ATTACHMENT 2

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HOLTEC INTERNATIONAL

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CRITICALITY SAFETY EVALUATION FOR THE NINE MILE POINT 2 RACK INSTALLATION PROJECT

FOR

NIAGARA MOHAWK POWER CORPORATION

by

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Summary of Revisions

Revision 1:

This revision incorporates the comments made by Carl Lepine of Nine Mile Point Unit 2 regarding bundle manufacturing tolerances and interaction between new and old racks.

Table of Contents

1.0 INTRODUCTION

This report is the calculation package to support the criticality analysis in the 50.59 report for Nine Mile Point Unit 2 (NMP2) rack installation project. This report describes in detail the criticality analysis performed to ensure the acceptability of the NMP2 fuel to be stored in the new Holtec spent fuel storage racks.

2.0 METHODOLOGY

The analytical methodology used in this report consists primarily of using two computer codes to perform the calculations, CASMO-4 [1-4] and MCNP-4A [5]. CASMO-4 was used to perform the in-core burnup calculations and then used to restart the burned fuel assemblies in the standard cold core geometry (SCCG) and in the storage rack. The core multiplication factors calculated in the rack configuration were used to determine the acceptable storage criteria. CASMO-4 was also used to calculate the reactivity effect of manufacturing tolerances. MCNP-4A was used to verify CASMO-4 results for reference cases and to perform large three-dimensional rack calculations. MCNP-4A was also used to determine the effect of eccentric fuel positioning with the rack.

Since CASMO-4 is a two-dimensional deterministic code, the models are infinite in the axial direction. Therefore the core multiplication factor being calculated is actually the infinite multiplication factor, k_{inf} (k_{eff} is used in this report when axial leakage is included in the model). For a reference case, the CASMO-4 results were compared to MCNP-4A results for verification. This was necessary for two reasons:

1. Since it is not possible to *fully* benchmark CASMO-4 against critical experiments, it had to be compared to MCNP-4A, which has been fully benchmarked, to verify the CASMO calculations and determine if a calculational correction factor was necessary.

2. It is standard practice at Holtec to compare criticality results from one code to results from another independent code for the purpose of validation.

A detailed discussion of the results from the MCNP-4A to CASMO-4 comparison is provided in Section 7.3.

2.1 Code Validation

As stated, CASMO-4 was used for burnup calculations during in-core operations and criticality calculations of rack configurations. As proof of its acceptability in this application, CASMO-4 has been verified [3,4] against Monte Carlo calculations and a few critical experiments.

Benchmarking of MCNP-4A against critical experiments has been performed at Holtec. The results of the benchmark calculations, presented in Appendix A, indicate a bias of 0.0009 ± 0.0011 for MCNP-4A over a wide range of compositions and geometries, evaluated at the 95% probability, 95% confidence level [6]. The MCNP-4A bias and calculational statistics were included in the MCNP-4A to CASMO-4A comparison which is discussed in Section 7.3.

3.0 ACCEPTANCE CRITERIA

The Holtec high-density spent fuel storage racks for the Nine Mile Point 2 Nuclear Power Station are designed to assure that the neutron multiplication factor (k_{eff}) is equal or less than 0.95 with the racks fully loaded with fuel of the highest anticipated reactivity and the pool flooded with unborated water at a temperature corresponding to the highest reactivity. The maximum calculated reactivity includes a margin for uncertainty in reactivity calculations and in manufacturing tolerances, statistically combined, giving assurance that the true k_{eff} will be equal to or less than 0.95 with a 95% probability at a 95% confidence level. Reactivity effects of abnormal and accident conditions have also been evaluated to assure that under credible abnormal and accident conditions, the reactivity will be maintained less than 0.95. The purpose of the present analysis is to confirm the acceptability of the rack design for the designated fuel assembly designs.

Applicable codes, standards and regulations, or pertinent sections thereof, include the following:

- *Code of Federal Regulations,* Title 10, Part 50, Appendix A, General Design Criterion 62, "Prevention of Criticality in Fuel Storage and Handling".
- USNRC Standard Review Plan, NUREG-0800, Section 9.1.2, Spent Fuel Storage, Rev. 3 – July 1981.

- USNRC Letter of April 14,1978 to all Power Reactor Licensees – OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications, including modification letter dated January 18, 1979.
- USNRC Regulatory Guide 1.13, Spent Fuel Storage Facility Design Basis, Rev. 2 (proposed), December 1981.
- ANSI/ANS-8.17-1974, Criticality Safety Criteria for the Handling, Storage and Transportation of LWR Fuel Outside Reactors.
- L. Kopp, Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants" USNRC Internal Memorandum from L. Kopp to Timothy Collins, August 19, 1998.

USNRC guidelines and the applicable ANSI standards specify that the maximum *effective* multiplication factor, k_{eff}, including uncertainties, shall be less than or equal to 0.95. The *infinite* multiplication factor, k_{inf}, is calculated for a radially and axially infinite array, neglecting neutron loss due to leakage from the actual storage rack, and therefore is a higher and more conservative value.

4.0 ASSUMPTIONS

To assure that the true reactivity will always be less than the calculated reactivity, the following conservative design criteria and assumptions were made:

- The racks were assumed to contain the most reactive fuel authorized to be stored in the facility without any control rods or any uncontained burnable poison.
- Moderator in the spent fuel pool rack is pure, unborated water at a temperature within the design basis range corresponding to the highest reactivity.
- Criticality safety analyses are based upon the infinite multiplication factor (k_{inf}), i.e., lattice of storage racks is assumed infinite in all directions. No credit is taken for axial or radial neutron leakage, except in the assessment of certain abnormal or accident conditions where neutron leakage is inherent.

- Neutron absorption in minor structural members is neglected, i.e. spacer grids are replaced by water.
- In-core depletion calculations assume conservative operating conditions and include voids due to boiling during in-core BWR operations.
- Uniform average enrichments were used for all fuel pins in the fuel assembly, which has been found to be conservative compared to calculations with distributed enrichments. This is a conservative assumption.

5.0 INPUT DATA

5.1 Fuel Assembly Specifications

The design basis fuel assembly, chosen from the fuel assembly designs present at the NMP2 site [9], is a standard GE-14 assembly with UO_2 rods clad in Zircaloy.

Other designs were also evaluated, as listed below.

- A GE-6/6B design with 62 fuel rods and 2 water rods
- A GE-9B design 8x8 assembly with 60 fuel rods and 1 large central water rod.
- A GE-11 design 9x9 assembly with 74 fuel rods and 2 large water rods.
- A GE-13 design 9x9 assembly with 74 fuel rods and 2 large water rods.

As the GE-11 and GE-13 are identical in regards to physical characteristics that are important to criticality, they are not modeled separately. The GE-11/GE-13 and the GE-14 fuel designs have partial length fuel rods, which would result in a planar region of higher reactivity above the partial length rods, if all of the parameters were the same. For conservatism, this region was used for the design basis calculations for the GE-11/GE-13 and GE-14 assemblies. Design parameters for the five fuel assembly design types considered in this evaluation are summarized in Table 1.

5.2 Storage Rack Cell Specifications

The storage cell characteristics were taken from the following Holtec drawings. The information on these drawings is summarized below.

- Holtec Drawing 3307, Sheet 2, Rev. 2
- Holtec Drawing 3307, Sheet 3, Rev. 1
- Holtec Drawing 3307, Sheet 4, Rev. 1

The tolerances on the box wall stainless steel thickness are taken from ASME standard for sheet material.

The high-density storage rack cells consist of an egg-crate structure, a cell of which is illustrated in Figure 1, with fixed neutron absorber material (Boral) of 0.0216 g/cm^2 nominal ( ) boron-10 areal density positioned between the fuel assembly storage cells in a 0.085-inch channel. This arrangement provides a nominal center-to-center lattice spacing of 6.18 inches. Manufacturing tolerances used in evaluating uncertainties in reactivity are indicated in Section 7.2. The 0.075-inch stainless steel box that defines the fuel assembly storage cell has a nominal inside dimension of 5.985 inches. This allows adequate clearance for inserting/removing the fuel assemblies, with or without the Zircaloy flow channel. The Boral panels are 145 inches long, 4.75 inches wide and 0.075 inches thick. Boral panels are used on only one exterior surface of the modules that face each other across the small water gap between the modules.

6.0 COMPUTER CODES

In the fuel-rack evaluation, criticality analysis of the high-density spent fuel storage racks were performed with the CASMO-4 [1] code, a two-dimensional multi-group transport code. Independent verification calculations were made with the MCNP-4A code [5] (a continuous energy Monte Carlo code developed by the Los Alamos National Laboratory).

Benchmark calculations are presented in Appendix A of this report and indicate a bias of 0.0009 ± 0.0011 for MCNP. In the geometric model used in the calculations, each fuel rod and its cladding were explicitly described and reflecting boundary conditions (zero neutron current) were used in the axial direction and at the equivalent centerline of the Boral and steel plate between storage cells. These boundary conditions have the effect of conservatively creating an infinite array of storage cells in all directions.

The CASMO4 computer code was used as the primary method of analysis as well as a means of evaluating small reactivity increments associated with manufacturing tolerances. Burnup calculations were also performed with CASMO4, using the restart option to describe spent fuel in the storage cell. MCNP-4A was used to assess the reactivity consequences of eccentric fuel positioning and abnormal locations of fuel assemblies that required a three-dimensional model.

7.0 CALCULATIONS

This section will describe the calculations that were used to determine the acceptable storage criteria for the BWR racks provided by Holtec International. Unless otherwise stated, all calculations assumed nominal characteristics for the fuel and the fuel storage cells. The effect of the manufacturing tolerances is accounted for with a reactivity adjustment as described below.

As discussed in Section 2.0, CASMO-4 was the primary code used in the calculations. MCNP-4A was used to check CASMO-4 for reference cases and to perform certain calculations which are not possible with CASMO-4 (e.g., eccentric fuel positioning).

Since CASMO-4 is a two-dimensional code, the fuel assembly hardware above and below the active fuel length is not represented. The three-dimensional MCNP models that included axial leakage did not include the fuel assembly hardware in the model. Instead, 30 cm of water was conservatively modeled above and below the active fuel length.

Figure 2 is a plot of the calculational model used in MCNP-4A. Figure 2 was created with the two dimensional plotter in MCNP-4A and clearly indicates the explicit modeling of the fuel rods in each assembly.

The goal of the BWR calculations was to verify that the fuel assemblies listed in Table 1 are acceptable for storage with maximum planar average enrichments less than or equal 4.95 wt% ^{235}U. Additionally, the limiting k_{inf} in the standard cold core geometry (SCCG) for the assemblies in Table 1 must be determined to ensure that the k_{inf} in the rack is less than or equal to 0.95. SCCG is defined as an infinite array of fuel assemblies on a 6 inch lattice spacing at 20° C, without any control absorber or voids.

The general methodology was to perform in-core depletion calculations for these assemblies using CASMO-4 and then analytically restart the assemblies in the rack geometry and in the SCCG geometry. The burnup at the limiting k_{inf} in the SCCG was determined and then the k_{inf} in the rack was calculated at this burnup. Reactivity allowances for manufacturing tolerances, depletion uncertainty and for possible differences with vendor calculations were added to the rack k_{inf} and the result compared to the regulatory limit of 0.95. Since the final k_{inf} was less than the regulatory limit, storage of the assemblies in Table 1, with planar average enrichments less than or equal to 4.95 wt% ^{235}U and with a maximum SCCG k_{inf} less than or equal to 1.32, is acceptable.

7.1 Reference Fuel Assembly

The GE-11/GE-13 and GE 14 assemblies both contain some partial length fuel rods. Since CASMO-4 is a two-dimensional code it is not possible to properly represent the three-dimensional nature of a fuel assembly which contains partial length rods. Therefore two separate calculations were performed for the GE-11/GE-13 and the GE-14 assembly types. The first calculation replaces the partial length fuel rods with full length fuel rods. The second calculation removes the partial length fuel rods and replaces them with water.

Even though all the fuel assemblies listed in Table 1 were evaluated for storage acceptability, a reference fuel assembly was determined for miscellaneous calculations (e.g. tolerance calculations). In order to determine the reference assembly, all fuel assemblies were analyzed in the rack configuration at 0 burnup (fresh) and at the burnup corresponding to a k_{inf} in the SCCG of 1.32 for an enrichment of 4.95 wt% ^{235}U. The results of this comparison are presented on Worksheet C.2 in Appendix C. These results indicate that the GE-14 assembly with partial length rods replaced by water is the most reactive assembly either when fresh or at a burnup corresponding to a k_{inf} of 1.32 in the SCCG. Therefore, the GE-14 assembly with the partial length fuel rods replaced by water, was chosen as the reference assembly for the various CASMO-4 analyses.

7.2 *Manufacturing Tolerances and Burnup Uncertainty*

In the calculation of the final k_{inf}, the effect of manufacturing tolerances on reactivity must be included. CASMO-4 was used to perform these calculations. The reference fuel assembly, with an initial nominal enrichment of 4.95 wt% ^{235}U was used for these studies. To determine the Δk associated with a specific manufacturing tolerance, the reference k_{inf} was compared to the k_{inf} from a calculation with the tolerance included. All of the Δk values from the various tolerances are statistically combined (square root of the sum of the squares) to determine the final reactivity allowance for manufacturing tolerances. Only the Δk values in the positive direction (increasing reactivity) were used in the statistical combination.

The following is a list of the manufacturing tolerances that were included.

- UO_2 density - ± [ ]% of nominal density.
- Cell box ID and Pitch[1] - ± [ ] inches.
- Box wall thickness - ± [ ] inches.
- Boral width – modeled at the minimum width ([ ]).
- Enrichment – ± [ ] wt% ^{235}U.

