0.0046	0.0051
60.0	0.7244	0.7622	0.8269	0.7266	0.0022	0.8292	0.0024	0.7272	0.0028	0.8299	0.0031	0.7671	0.0049	0.8315	0.0046	0.0049

max 0.0058

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With respect to RAI 34, additional calculations were performed with the WABA cases to demonstrate that the peak reactivity effect is the same even when the WABA rods are left in the rack model. This is done because in the LAR Table 4.7.11 calculations the WABA rods were left in the rack model during restart calculations. Calculations were performed with the WABA removed during the restart to demonstrate that the calculations in Table 4.7.11 (maximum value of 0.0062) captured the bounding result.

Results of the CASMO-4 Calculations of WABA Bias Dependence on Number of WABA Rods and Fuel Enrichment (WABA removed for rack restart)

WABA Rods	0	12	20	n/a	0	12	16	n/a	
Enrichment wt% U-235	2.6				3.0				
Input File	bvdb5-26	bvwaba12-26-rai	bvwaba20-26-rai		bvdb5-30	bvwaba12-30-rai	bvwaba16-30-rai		
Burnup (GWD/MTU)	**Ref**	**k-inf**	**k-inf**	**Delta-k (max - ref)**	**Ref**	**k-inf**	**k-inf**	**Delta-k (max - ref)**	**Max Delta-k**
0.0	1.0400	1.0400	1.0400	0.0000	1.0779	1.0779	1.0779	0.0000	0.0000
0.1	1.0373	1.0373	1.0374	0.0000	1.0754	1.0754	1.0754	0.0000	0.0000
2.0	1.0192	1.0198	1.0203	0.0011	1.0560	1.0564	1.0566	0.0006	0.0011
4.0	1.0022	1.0034	1.0043	0.0021	1.0389	1.0398	1.0401	0.0012	0.0021
6.0	0.9849	0.9867	0.9879	0.0030	1.0215	1.0229	1.0233	0.0018	0.0030
8.0	0.9680	0.9704	0.9719	0.0038	1.0046	1.0065	1.0070	0.0024	0.0038
10.0	0.9520	0.9547	0.9565	0.0045	0.9885	0.9907	0.9913	0.0029	0.0045
11.0	0.9442	0.9470	0.9489	0.0047	0.9806	0.9829	0.9836	0.0030	0.0047
12.5	0.9328	0.9359	0.9379	0.0051	0.9692	0.9717	0.9725	0.0033	0.0051
15.0	0.9147	0.9182	0.9205	0.0058	0.9509	0.9538	0.9547	0.0038	0.0058
17.5	0.8972	0.9009	0.9034	0.0062	0.9331	0.9363	0.9373	0.0041	0.0062
20.0	0.8804	0.8840	0.8863	0.0060	0.9160	0.9191	0.9200	0.0041	0.0060
22.5	0.8642	0.8676	0.8698	0.0055	0.8993	0.9023	0.9032	0.0039	0.0055
25.0	0.8488	0.8519	0.8540	0.0052	0.8833	0.8861	0.8869	0.0037	0.0052
27.5	0.8340	0.8370	0.8389	0.0049	0.8677	0.8704	0.8712	0.0035	0.0049
30.0	0.8200	0.8227	0.8246	0.0047	0.8528	0.8554	0.8562	0.0034	0.0047
32.5	0.8066	0.8093	0.8111	0.0044	0.8384	0.8409	0.8417	0.0033	0.0044
35.0	0.7940	0.7965	0.7983	0.0042	0.8247	0.8271	0.8279	0.0032	0.0042
37.5	0.7822	0.7846	0.7862	0.0040	0.8116	0.8139	0.8146	0.0031	0.0040
40.0	0.7712	0.7734	0.7750	0.0038	0.7991	0.8013	0.8021	0.0030	0.0038

max 0.0062

With respect to the range of enrichments and device loading, the fuel assemblies used at BVPS-2 have either had no integral or non-integral reactivity control devices or have had one of the following configurations with respect to integral and non-integral reactivity control devices: water displacement rods (WDR), WABA, IFBA, and IFBA and WDR configurations. No other types have been used or are anticipated to be used. As committed to in the letter dated March 18, 2010, a process is being established to ensure that the design features and operating parameters of fuel used in the future at BVPS-2 are consistent with the assumptions of the criticality analysis.

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The following table summarizes the use of integral and non-integral absorbers, and includes assembly enrichment for each case:

Listing of the Range of Integral and Non-integral Absorber Configurations

Region	Enrichment wt% U-235	(Integral or Non-integral)
1	2.105	0
2, 2A	2.602	12, 16, 20 WABA locations
3	3.099	12, 16 WABA locations
4A, 4B	3.407	100 IFBA and 4 WDR
	3.407	128 IFBA
	3.407	128 IFBA and 8 WDR
	3.798	100 IFBA and 4 WDR
	3.798	128 IFBA
	3.798	128 IFBA and 4 WDR
	3.798	32 IFBA
	3.798	64 IFBA
5A, 5B, 5C	3.599	128 IFBA
	3.820	128 IFBA
	4.201	0, 100, 128 IFBA
6A, 6B	3.607	64, 80, 128 IFBA
	4.015	0, 80 IFBA
7A, 7B	3.604	0, 48, 128 IFBA
	4.008	48, 80 IFBA
8A, 8B	3.608	64, 80, 128 IFBA
	4.210	64, 128 IFBA
9A, 9B	4.012	64, 128 IFBA
	4.401	64, 104, 128 IFBA
10A, 10B	3.804	80, 104, 128 IFBA
	4.193	64 IFBA
11A, 11B	4.201	0, 80, 128 IFBA
	4.801	32, 104 IFBA
12A, 12B	4.201	128 IFBA
	4.795	48, 64, 104, 128 IFBA
13A, 13B	4.397	48, 104 IFBA
	4.946	48, 104 IFBA
14A, 14B	4.196	32, 104 IFBA
	4.787	48, 104 IFBA
15A, 15B	4.600	32, 128 IFBA
	4.950	80, 104, 128 IFBA
16A, 16B	4.400	64, 104, 128 IFBA
	4.950	64, 104 IFBA
17A, 17B	4.200	80, 104, 128 IFBA
	4.800	64, 80 IFBA