Other manufacturing tolerances of the fuel assembly such as fuel pin pitch, pellet O.D., clad thickness, etc. have a negligible impact on reactivity and therefore are not included. Worksheet C.3 in Appendix C shows the k_{inf} from the reference case as compared to the k_{inf} from the cases with the increased and decreased UO_2 and ^{235}U enrichment. Worksheet C.3 also shows the k_{inf} from the reference case as compared to the k_{inf} from the cases with the manufacturing tolerances included. The Δk was calculated for a fresh assembly and at a burnup corresponding to a k_{inf} in the SCCG of 1.32. Conservatively, the largest uncertainty from either the fresh or burned condition was used in the statistical combination of uncertainties.

CASMO-4 was used to perform the depletion calculations. Since there are no depleted fuel critical experiments with which to benchmark CASMO-4's depletion calculations, a reactivity

[1] As the Cell Box I.D. and the Pitch are interrelated, a change in one of these parameters will necessarily change the other parameter. Therefore, a [ ] change in the Box I.D. results in a [ ] change in the pitch.

allowance for uncertainty in depletion is needed. This uncertainty is statistically combined with the uncertainties from the manufacturing tolerances. Conservatively, 5% of the reactivity decrement from 0 burnup (fresh fuel) to the burnup corresponding to a k_{inf} in the SCCG of 1.32 is used as the reactivity allowance for depletion. Worksheet C.2 in Appendix C shows the reactivity decrement for the Holtec racks. The largest reactivity decrement for the fuel assemblies analyzed was used in the calculation of the total uncertainty.

Worksheet C.8 in Appendix C shows the final statistical combination of the reactivity uncertainties from the consideration of the manufacturing tolerances and depletion.

7.3 CASMO-4 to MCNP-4A Comparison

Since CASMO-4 cannot be benchmarked against a majority of the benchmarked critical experiments, the reference CASMO-4 calculations were compared to the MCNP-4A calculations for validation and to determine if any code to code correction factor is necessary. MCNP-4A has been thoroughly benchmarked against critical experiments as described in Appendix A and is therefore considered the reference code to which reference CASMO-4 calculations are compared. The CASMO-4 calculations are two-dimensional models, infinite in height with reflecting boundary conditions that simulate an infinite array of assemblies. Additionally, the MCNP-4A models differ slightly from the CASMO-4 model in the representation of the Boral and the rack cell wall, due to the limited geometry capabilities of CASMO-4. For purposes of this comparison, all fuel assembly types were assumed to have a nominal bundle average enrichment of 4.95 wt% ^{235}U with no gadolinium.

The MCNP-4A calculated k_{inf} values were combined with the bias (from Appendix A) and the calculational statistics for the comparison. The MCNP calculational statistics, for MCNP-4A, were statistically combined with the bias uncertainty from Appendix A.

The results of the comparison are presented on Worksheet C.5 in Appendix C. These results show that the CASMO-4 models are slightly non-conservative when compared to the MCNP-4a models. Therefore, the maximum positive correction factor is applied to determine the maximum k_{eff} on Worksheet C.8 and C.9 in Appendix C.

7.4 *Temperature Effect*

The effect on reactivity of increasing the spent fuel pool temperature was evaluated using CASMO-4. The results are presented on Worksheet C.4 in Appendix C. The highest temperature evaluated was 120° C (248° F). A case including 10% void was also evaluated at this temperature in order to simulate boiling at the bottom of the spent fuel pool. These results clearly indicate that the spent fuel pool temperature coefficient of reactivity is always negative.

7.5 *Effect of the Channel and Eccentric Fuel Positioning*

7.5.1 Channel Removal and Channel Thickness

The BWR fuel assemblies usually have a zircaloy channel attached to the fuel bundle. However, it can not be guaranteed that this channel will be present during storage. Therefore, MCNP-4A calculations were performed to verify that including the channel in the final analysis in conservative. The results of this study are presented on Worksheet C.1 in Appendix C.

Additionally, the channels do not have a uniform thickness around the entire assembly. Rather, the channels are typically thinner on the sides and thicker on the corners. To reduce the complexity of the model, the MCNP-4a and CASMO-4 models assume that the channels are uniformly thick and the corners are square (rather than rounded). To ensure that the models are conservative, the effect of the channel thickness on reactivity was determined. The results of this study are on Worksheet C.1 in Appendix C and show that by modeling the channel with a uniform maximum thickness, the results are conservative.

7.5.2 Channel Bulging

Another possible reactivity effect results from the potential bulging of the zircaloy channel, which moves the channel wall outward toward the Boral absorber. It was conservatively assumed that the maximum bulging that could occur would result in the bowed channel touching the cell walls. Since this would not occur over the entire length of the channel, the model assumed that the entire channel was enlarged so that the mid-point of the channel wall was placed equidistant between the channel outer dimension and the cell wall. The calculations to determine the channel I.D. and O.D., while preserving the volume of Zircaloy, are shown on Worksheet C.7 in Appendix C. This reactivity effect was evaluated using MCNP-4a and comparison with the reference case (no channel bulging) is shown on Worksheet C.1 in

Appendix C. The MCNP-4A calculation was performed using the GE-14 assembly with the partial length fuel rods replaced by water. This positive reactivity allowance is conservatively added to the calculated k_{inf} instead of being statistically combined with the other reactivity uncertainties.

7.5.3 Eccentric Positioning

The fuel assembly is assumed to be normally located in the center of the storage rack cell and in the BWR rack there are bottom fittings and spacers that mechanically restrict lateral movement of the fuel assemblies. Nevertheless, MCNP-4A calculations were made with the fuel assemblies assumed to be in the corner of the storage rack cell. These calculations indicate that eccentric positioning results in a negligible increase in reactivity as shown on Worksheet C.1 in Appendix C. The highest reactivity, therefore, corresponds to the reference design with the fuel assemblies positioned at the center of the storage cells.

7.6 Comparison to Vendor Calculations

CASMO-4 was used to perform depletion calculations and to calculate the k_{inf} in the SCCG. Since the fuel vendor also calculates the k_{inf} in the SCCG with potentially different analytical techniques, a reactivity allowance for comparisons between vendor calculations and Holtec calculations is applied. Conservatively, a flat reactivity allowance of 0.01 Δk is used. This value is not statistically combined with the other uncertainties but rather added directly to the calculated k_{inf}. The allowance also is used to encompass any potential differences between the SCCG calculations performed here and by the vendor.

7.7 Boral Height Reduction

MCNP-4A calculations were performed in which the Boral height was lowered inches below the top of the active fuel (which is identical to raising the Boral height above the bottom of the active fuel). These calculation are infinite in the lateral direction and therefore are highly conservative. The results of these calculations are presented on Worksheet C.1 in Appendix C and show that extending the active fuel region of a fuel assembly above or below the Boral (up to inches) has a negligible impact on the reactivity of the rack.

7.8 Final Calculations

7.8.1 Maximum k_{inf} in the Standard Cold Core Geometry

It is conventional practice for the fuel vendor to, in developing a specific assembly design, to provide values for k_{inf} in the SCCG for each planar (axial) region of significantly different compositions or arrangements. These k_{inf} values are provided at 0% void (core inlet), 40% void (core average), and 70% void (exit condition). The 40% core average is the most meaningful since the 0% and 70% void calculations are applicable only to the ends of the assemblies (small volume and high leakage). The initial design Gd_2O_3 loading enters into the fuel vendor's calculations of the burnup at which the peak reactivity occurs. At this burnup, the gadolinium is essentially depleted. Consequently, calculations of the reactivity in the storage rack do not need to include gadolinium, but only the average enrichment. Calculations are provided herein illustrating this fact and correlating the k_{inf} in the storage rack to the vendor supplied k_{inf} in the SCCG. Figure 3 illustrates the variation in reactivity in the storage rack with values of the k_{inf} in the SCCG.

In order to confirm that the NMP2 fuel is acceptable to be stored in the new Holtec spent fuel racks, the maximum k_{inf} in the SCCG that will limit the k_{inf} in the rack to less than or equal to 0.95 had to be determined. This was performed for each fuel assembly listed in Table 1 and the results are provided on Worksheet C.8 in Appendix C. As discussed earlier, the GE-11/GE-13 and the GE-14 assemblies were analyzed twice to account for the partial length rods.

The statistically combined reactivity allowances for manufacturing tolerances and depletion, the effect of channel bulging, the correction factor from the MCNP-4A and CASMO-4 comparison and the 0.01 Δk allowance for comparison to vendor calculations are included. Table 2 summarizes the results from Worksheet C.8 of Appendix C and demonstrates that by limiting the k_{inf} in the SCCG to 1.32 for the Nine Mile Point 2 fuel assemblies the k_{inf} in the new Holtec spent fuel storage racks will be less then 0.95.

7.8.2 Criteria For Minimum Gadolinium Loading

Gadolinia (Gd_2O_3) is normally used in BWR fuel to augment reactivity control during in-core operation. A very wide variety of Gd_2O_3 loading are commonly used – often differing in planar (axial) regions. Furthermore, the Gd_2O_3 loadings for fuel of 4.95 wt% nominal initial enrichment have not yet been developed. However, it is possible to develop and define criteria for the minimum Gd_2O_3 loadings required to assure that the peak reactivity over burnup is always less than the regulatory limit of 0.95.

Gadolinium has a higher cross-section than ^{235}U and the reactivity of an assembly increases with burnup, reaching a maximum at some point in burnup where the Gadolinium is virtually depleted. For fuel with an initial nominal enrichment of 4.95 wt%, Figure 4 illustrates the reactivity variation with burnup for several illustrative gadolinia loadings, with the reference fuel assembly, evaluated in the spent fuel storage racks (without bias or uncertainties). Some of these example fuel assemblies would be acceptable for storage and some would not. Also shown in Figure 4 is the calculation without any Gd_2O_3. The maximum reactivity from each of the calculations in Figure 4 is determined and plotted versus the initial gadolinia loading in Figure 5. The minimum loading is calculated assuming a total of either 6 or 8 rods contain Gd_2O_3. The resulting minimum loading is determined by a linear interpolation on Worksheet C.6 in Appendix C. These results are summarized in Table 3, and indicate that a minimum loading of 4.2% in 6 rods is required to ensure that k_{inf} in the storage rack is less than or equal to 0.95.

7.9 Long Term Reactivity Changes

At reactor shutdown, the reactivity of the fuel initially decreases due to the growth of ^{135}Xe, from ^{135}I decay. Subsequently, the Xenon decays and the reactivity increases to a maximum at several hundred hours when the Xenon is gone. Over the next 30 years, the reactivity continuously decreases due primarily to ^{241}Pu decay and ^{241}Am growth. At lower burnup, the reactivity decrease will be less pronounced since less ^{241}Pu would have been produced. No credit is taken for this long-term decrease in reactivity other than to indicate additional and increasing conservatism in the design criticality analysis.

7.10 Abnormal and Accident Conditions

7.10.1 Dropped Fuel Assembly

For a drop on top of the rack, the fuel assembly will come to rest horizontally on top of the rack with a minimum separation distance from the active fuel region of more then 12 inches, which is sufficient to preclude neutron coupling (i.e. an effectively infinite separation). Maximum expected deformation under seismic or accident conditions will not reduce the minimum spacing to less than 12 inches.

It is also possible to vertically drop an assembly into a location occupied by another assembly. Such a vertical impact would at most cause a small compression of the stored assembly, reducing the water-to-fuel ratio and thereby reducing reactivity. In addition, the distance between the active fuel regions of both assemblies will be more than sufficient to ensure no neutron interaction between the two assemblies.

The last scenario is the drop of a fuel assembly into an open storage cell. The dropped assembly would impact the baseplate and could result in a localized deformation of the baseplate that would affect that storage cell and the cells immediately surrounding it. A conservatively bounding analysis in Reference [8] has shown that the deformation could be approximately 2.5 inches. The consequence of this drop accident on criticality is that the active fuel length of that fuel assembly, and possibly the surrounding assemblies, could extend below the Boral panels. The conservative analysis presented in Section 7.7 has demonstrated that the consequences of this accident are negligible.

7.10.2 Fuel Rack Lateral Movement

Boral panels are installed in the rack wall along one side of the water gap between adjacent racks. With this configuration, the maximum reactivity of the storage rack is not dependent upon the water gap spacing between modules. Thus, misalignment of the racks or seismically induced movement will not affect the reactivity of the rack. The reactivity effects of abnormal and accident conditions are summarized in Table 2.2.

7.10.3 Abnormal Location of a Fuel Assembly

It is hypothetically possible to suspend a fuel assembly of the highest allowable reactivity outside and adjacent to the fuel rack, although such an accident condition is highly unlikely. The exterior walls of the rack modules facing the outside (where such an accident condition might be conceivable) is a region of high neutron leakage. Additionally, all outer rack surfaces where such an assembly could be suspended, with the exception of the west wall of Rack J, have Boral panels. For comparison to the reference k_{inf}, calculations were performed for the condition of a fuel assembly suspended directly west of Rack J, near the gap between Rack I and Rack J. Models were created both with and without an extraneous fuel assembly present. Calculations were performed with the GE-14 fuel assembly at both 3.2 wt% and 4.95 wt%. Descriptions of the models and the reactivity effect of a misplaced assembly is detailed on Worksheet C.1 in Appendix C. With neutron leakage included, the k_{eff} with an extraneous fuel assembly of the maximum reactivity, located outside and adjacent to the fuel rack, is significantly less than the MCNP-4a k_{inf}. Additionally, comparison of the k_{eff} of an extraneous fuel assembly outside and adjacent to the fuel rack, to the k_{eff} of the same model, without the extraneous fuel assembly indicates that such an accident has a negligible effect on the reactivity.

7.11 Interaction with Boraflex Racks

There is no direct interaction between the Boraflex and Boral racks that would effect the limitations of either type of rack. Boral panels are installed along all Holtec rack walls facing the existing Boraflex racks and the water gap between the Boraflex and Boral racks are at least 2.5" to preclude neutron coupling between the racks. With this configuration, the maximum reactivity of the storage rack is not dependent upon the interaction of the Boraflex and Boral racks.

8.0 COMPUTER FILES

A list of the file names and a brief description of the calculations that were performed for this analysis is provided in Appendix D. All related computer files are stored on the computer server at the Holtec International office in Marlton, NJ. The files are stored in the following directory: G:\PROJECTS\1101\KWC.

9.0 RESULTS AND CONCLUSIONS

The fuel assembly used as the principal design basis for the racks is the GE-14 (10x10), containing UO_2 fuel rods clad in Zircaloy, and using uniform nominal initial enrichments up to 4.95 wt% ^{235}U. Explicit analyses of all other fuel assembly types were performed to confirm their acceptability for storage in the high-density racks. The effects of calculational and manufacturing tolerances were evaluated and added in determining the maximum k_{eff} in the storage rack.

In BWR fuel, there is a wide variety of designs, including enrichment distribution and gadolinia loading, which often vary in both the axial and radial directions. Two different criteria which bound fuel acceptable for safe storage are defined below.

1. A maximum nominal enrichment of 4.95 wt% ^{235}U, with a maximum planar k_{inf} in the standard cold core geometry (SCCG) of 1.32, where the SCCG is defined as the multiplication factor (k_{inf}) for an infinite array of fuel assemblies on a 6-inch lattice spacing, at 20° C without voids or control rods.
2. A maximum nominal enrichment for the GE-14 assembly of 4.95 wt% ^{235}U with a minimum enrichment of 4.2 wt% Gd_2O_3 in at least 6 rods

These criteria are discussed more fully in subsequent paragraphs of this report. Either of these criteria is sufficient to determine the acceptability of fuel for safe storage in the spent fuel racks. These criteria should be applied to the axial (planar) region of highest reactivity. Each planar region should be separately evaluated to assure that the planar region of highest reactivity is assessed.

The basic calculations supporting the criticality safety of the Nine Mile Point 2 fuel storage racks are summarized in Tables 2 and 3.

Abnormal and accident conditions were also evaluated. None of the abnormal or accident conditions that have been identified as credible will result in exceeding the limiting reactivity (k_{eff} of 0.95). The effects on reactivity of credible abnormal and accident conditions are summarized on Worksheet C.1 in Appendix C. The double contingency principle of ANSI 16.1-1975 (and the USNRC letter of April 1978) specifies that it shall require at least two unlikely independent and concurrent events to produce a criticality accident. This principle precludes consideration of the simultaneous occurrence of multiple accident conditions. Other hypothetical events were considered and no credible occurrences or configurations have been identified that might have any adverse effect on the storage rack criticality safety.

10.0 REFERENCES

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Table 1

BWR Fuel Characteristics

Table 2

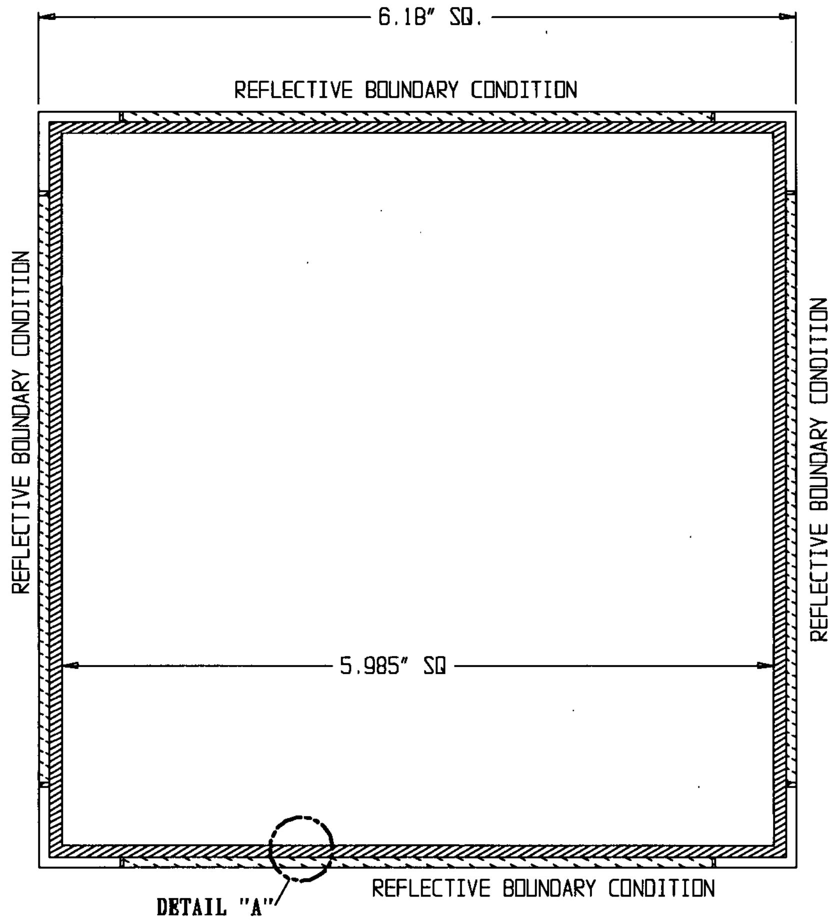
Summary of Criticality Safety Calculations
For Limiting k_{inf} in the SCCG

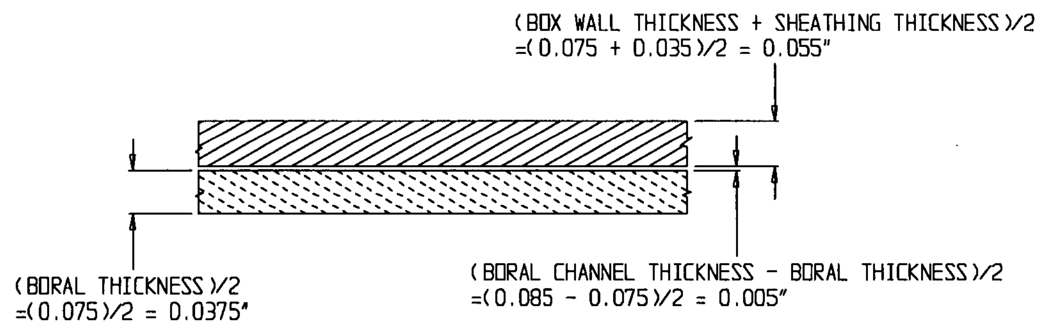
Fuel Assembly		GE-6/6B	GE-9B	GE-11/GE-13	GE-14
Temperature		4°C	4°C	4°C	4°C
SCCG k_{inf}		$\leq$ 1.32	$\leq$ 1.32	$\leq$ 1.32	$\leq$ 1.32
Enrichment (^{235}U)		4.95 wt%	4.95 wt%	4.95 wt%	4.95 wt%
CASMO-4 k_{inf}		0.9090	0.9107	0.9172	0.9202
Uncertainties					
B-10 Loading	0.0052				
UO_2 density	0.0027				
Enrichment	0.0023				
Box I.D./Pitch	0.0027				
Wall Thickness	0.0003				
Total Uncertainty		0.0069	0.0069	0.0069	0.0069
Depletion		0.0052	0.0052	0.0052	0.0052
Channel Bulging		0.0052	0.0052	0.0052	0.0052
Vendor Comparison		0.0100	0.0100	0.0100	0.0100
Correction Factor		0.0028	0.0028	0.0028	0.0028
Maximum k_{inf}		**0.9356**	**0.9373**	**0.9438**	**0.9468**
Regulatory Limit		**0.9500**	**0.9500**	**0.9500**	**0.9500**

Table 3

Summary of Criticality Safety Calculations
For Minimum Gd_2O_3

Fuel Assembly		GE-14
Temperature		4°C
Enrichment (^{235}U)		4.95 wt%
Min. Gd_2O_3 Loading		4.2 wt%
Reference CASMO-4 k_{inf}		0.9210
Uncertainties		
B-10 Loading	0.0052	
UO_2 density	0.0027	
Enrichment	0.0023	
Box I.D./Pitch	0.0027	
Wall Thickness	0.0003	
Total Uncertainty		0.0069
Depletion		0.0052
Channel Bulging		0.0052
Vendor Comparison		0.0100
Correction Factor		0.0028
Maximum k_{inf}		**0.9476**
Regulatory Limit		**0.9500**


6.18" SQ.
REFLECTIVE BOUNDARY CONDITION
REFLECTIVE BOUNDARY CONDITION
REFLECTIVE BOUNDARY CONDITION
5.985" SQ
REFLECTIVE BOUNDARY CONDITION
DETAIL "A"


(BOX WALL THICKNESS + SHEATHING THICKNESS)/2
=(0.075 + 0.035)/2 = 0.055"
(BORAL THICKNESS)/2
=(0.075)/2 = 0.0375"
(BORAL CHANNEL THICKNESS - BORAL THICKNESS)/2
=(0.085 - 0.075)/2 = 0.005"

DETAIL "A"

Figure 1: A Cross-Sectional View of the Calculational Model Used For BWR Rack Analysis (Not to Scale)

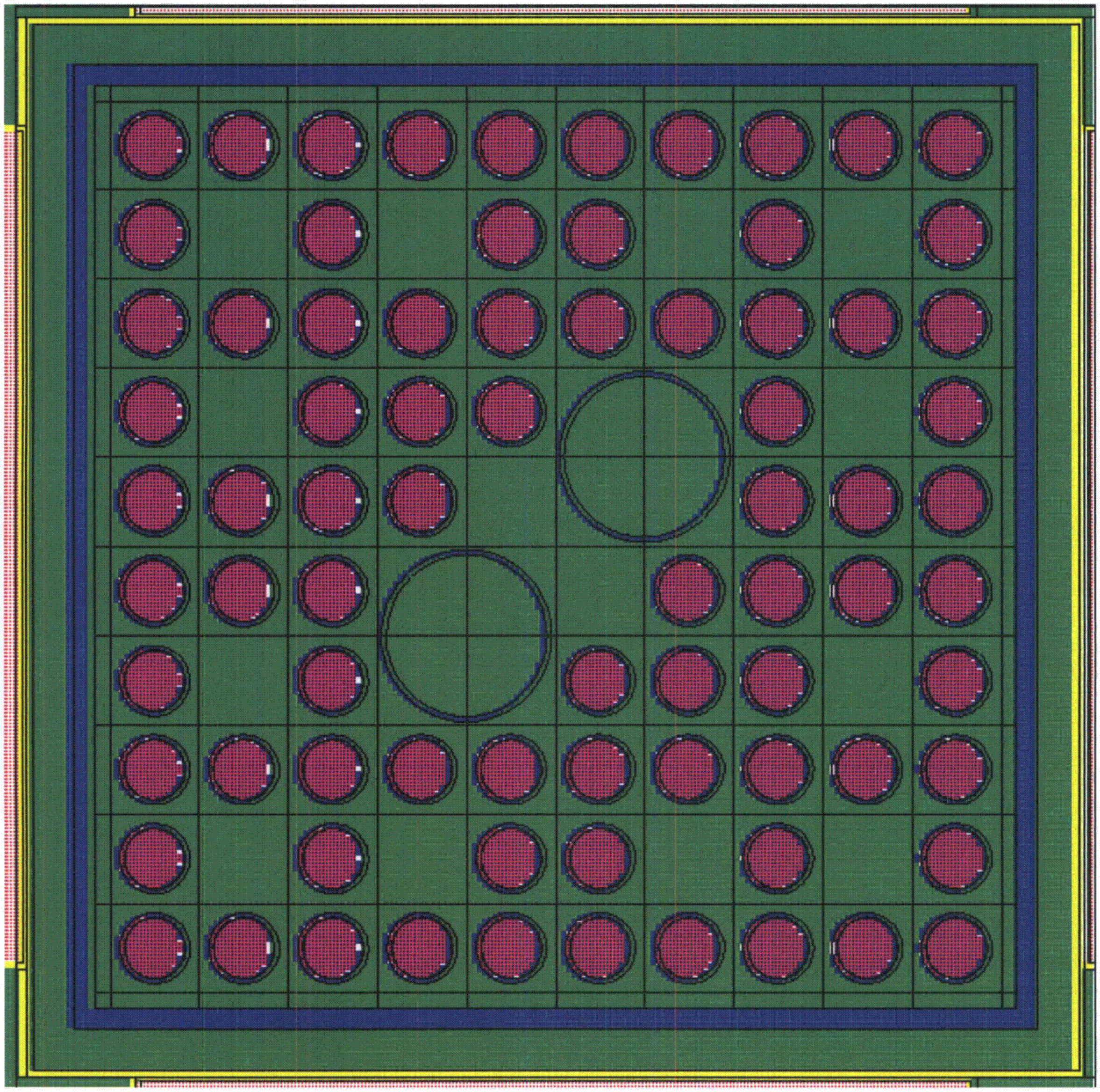


Figure 2: A Two Dimensional Representation of the Actual Calculational Model Used For the BWR Rack Analysis. This Figure was Drawn (To Scale) with the Two-Dimensional Plotter in MCNP4A.