NONPROPRIETARY VERSION OF THE RESPONSE

Summarizing the above table:

WABA enrichment range:	2.602 to 3.099 weight percent U-235
WDR enrichment range:	3.407 to 3.798 weight percent U-235
IFBA enrichment range:	3.407 to 4.950 weight percent U-235

Based on the data presented in the above table, the calculation results shown in Tables 4.7.8 through 4.7.10 cover the range of device loading and fuel assembly enrichments. Therefore, the calculation results in Tables 4.7.8 through 4.7.10 present the subset of possibilities that demonstrate the bounding configurations. Based on the information presented in the above table, initial enrichment and integral and non-integral configurations were selected to show trends in reactivity effect with respect to loading and enrichment, and also to bound the range of possible configurations. Table 4.7.10 shows the bounding IFBA case, which includes 8 WDRs and 128 IFBA pins. This is the lowest enrichment, maximum loading case and is bounding of all IFBA and WDR configurations. However, as shown in Table 4.7.11, the WABA loading is more limiting and was therefore selected for determination of the bias. The bias itself was selected from this table as the maximum reactivity difference case, at 17.5 GWD/MTU.

Based on the information presented in the table above entitled "Listing of the Range of Integral and Non-integral Absorber Configurations," the calculation results in Table 4.7.8 through 4.7.10 were performed to determine the reactivity effect of the integral and non-integral absorbers with the objective of determining a reactivity bias to be applied to all fuel assemblies. The analysis was performed in this manner to be conservative. This is conservative because not all fuel used integral or non-integral absorbers and the IFBA actually results in a negative reactivity effect for fuel that does not have sufficient burnup. Furthermore, this is conservative because as can be seen from the above table, only fuel regions 2 and 3 used WABA, and the WABA sensitivity calculations showed the greatest positive reactivity effect in the storage racks and set the reactivity bias higher than what would normally be applied for the WDR, IFBA, and IFBA/WDR cases. Thus, the final k_{eff} includes fresh fuel in the calculation, and this reactivity bias is also being applied to fresh fuel.

Finally, additional clarification is provided to confirm that the reactivity bias calculations were bounding of the part length absorber case. Sensitivity calculations were done with part length IFBA and part length WABA rods. The guidance found in NUREG/CR-6760, "Study of the Effect of Integral Burnable Absorbers for PWR Burnup Credit," concludes that part length IFBA may bound the full length IFBA in the spent fuel storage rack. The study performed in NUREG/CR-6760 determines the spent fuel isotopic composition for fuel with and without IFBA. These compositions are then modeled with a 3D code like MCNP with a segmented axial burnup profile. The sensitivity study performed for this response follows a similar methodology. [[[PROPRIETARY - [redacted]

NONPROPRIETARY VERSION OF THE RESPONSE

[redacted]]]] The results show that cases using full length IFBA and WABA rods bound the cases that use part length IFBA and WABA rods.

In evaluating the studies performed in NUREG/CR-6760 for both full-length and part-length IFBA rods, it appears that the reason that part-length IFBA rods produced a larger (more positive) IFBA reactivity effect was that there was considerable residual IFBA remaining in the ends of the full-length IFBA rods, even at high assembly-average -burnups (i.e., the IFBA never completely burned out of the full-length rods because of the low fluxes at the ends of the rods). In fact, this residual effect was sufficiently large that the NUREG/CR-6760 study showed a negative IFBA reactivity effect at all burnups for full-length IFBA rods (in Table 10 of the NUREG). For this criticality analysis, the IFBA reactivity effect is calculated using a two-dimensional model in which there are no "end effects", since the assembly is essentially modeled as infinite in the axial direction. In this two-dimensional model, the IFBA completely burns out. With no residual IFBA present, the positive IFBA reactivity effect is maximized. Therefore, the two-dimensional model used in this analysis to determine the IFBA reactivity effect will produce bounding results.

NONPROPRIETARY VERSION OF THE RESPONSE

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NONPROPRIETARY VERSION OF THE RESPONSE

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34. Table 4.7.11 has a problem that is similar to that observed in Table 4.7.10. The k_∞ values presented from 0 to 15 GWd/MTU appear to include the worth of the WABA rods. In Table 4.7.11, it is clearly not appropriate to include the effects of the presence of the WABA rods in the bias calculations. Table 4.7.11 should have shown the impact of depletion with WABAs present, but the k_∞ values presented should have been from restarts in rack geometry with WABAs removed.

Revise the analysis to correctly calculate the bias associated with depleting fuel with WABA present or justify not doing so. Secondly, justify not performing the calculations for the full range of initial enrichments and WABA loadings permitted.

Response

Information is provided in the response to RAI item 33, above.