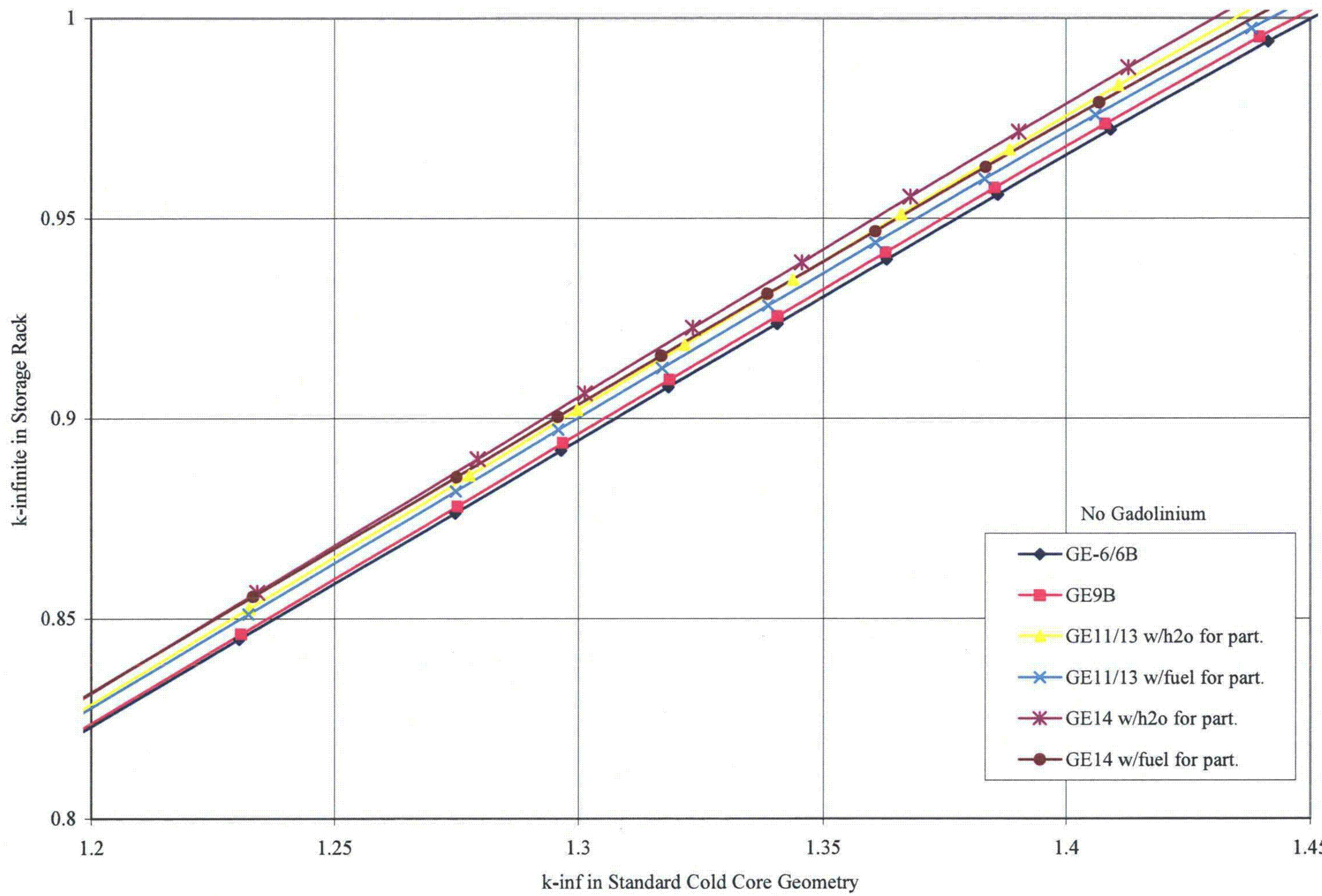


Figure 3: Correlation of the k_{inf} in the SCCG and k_{inf} in the Storage Rack for NMP2 Fuel Designs

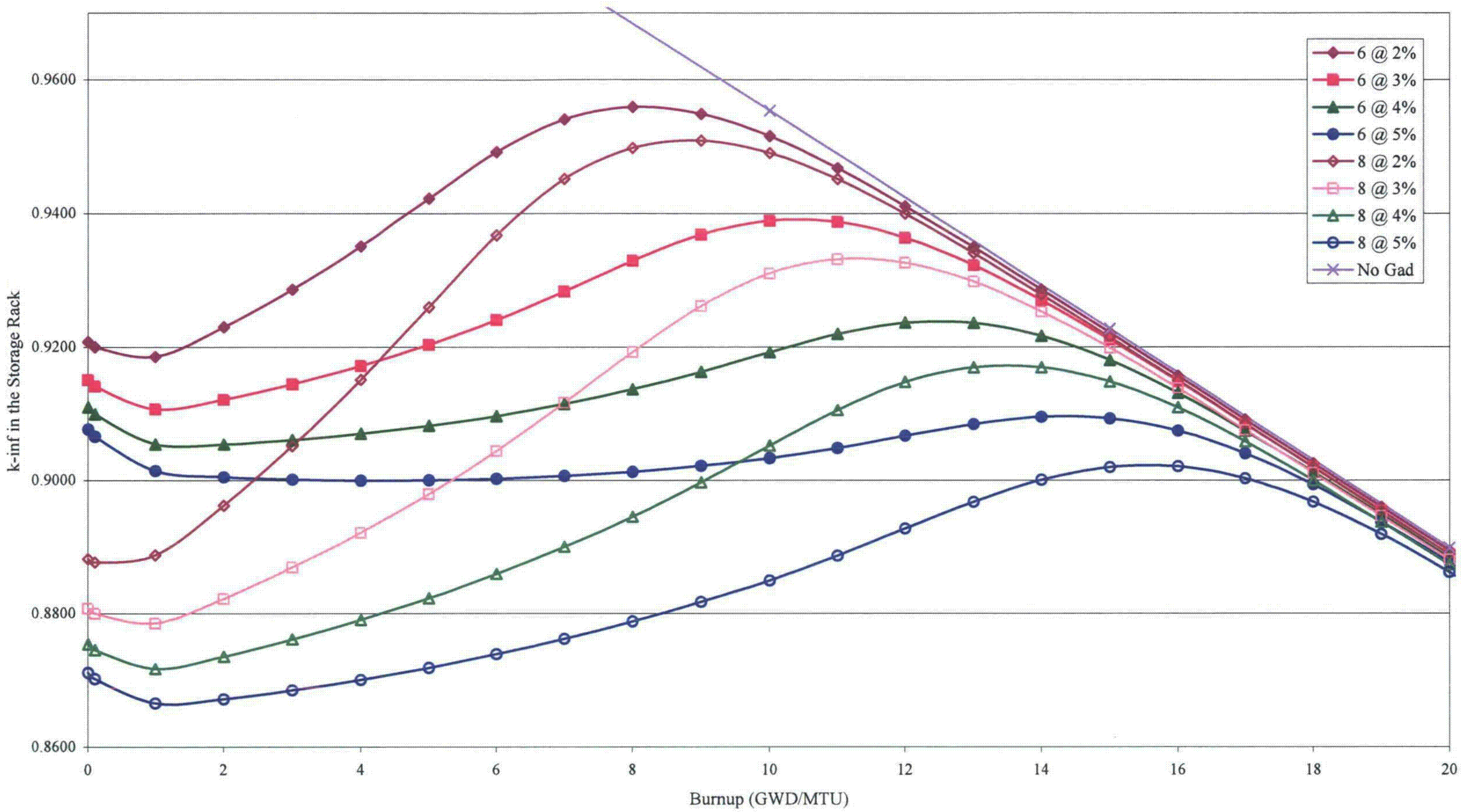


Figure 4: K_{inf} in the Storage Rack at Various Fuel Burnups and Gadolinia Loadings

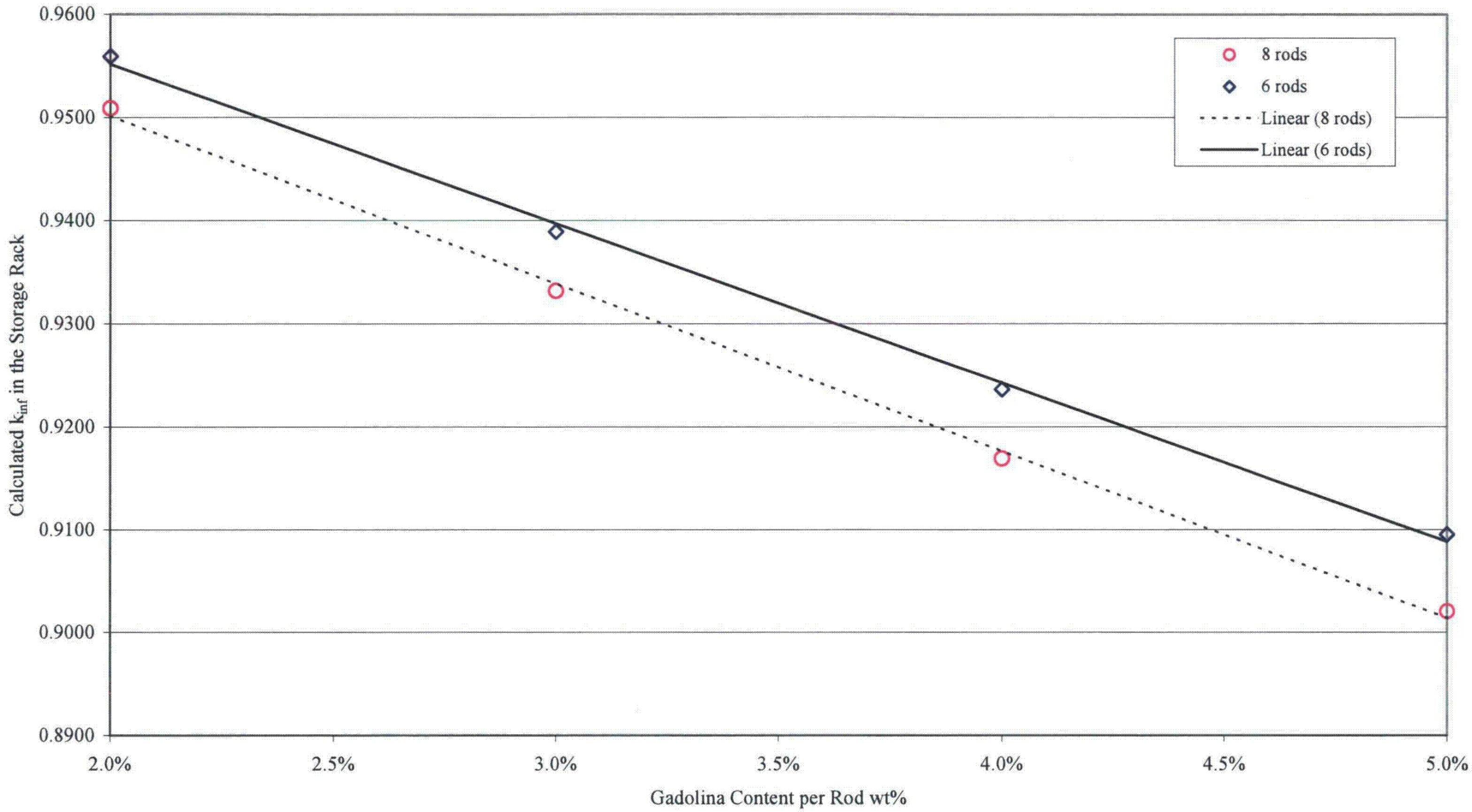


Figure 5: Correlation of the k_{inf} in the Storage Rack and the k_{inf} in the SCCG

Appendix A
Benchmark Calculations

(total number of pages: 26 including this page)

(this appendix was taken from a different report and because of this the next page is labeled Appendix 4A, Page 1)

APPENDIX 4A: BENCHMARK CALCULATIONS

4A.1 INTRODUCTION AND SUMMARY

Benchmark calculations have been made on selected critical experiments, chosen, in so far as possible, to bound the range of variables in the rack designs. Two independent methods of analysis were used, differing in cross section libraries and in the treatment of the cross sections. MCNP4a [4A.1] is a continuous energy Monte Carlo code and KENO5a [4A.2] uses group-dependent cross sections. For the KENO5a analyses reported here, the 238-group library was chosen, processed through the NITAWL-II [4A.2] program to create a working library and to account for resonance self-shielding in uranium-238 (Nordheim integral treatment). The 238 group library was chosen to avoid or minimize the errors† (trends) that have been reported (e.g., [4A.3 through 4A.5]) for calculations with collapsed cross section sets.

In rack designs, the three most significant parameters affecting criticality are (1) the fuel enrichment, (2) the ^{10}B loading in the neutron absorber, and (3) the lattice spacing (or water-gap thickness if a flux-trap design is used). Other parameters, within the normal range of rack and fuel designs, have a smaller effect, but are also included in the analyses.

Table 4A.1 summarizes results of the benchmark calculations for all cases selected and analyzed, as referenced in the table. The effect of the major variables are discussed in subsequent sections below. It is important to note that there is obviously considerable overlap in parameters since it is not possible to vary a single parameter and maintain criticality; some other parameter or parameters must be concurrently varied to maintain criticality.

One possible way of representing the data is through a spectrum index that incorporates all of the variations in parameters. KENO5a computes and prints the "energy of the average lethargy causing fission" (EALF). In MCNP4a, by utilizing the tally option with the identical 238-group energy structure as in KENO5a, the number of fissions in each group may be collected and the EALF determined (post-processing).

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† Small but observable trends (errors) have been reported for calculations with the 27-group and 44-group collapsed libraries. These errors are probably due to the use of a single collapsing spectrum when the spectrum should be different for the various cases analyzed, as evidenced by the spectrum indices.

Figures 4A.1 and 4A.2 show the calculated k_{eff} for the benchmark critical experiments as a function of the EALF for MCNP4a and KENO5a, respectively (UO_2 fuel only). The scatter in the data (even for comparatively minor variation in critical parameters) represents experimental error† in performing the critical experiments within each laboratory, as well as between the various testing laboratories. The B&W critical experiments show a larger experimental error than the PNL criticals. This would be expected since the B&W criticals encompass a greater range of critical parameters than the PNL criticals.

Linear regression analysis of the data in Figures 4A.1 and 4A.2 show that there are no trends, as evidenced by very low values of the correlation coefficient (0.13 for MCNP4a and 0.21 for KENO5a). The total bias (systematic error, or mean of the deviation from a k_{eff} of exactly 1.000) for the two methods of analysis are shown in the table below.

Calculational Bias of MCNP4a and KENO5a	
MCNP4a	0.0009±0.0011
KENO5a	0.0030±0.0012

The bias and standard error of the bias were derived directly from the calculated k_{eff} values in Table 4A.1 using the following equations††, with the standard error multiplied by the one-sided K-factor for 95% probability at the 95% confidence level from NBS Handbook 91 [4A.18] (for the number of cases analyzed, the K-factor is ~2.05 or slightly more than 2).

$$\bar{k} = \frac{1}{n} \sum_{i}^{n} k_i \qquad (4A.1)$$

† A classical example of experimental error is the corrected enrichment in the PNL experiments, first as an addendum to the initial report and, secondly, by revised values in subsequent reports for the same fuel rods.

†† These equations may be found in any standard text on statistics, for example, reference [4A.6] (or the MCNP4a manual) and is the same methodology used in MCNP4a and in KENO5a.

$$\sigma_{\bar{k}}^2 = \frac{\sum_{i=1}^{n} k_i^2 - (\sum_{i=1}^{n} k_i)^2 / n}{n\,(n-1)} \qquad (4A.2)$$

$$Bias = (1 - \bar{k}) \pm K\, \sigma_{\bar{k}} \qquad (4A.3)$$

where k_i are the calculated reactivities of n critical experiments; $\sigma_{\bar{k}}$ is the unbiased estimator of the standard deviation of the mean (also called the standard error of the bias (mean)); K is the one-sided multiplier for 95% probability at the 95% confidence level (NBS Handbook 91 [4A.18]).

Formula 4.A.3 is based on the methodology of the National Bureau of Standards (now NIST) and is used to calculate the values presented on page 4.A-2. The first portion of the equation, $(1-\bar{k})$, is the actual bias which is added to the MCNP4a and KENO5a results. The second term, $K\sigma_{\bar{k}}$, is the uncertainty or standard error associated with the bias. The K values used were obtained from the National Bureau of Standards Handbook 91 and are for one-sided statistical tolerance limits for 95% probability at the 95% confidence level. The actual K values for the 56 critical experiments evaluated with MCNP4a and the 53 critical experiments evaluated with KENO5a are 2.04 and 2.05, respectively.

The bias values are used to evaluate the maximum k_{eff} values for the rack designs. KENO5a has a slightly larger systematic error than MCNP4a, but both result in greater precision than published data [4A.3 through 4A.5] would indicate for collapsed cross section sets in KENO5a (SCALE) calculations.

4A.2 Effect of Enrichment

The benchmark critical experiments include those with enrichments ranging from 2.46 w/o to 5.74 w/o and therefore span the enrichment range for rack designs. Figures 4A.3 and 4A.4 show the calculated k_{eff} values (Table 4A.1) as a function of the fuel enrichment reported for the critical experiments. Linear regression analyses for these data confirms that there are no trends, as indicated by low values of the correlation coefficients (0.03 for MCNP4a and 0.38 for KENO5a). Thus, there are no corrections to the bias for the various enrichments.

As further confirmation of the absence of any trends with enrichment, a typical configuration was calculated with both MCNP4a and KENO5a for various enrichments. The cross-comparison of calculations with codes of comparable sophistication is suggested in Reg. Guide 3.41. Results of this comparison, shown in Table 4A.2 and Figure 4A.5, confirm no significant difference in the calculated values of k_{eff} for the two independent codes as evidenced by the 45° slope of the curve. Since it is very unlikely that two independent methods of analysis would be subject to the same error, this comparison is considered confirmation of the absence of an enrichment effect (trend) in the bias.

4A.3 Effect of ^{10}B Loading

Several laboratories have performed critical experiments with a variety of thin absorber panels similar to the Boral panels in the rack designs. Of these critical experiments, those performed by B&W are the most representative of the rack designs. PNL has also made some measurements with absorber plates, but, with one exception (a flux-trap experiment), the reactivity worth of the absorbers in the PNL tests is very low and any significant errors that might exist in the treatment of strong thin absorbers could not be revealed.

Table 4A.3 lists the subset of experiments using thin neutron absorbers (from Table 4A.1) and shows the reactivity worth (Δk) of the absorber.†

No trends with reactivity worth of the absorber are evident, although based on the calculations shown in Table 4A.3, some of the B&W critical experiments seem to have unusually large experimental errors. B&W made an effort to report some of their experimental errors. Other laboratories did not evaluate their experimental errors.

To further confirm the absence of a significant trend with ^{10}B concentration in the absorber, a cross-comparison was made with MCNP4a and KENO5a (as suggested in Reg. Guide 3.41). Results are shown in Figure 4A.6 and Table 4A.4 for a typical geometry. These data substantiate the absence of any error (trend) in either of the two codes for the conditions analyzed (data points fall on a 45° line, within an expected 95% probability limit).

† The reactivity worth of the absorber panels was determined by repeating the calculation with the absorber analytically removed and calculating the incremental (Δk) change in reactivity due to the absorber.

4A.4 Miscellaneous and Minor Parameters

4A.4.1 Reflector Material and Spacings

PNL has performed a number of critical experiments with thick steel and lead reflectors.† Analysis of these critical experiments are listed in Table 4A.5 (subset of data in Table 4A.1). There appears to be a small tendency toward overprediction of k_{eff} at the lower spacing, although there are an insufficient number of data points in each series to allow a quantitative determination of any trends. The tendency toward overprediction at close spacing means that the rack calculations may be slightly more conservative than otherwise.

4A.4.2 Fuel Pellet Diameter and Lattice Pitch

The critical experiments selected for analysis cover a range of fuel pellet diameters from 0.311 to 0.444 inches, and lattice spacings from 0.476 to 1.00 inches. In the rack designs, the fuel pellet diameters range from 0.303 to 0.3805 inches O.D. (0.496 to 0.580 inch lattice spacing) for PWR fuel and from 0.3224 to 0.494 inches O.D. (0.488 to 0.740 inch lattice spacing) for BWR fuel. Thus, the critical experiments analyzed provide a reasonable representation of power reactor fuel. Based on the data in Table 4A.1, there does not appear to be any observable trend with either fuel pellet diameter or lattice pitch, at least over the range of the critical experiments applicable to rack designs.

4A.4.3 Soluble Boron Concentration Effects

Various soluble boron concentrations were used in the B&W series of critical experiments and in one PNL experiment, with boron concentrations ranging up to 2550 ppm. Results of MCNP4a (and one KENO5a) calculations are shown in Table 4A.6. Analyses of the very high boron concentration experiments (> 1300 ppm) show a tendency to slightly overpredict reactivity for the three experiments exceeding 1300 ppm. In turn, this would suggest that the evaluation of the racks with higher soluble boron concentrations could be slightly conservative.

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† Parallel experiments with a depleted uranium reflector were also performed but not included in the present analysis since they are not pertinent to the Holtec rack design.

4A.5 MOX Fuel

The number of critical experiments with PuO_2 bearing fuel (MOX) is more limited than for UO_2 fuel. However, a number of MOX critical experiments have been analyzed and the results are shown in Table 4A.7. Results of these analyses are generally above a k_{eff} of 1.00, indicating that when Pu is present, both MCNP4a and KENO5a overpredict the reactivity. This may indicate that calculation for MOX fuel will be expected to be conservative, especially with MCNP4a. It may be noted that for the larger lattice spacings, the KENO5a calculated reactivities are below 1.00, suggesting that a small trend may exist with KENO5a. It is also possible that the overprediction in k_{eff} for both codes may be due to a small inadequacy in the determination of the Pu-241 decay and Am-241 growth. This possibility is supported by the consistency in calculated k_{eff} over a wide range of the spectral index (energy of the average lethargy causing fission).

4A.6 References

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[4A.2] SCALE 4.3, "A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation", NUREG-0200 (ORNL-NUREG-CSD-2/U2/R5, Revision 5, Oak Ridge National Laboratory, September 1995.

[4A.3] M.D. DeHart and S.M. Bowman, "Validation of the SCALE Broad Structure 44-G Group ENDF/B-Y Cross-Section Library for Use in Criticality Safety Analyses", NUREG/CR-6102 (ORNL/TM-12460) Oak Ridge National Laboratory, September 1994.

[4A.4] W.C. Jordan et al., "Validation of KENOV.a", CSD/TM-238, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, December 1986.

[4A.5] O.W. Hermann et al., "Validation of the Scale System for PWR Spent Fuel Isotopic Composition Analysis", ORNL-TM-12667, Oak Ridge National Laboratory, undated.

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[4A.9] L.W. Newman et al., Urania Gadolinia: Nuclear Model Development and Critical Experiment Benchmark, BAW-1810, Babcock and Wilcox Company, April 1984.

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[4A.11] S.R. Bierman and E.D. Clayton, Criticality Experiments with Subcritical Clusters of 2.35 w/o and 4.31 w/o ^{235}U Enriched UO_2 Rods in Water with Steel Reflecting Walls, PNL-3602, Battelle Pacific Northwest Laboratory, April 1981.

[4A.12] S.R. Bierman et al., Criticality Experiments with Subcritical Clusters of 2.35 w/o and 4.31 w/o ^{235}U Enriched UO_2 Rods in Water with Uranium or Lead Reflecting Walls, PNL-3926, Battelle Pacific Northwest Laboratory, December, 1981.

[4A.13] S.R. Bierman et al., Critical Separation Between Subcritical Clusters of 4.31 w/o ^{235}U Enriched UO_2 Rods in Water with Fixed Neutron Poisons, PNL-2615, Battelle Pacific Northwest Laboratory, October 1977.

[4A.14] S.R. Bierman, Criticality Experiments with Neutron Flux Traps Containing Voids, PNL-7167, Battelle Pacific Northwest Laboratory, April 1990.

[4A.15] B.M. Durst et al., Critical Experiments with 4.31 wt % ^{235}U Enriched UO_2 Rods in Highly Borated Water Lattices, PNL-4267, Battelle Pacific Northwest Laboratory, August 1982.

[4A.16] S.R. Bierman, Criticality Experiments with Fast Test Reactor Fuel Pins in Organic Moderator, PNL-5803, Battelle Pacific Northwest Laboratory, December 1981.

[4A.17] E.G. Taylor et al., Saxton Plutonium Program Critical Experiments for the Saxton Partial Plutonium Core, WCAP-3385-54, Westinghouse Electric Corp., Atomic Power Division, December 1965.

[4A.18] M.G. Natrella, Experimental Statistics, National Bureau of Standards, Handbook 91, August 1963.

Table 4A.1

Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF † (eV) MCNP4a	EALF † (eV) KENO5a
1	B&W-1484 (4A.7)	Core I	2.46	0.9964 ± 0.0010	0.9898± 0.0006	0.1759	0.1753
2	B&W-1484 (4A.7)	Core II	2.46	1.0008 ± 0.0011	1.0015 ± 0.0005	0.2553	0.2446
3	B&W-1484 (4A.7)	Core III	2.46	1.0010 ± 0.0012	1.0005 ± 0.0005	0.1999	0.1939
4	B&W-1484 (4A.7)	Core IX	2.46	0.9956 ± 0.0012	0.9901 ± 0.0006	0.1422	0.1426
5	B&W-1484 (4A.7)	Core X	2.46	0.9980 ± 0.0014	0.9922 ± 0.0006	0.1513	0.1499
6	B&W-1484 (4A.7)	Core XI	2.46	0.9978 ± 0.0012	1.0005 ± 0.0005	0.2031	0.1947
7	B&W-1484 (4A.7)	Core XII	2.46	0.9988 ± 0.0011	0.9978 ± 0.0006	0.1718	0.1662
8	B&W-1484 (4A.7)	Core XIII	2.46	1.0020 ± 0.0010	0.9952 ± 0.0006	0.1988	0.1965
9	B&W-1484 (4A.7)	Core XIV	2.46	0.9953 ± 0.0011	0.9928 ± 0.0006	0.2022	0.1986
10	B&W-1484 (4A.7)	Core XV ††	2.46	0.9910 ± 0.0011	0.9909 ± 0.0006	0.2092	0.2014
11	B&W-1484 (4A.7)	Core XVI ††	2.46	0.9935 ± 0.0010	0.9889 ± 0.0006	0.1757	0.1713
12	B&W-1484 (4A.7)	Core XVII	2.46	0.9962 ± 0.0012	0.9942 ± 0.0005	0.2083	0.2021
13	B&W-1484 (4A.7)	Core XVIII	2.46	1.0036 ± 0.0012	0.9931 ± 0.0006	0.1705	0.1708

Table 4A.1

Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF † (eV) MCNP4a	EALF † (eV) KENO5a
14	B&W-1484 (4A.7)	Core XIX	2.46	0.9961 ± 0.0012	0.9971 ± 0.0005	0.2103	0.2011
15	B&W-1484 (4A.7)	Core XX	2.46	1.0008 ± 0.0011	0.9932 ± 0.0006	0.1724	0.1701
16	B&W-1484 (4A.7)	Core XXI	2.46	0.9994 ± 0.0010	0.9918 ± 0.0006	0.1544	0.1536
17	B&W-1645 (4A.8)	S-type Fuel, w/886 ppm B	2.46	0.9970 ± 0.0010	0.9924 ± 0.0006	1.4475	1.4680
18	B&W-1645 (4A.8)	S-type Fuel, w/746 ppm B	2.46	0.9990 ± 0.0010	0.9913 ± 0.0006	1.5463	1.5660
19	B&W-1645 (4A.8)	SO-type Fuel, w/1156 ppm B	2.46	0.9972 ± 0.0009	0.9949 ± 0.0005	0.4241	0.4331
20	B&W-1810 (4A.9)	Case 1 1337 ppm B	2.46	1.0023 ± 0.0010	NC	0.1531	NC
21	B&W-1810 (4A.9)	Case 12 1899 ppm B	2.46/4.02	1.0060 ± 0.0009	NC	0.4493	NC
22	French (4A.10)	Water Moderator 0 gap	4.75	0.9966 ± 0.0013	NC	0.2172	NC
23	French (4A.10)	Water Moderator 2.5 cm gap	4.75	0.9952 ± 0.0012	NC	0.1778	NC
24	French (4A.10)	Water Moderator 5 cm gap	4.75	0.9943 ± 0.0010	NC	0.1677	NC
25	French (4A.10)	Water Moderator 10 cm gap	4.75	0.9979 ± 0.0010	NC	0.1736	NC
26	PNL-3602 (4A.11)	Steel Reflector, 0 separation	2.35	NC	1.0004 ± 0.0006	NC	0.1018

Table 4A.1

Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF† (eV) MCNP4a	EALF† (eV) KENO5a
27	PNL-3602 (4A.11)	Steel Reflector, 1.321 cm sepn.	2.35	0.9980 ± 0.0009	0.9992 ± 0.0006	0.1000	0.0909
28	PNL-3602 (4A.11)	Steel Reflector, 2.616 cm sepn	2.35	0.9968 ± 0.0009	0.9964 ± 0.0006	0.0981	0.0975
29	PNL-3602 (4A.11)	Steel Reflector, 3.912 cm sepn.	2.35	0.9974 ± 0.0010	0.9980 ± 0.0006	0.0976	0.0970
30	PNL-3602 (4A.11)	Steel Reflector, infinite sepn.	2.35	0.9962 ± 0.0008	0.9939 ± 0.0006	0.0973	0.0968
31	PNL-3602 (4A.11)	Steel Reflector, 0 cm sepn.	4.306	NC	1.0003 ± 0.0007	NC	0.3282
32	PNL-3602 (4A.11)	Steel Reflector, 1.321 cm sepn.	4.306	0.9997 ± 0.0010	1.0012 ± 0.0007	0.3016	0.3039
33	PNL-3602 (4A.11)	Steel Reflector, 2.616 cm sepn.	4.306	0.9994 ± 0.0012	0.9974 ± 0.0007	0.2911	0.2927
34	PNL-3602 (4A.11)	Steel Reflector, 5.405 cm sepn.	4.306	0.9969 ± 0.0011	0.9951 ± 0.0007	0.2828	0.2860
35	PNL-3602 (4A.11)	Steel Reflector, Infinite sepn. ††	4.306	0.9910 ± 0.0020	0.9947 ± 0.0007	0.2851	0.2864
36	PNL-3602 (4A.11)	Steel Reflector, with Boral Sheets	4.306	0.9941 ± 0.0011	0.9970 ± 0.0007	0.3135	0.3150
37	PNL-3926 (4A.12)	Lead Reflector, 0 cm sepn.	4.306	NC	1.0003 ± 0.0007	NC	0.3159
38	PNL-3926 (4A.12)	Lead Reflector, 0.55 cm sepn.	4.306	1.0025 ± 0.0011	0.9997 ± 0.0007	0.3030	0.3044
39	PNL-3926 (4A.12)	Lead Reflector, 1.956 cm sepn.	4.306	1.0000 ± 0.0012	0.9985 ± 0.0007	0.2883	0.2930

Table 4A.1

Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF[†] (eV) MCNP4a	EALF[†] (eV) KENO5a
40	PNL-3926 (4A.12)	Lead Reflector, 5.405 cm sepn.	4.306	0.9971 ± 0.0012	0.9946 ± 0.0007	0.2831	0.2854
41	PNL-2615 (4A.13)	Experiment 004/032 - no absorber	4.306	0.9925 ± 0.0012	0.9950 ± 0.0007	0.1155	0.1159
42	PNL-2615 (4A.13)	Experiment 030 - Zr plates	4.306	NC	0.9971 ± 0.0007	NC	0.1154
43	PNL-2615 (4A.13)	Experiment 013 - Steel plates	4.306	NC	0.9965 ± 0.0007	NC	0.1164
44	PNL-2615 (4A.13)	Experiment 014 - Steel plates	4.306	NC	0.9972 ± 0.0007	NC	0.1164
45	PNL-2615 (4A.13)	Exp. 009 1.05% Boron-Steel plates	4.306	0.9982 ± 0.0010	0.9981 ± 0.0007	0.1172	0.1162
46	PNL-2615 (4A.13)	Exp. 012 1.62% Boron-Steel plates	4.306	0.9996 ± 0.0012	0.9982 ± 0.0007	0.1161	0.1173
47	PNL-2615 (4A.13)	Exp. 031 - Boral plates	4.306	0.9994 ± 0.0012	0.9969 ± 0.0007	0.1165	0.1171
48	PNL-7167 (4A.14)	Experiment 214R - with flux trap	4.306	0.9991 ± 0.0011	0.9956 ± 0.0007	0.3722	0.3812
49	PNL-7167 (4A.14)	Experiment 214V3 - with flux trap	4.306	0.9969 ± 0.0011	0.9963 ± 0.0007	0.3742	0.3826
50	PNL-4267 (4A.15)	Case 173 - 0 ppm B	4.306	0.9974 ± 0.0012	NC	0.2893	NC
51	PNL-4267 (4A.15)	Case 177 - 2550 ppm B	4.306	1.0057 ± 0.0010	NC	0.5509	NC
52	PNL-5803 (4A.16)	MOX Fuel - Type 3.2 Exp. 21	20% Pu	1.0041 ± 0.0011	1.0046 ± 0.0006	0.9171	0.8868

Table 4A.1

Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF† (eV) MCNP4a	EALF† (eV) KENO5a
53	PNL-5803 (4A.16)	MOX Fuel - Type 3.2 Exp. 43	20% Pu	1.0058 ± 0.0012	1.0036 ± 0.0006	0.2968	0.2944
54	PNL-5803 (4A.16)	MOX Fuel - Type 3.2 Exp. 13	20% Pu	1.0083 ± 0.0011	0.9989 ± 0.0006	0.1665	0.1706
55	PNL-5803 (4A.16)	MOX Fuel - Type 3.2 Exp. 32	20% Pu	1.0079 ± 0.0011	0.9966 ± 0.0006	0.1139	0.1165
56	WCAP-3385 (4A.17)	Saxton Case 52 PuO2 0.52" pitch	6.6% Pu	0.9996 ± 0.0011	1.0005 ± 0.0006	0.8665	0.8417
57	WCAP-3385 (4A.17)	Saxton Case 52 U 0.52" pitch	5.74	1.0000 ± 0.0010	0.9956 ± 0.0007	0.4476	0.4580
58	WCAP-3385 (4A.17)	Saxton Case 56 PuO2 0.56" pitch	6.6% Pu	1.0036 ± 0.0011	1.0047 ± 0.0006	0.5289	0.5197
59	WCAP-3385 (4A.17)	Saxton Case 56 borated PuO2	6.6% Pu	1.0008 ± 0.0010	NC	0.6389	NC
60	WCAP-3385 (4A.17)	Saxton Case 56 U 0.56" pitch	5.74	0.9994 ± 0.0011	0.9967 ± 0.0007	0.2923	0.2954
61	WCAP-3385 (4A.17)	Saxton Case 79 PuO2 0.79" pitch	6.6% Pu	1.0063 ± 0.0011	1.0133 ± 0.0006	0.1520	0.1555
62	WCAP-3385 (4A.17)	Saxton Case 79 U 0.79" pitch	5.74	1.0039 ± 0.0011	1.0008 ± 0.0006	0.1036	0.1047

Notes: NC stands for not calculated.

† EALF is the energy of the average lethargy causing fission.

†† These experimental results appear to be statistical outliers (>3σ) suggesting the possibility of unusually large experimental error. Although they could justifiably be excluded, for conservatism, they were retained in determining the calculational basis.

Table 4A.2

COMPARISON OF MCNP4a AND KENO5a CALCULATED REACTIVITIES[†] FOR VARIOUS ENRICHMENTS

Enrichment	Calculated $k_{eff} \pm 1\sigma$	
	MCNP4a	**KENO5a**
3.0	0.8465 ± 0.0011	0.8478 ± 0.0004
3.5	0.8820 ± 0.0011	0.8841 ± 0.0004
3.75	0.9019 ± 0.0011	0.8987 ± 0.0004
4.0	0.9132 ± 0.0010	0.9140 ± 0.0004
4.2	0.9276 ± 0.0011	0.9237 ± 0.0004
4.5	0.9400 ± 0.0011	0.9388 ± 0.0004

† Based on the GE 8x8R fuel assembly.

Table 4A.3

MCNP4a CALCULATED REACTIVITIES FOR
CRITICAL EXPERIMENTS WITH NEUTRON ABSORBERS

Ref.	**Experiment**		**Δk Worth of Absorber**	**MCNP4a Calculated k_{eff}**	**EALF † (eV)**
4A.13	PNL-2615	Boral Sheet	0.0139	0.9994±0.0012	0.1165
4A.7	B&W-1484	Core XX	0.0165	1.0008±0.0011	0.1724
4A.13	PNL-2615	1.62% Boron-steel	0.0165	0.9996±0.0012	0.1161
4A.7	B&W-1484	Core XIX	0.0202	0.9961±0.0012	0.2103
4A.7	B&W-1484	Core XXI	0.0243	0.9994±0.0010	0.1544
4A.7	B&W-1484	Core XVII	0.0519	0.9962±0.0012	0.2083
4A.11	PNL-3602	Boral Sheet	0.0708	0.9941±0.0011	0.3135
4A.7	B&W-1484	Core XV	0.0786	0.9910±0.0011	0.2092
4A.7	B&W-1484	Core XVI	0.0845	0.9935±0.0010	0.1757
4A.7	B&W-1484	Core XIV	0.1575	0.9953±0.0011	0.2022
4A.7	B&W-1484	Core XIII	0.1738	1.0020±0.0011	0.1988
4A.14	PNL-7167	Expt 214R flux trap	0.1931	0.9991±0.0011	0.3722

† EALF is the energy of the average lethargy causing fission.

Table 4A.4

COMPARISON OF MCNP4a AND KENO5a
CALCULATED REACTIVITIES† FOR VARIOUS ^{10}B LOADINGS

^{10}B, g/cm^2	Calculated k_{eff} ± 1σ	
	MCNP4a	**KENO5a**
0.005	1.0381 ± 0.0012	1.0340 ± 0.0004
0.010	0.9960 ± 0.0010	0.9941 ± 0.0004
0.015	0.9727 ± 0.0009	0.9713 ± 0.0004
0.020	0.9541 ± 0.0012	0.9560 ± 0.0004
0.025	0.9433 ± 0.0011	0.9428 ± 0.0004
0.03	0.9325 ± 0.0011	0.9338 ± 0.0004
0.035	0.9234 ± 0.0011	0.9251 ± 0.0004
0.04	0.9173 ± 0.0011	0.9179 ± 0.0004

† Based on a 4.5% enriched GE 8x8R fuel assembly.

Table 4A.5

CALCULATIONS FOR CRITICAL EXPERIMENTS WITH THICK LEAD AND STEEL REFLECTORS†

Ref.	Case	E, wt%	Separation, cm	MCNP4a k_{eff}	KENO5a k_{eff}
4A.11	Steel Reflector	2.35	1.321	0.9980±0.0009	0.9992±0.0006
		2.35	2.616	0.9968±0.0009	0.9964±0.0006
		2.35	3.912	0.9974±0.0010	0.9980±0.0006
		2.35	∞	0.9962±0.0008	0.9939±0.0006
4A.11	Steel Reflector	4.306	1.321	0.9997±0.0010	1.0012±0.0007
		4.306	2.616	0.9994±0.0012	0.9974±0.0007
		4.306	3.405	0.9969±0.0011	0.9951±0.0007
		4.306	∞	0.9910±0.0020	0.9947±0.0007
4A.12	Lead Reflector	4.306	0.55	1.0025±0.0011	0.9997±0.0007
		4.306	1.956	1.0000±0.0012	0.9985±0.0007
		4.306	5.405	0.9971±0.0012	0.9946±0.0007

† Arranged in order of increasing reflector-fuel spacing.

Table 4A.6

CALCULATIONS FOR CRITICAL EXPERIMENTS WITH VARIOUS SOLUBLE BORON CONCENTRATIONS

Reference	**Experiment**	**Boron Concentration, ppm**	**Calculated k_{eff}**	
			MCNP4a	**KENO5a**
4A.15	PNL-4267	0	0.9974 ± 0.0012	-
4A.8	B&W-1645	886	0.9970 ± 0.0010	0.9924 ± 0.0006
4A.9	B&W-1810	1337	1.0023 ± 0.0010	-
4A.9	B&W-1810	1899	1.0060 ± 0.0009	-
4A.15	PNL-4267	2550	1.0057 ± 0.0010	-

Table 4A.7

CALCULATIONS FOR CRITICAL EXPERIMENTS WITH MOX FUEL

Reference	Case†	MCNP4a		KENO5a	
		k_{eff}	EALF††	k_{eff}	EALF††
PNL-5803 [4A.16]	MOX Fuel - Exp. No. 21	1.0041±0.0011	0.9171	1.0046±0.0006	0.8868
	MOX Fuel - Exp. No. 43	1.0058±0.0012	0.2968	1.0036±0.0006	0.2944
	MOX Fuel - Exp. No. 13	1.0083±0.0011	0.1665	0.9989±0.0006	0.1706
	MOX Fuel - Exp. No. 32	1.0079±0.0011	0.1139	0.9966±0.0006	0.1165
WCAP-3385-54 [4A.17]	Saxton @ 0.52" pitch	0.9996±0.0011	0.8665	1.0005±0.0006	0.8417
	Saxton @ 0.56" pitch	1.0036±0.0011	0.5289	1.0047±0.0006	0.5197
	Saxton @ 0.56" pitch borated	1.0008±0.0010	0.6389	NC	NC
	Saxton @ 0.79" pitch	1.0063±0.0011	0.1520	1.0133±0.0006	0.1555

Note: NC stands for not calculated

† Arranged in order of increasing lattice spacing.

†† EALF is the energy of the average lethargy causing fission.

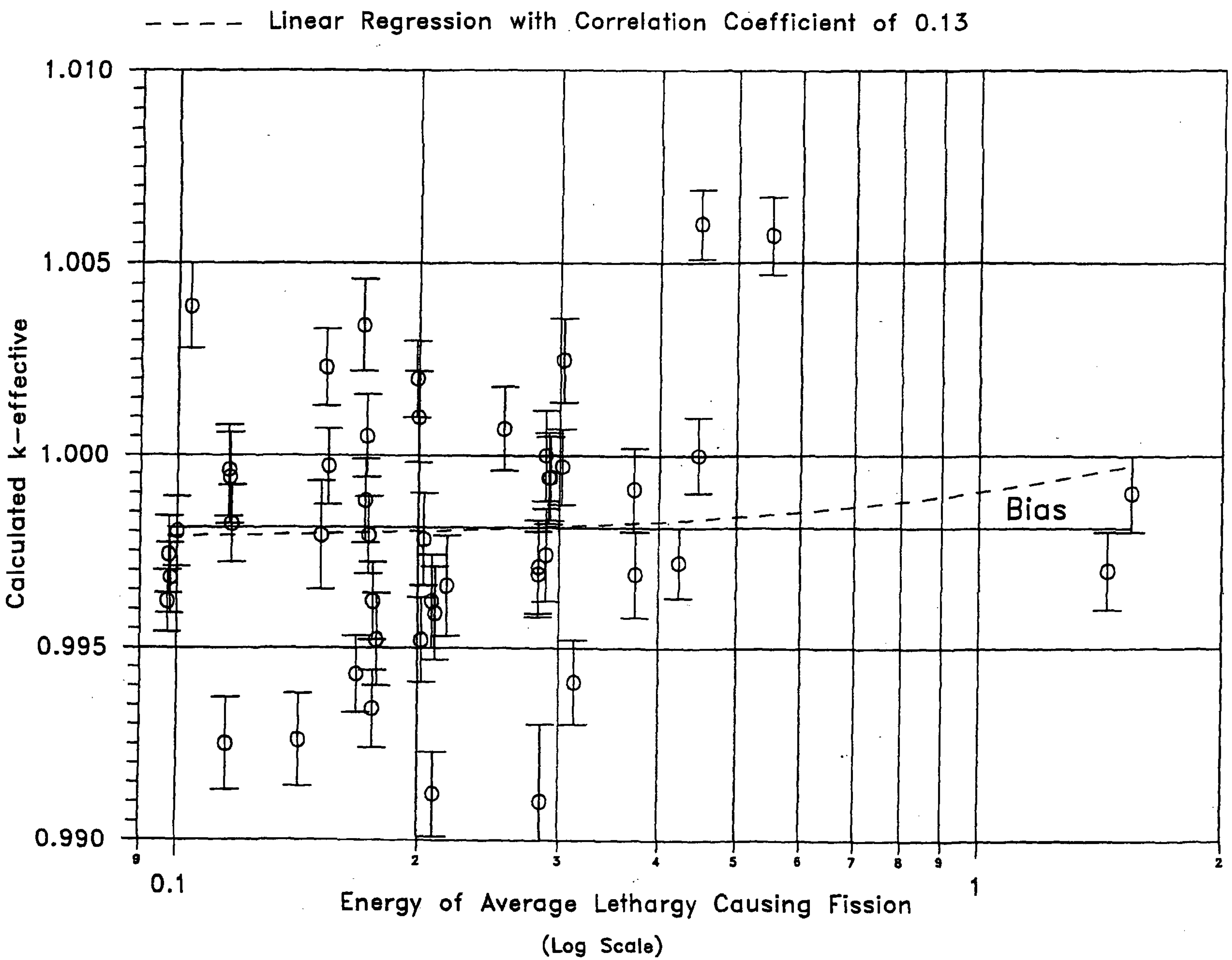

FIGURE 4A.1 MCNP CALCULATED k-eff VALUES for VARIOUS VALUES OF THE SPECTRAL INDEX

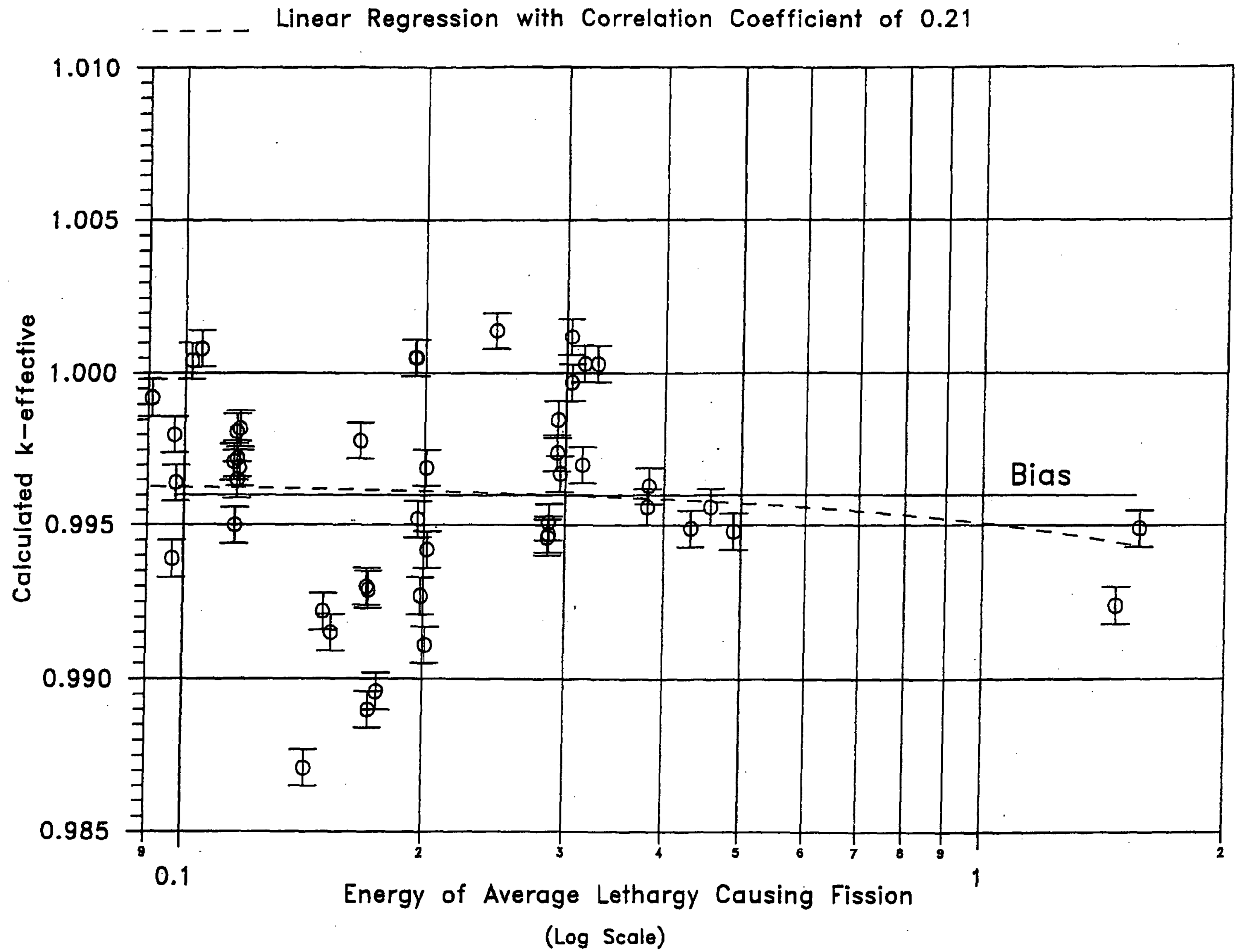

FIGURE 4A.2 KENO5a CALCULATED k-eff VALUES FOR VARIOUS VALUES OF THE SPECTRAL INDEX

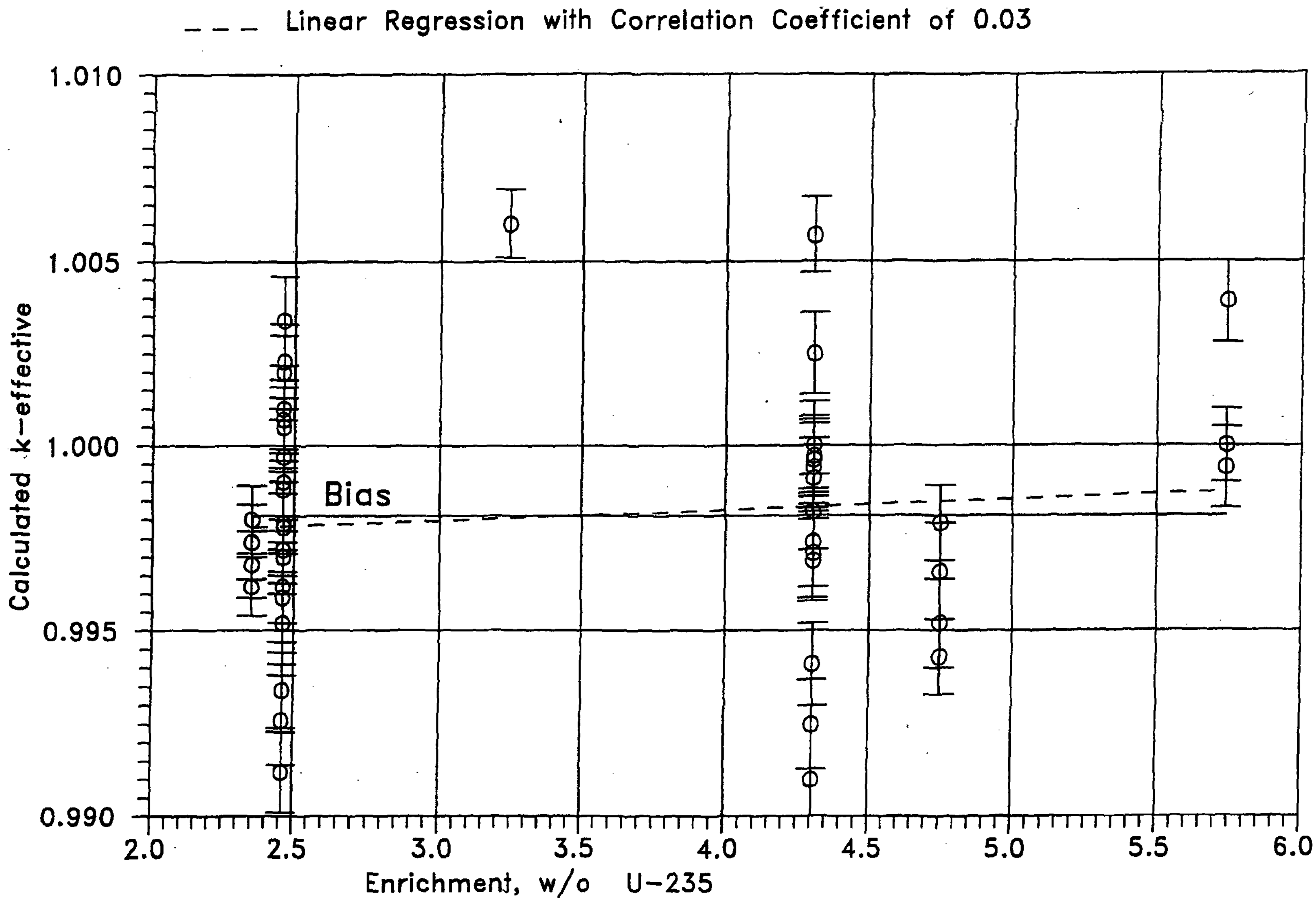

FIGURE 4A.3 MCNP CALCULATED k-eff VALUES AT VARIOUS U-235 ENRICHMENTS

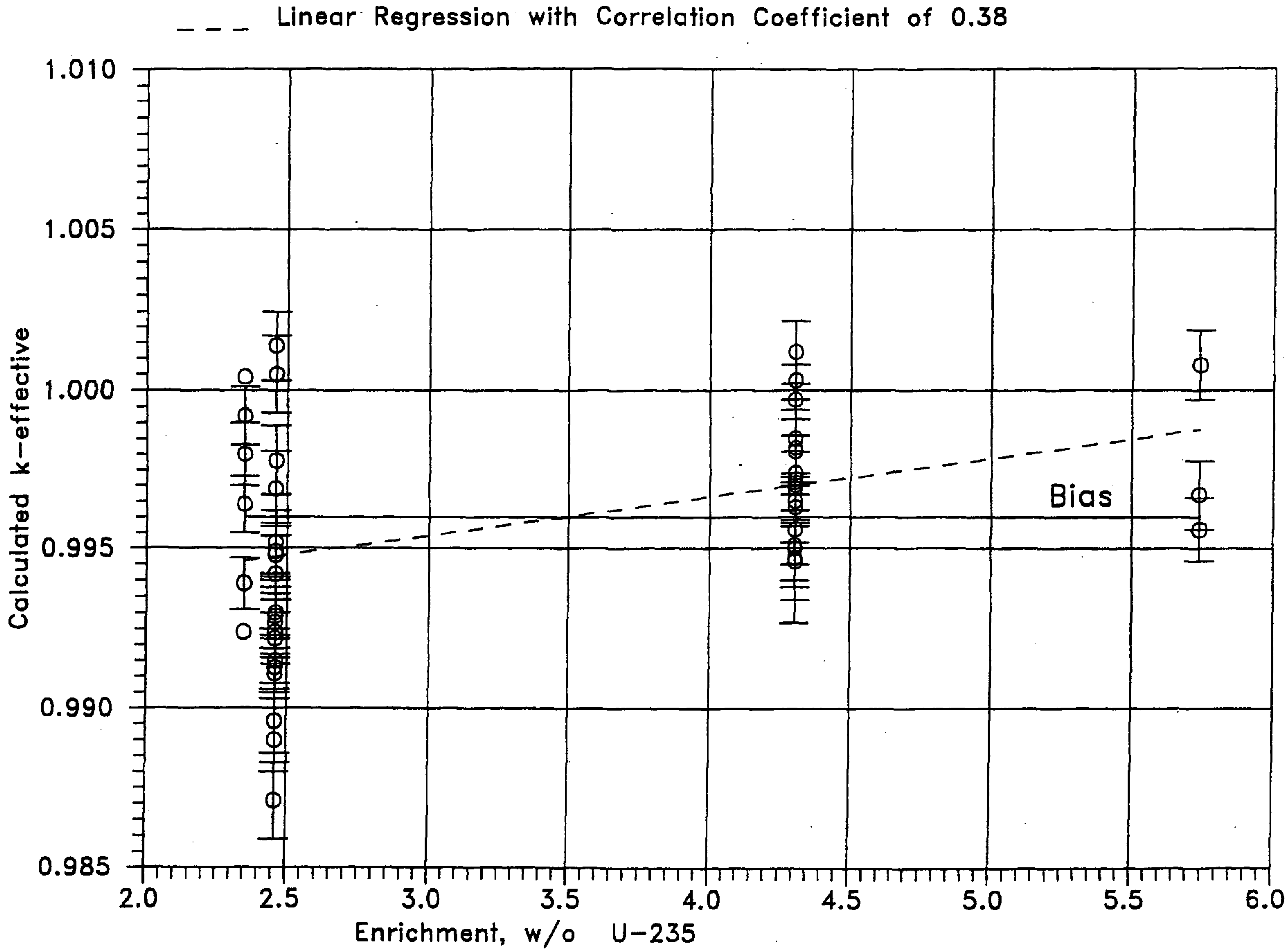

FIGURE 4A.4 KENO CALCULATED k-eff VALUES AT VARIOUS U-235 ENRICHMENTS

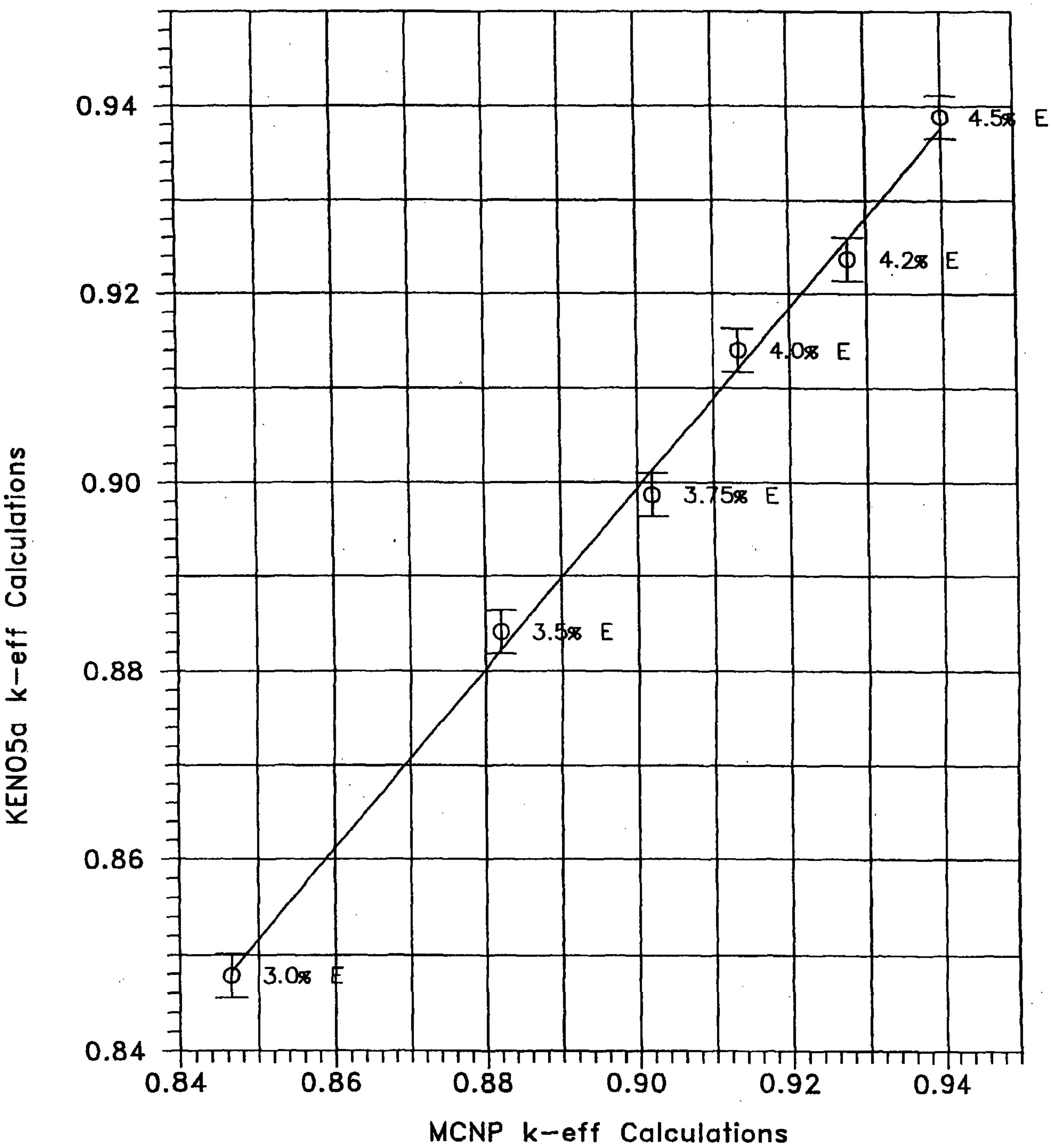

FIGURE 4A.5 COMPARISON OF MCNP AND KENO5A CALCULATIONS FOR VARIOUS FUEL ENRICHMENTS

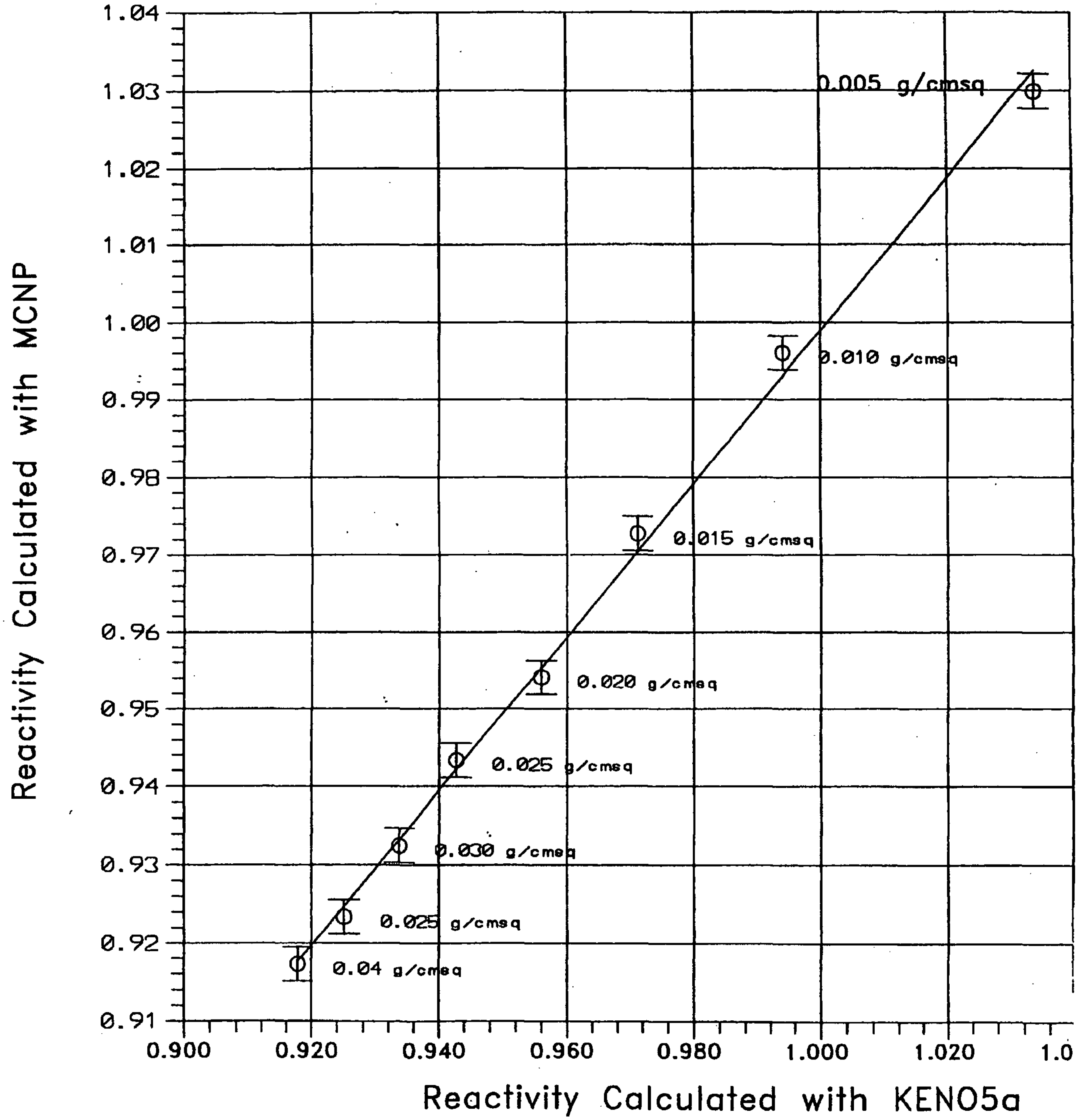

FIGURE 4A.6 COMPARISON OF MCNP AND KENO5a CALCULATIONS FOR VARIOUS BORON-10 AREAL DENSITIES

Appendix B
Boral Composition

PROPRIETARY

Appendix C
BWR Fuel Calculations

(total number of pages: 11 including this page)

Index of EXCEL Worksheets

(EXCEL file Appendix C.xls)

Reference GE-14 assembly w. partial rods replaced by water at 4.95 wt% enrichment and density of 10.631 g/cc			
	MCNP	k-inf	delta k
Fuel Channel Reactivity Effect - 4.95 wt%	run	in rack	
Reference Assembly	nmp206	1.0219	reference
Fuel Channel Removed	nmp208	1.0159	-0.0060
Thinner Fuel Channel	nmp209	1.0212	-0.0007
	MCNP	k-inf	delta k
Channel Bulging Reactivity Effect - 4.95 wt%	run	in rack	
Reference GE-14	nmp206	1.0219	reference
With Channel Bulging	nmp210	1.0271	**0.0052**
	MCNP	k-inf	delta k
Eccentric positioning - 4.95 wt%	run	in rack	
reference fuel assembly	nmp206	1.0219	reference
reference fuel assembly - eccentric positioning	nmp207	1.0221	**0.0002**
	MCNP	k-inf	delta k
Boral Height Reduction - 3.2 wt%	run	in rack	
Reference Assembly	nmp216	0.9152	reference
	nmp211	0.9134	-0.0018
	nmp212	0.9142	-0.0010
	nmp213	0.9154	0.0002
	MCNP	k-inf	delta k
Misplaced Assembly	run	in rack	from ref.
Infinite Array - Reference Assembly 4.95%	nmp206	1.0219	reference
Rack I and Rack J - Reference (no misplaced assembly) - 4.95%	nmp215	1.0010	-0.0209
Rack I and Rack J - Reference (with misplaced assembly, with channel) - 4.95% in rack	nmp214	0.9997	-0.0222
Rack I and Rack J - Reference (with misplaced assembly, no channel) - 4.95% in rack	nmp219	1.0004	-0.0215
Infinite Array - Reference Assembly 3.2%	nmp216	0.9152	reference
Rack I and Rack J - Reference (no misplaced assembly) - 3.2% in rack	nmp218	0.8946	-0.0206
Rack I and Rack J - Reference (with misplaced assemblyof 4.95 wt% enrichment) - 3.2% in rack	nmp217	0.8955	-0.0196

Worksheet C.2: Determination of Reference Assembly, Depletion Uncertainty and k_{inf} in the SCCG

	GE-6/6B		GE9B		GE11/13 w/h2o for part.		GE11/13 w/fuel for part.		GE14 w/h2o for part.		GE14 w/fuel for part.	
Burnup	SCCG	Rack	SCCG	Rack	SCCG	Rack	SCCG	Rack	SCCG	Rack	SCCG	Rack
0	1.46558	1.00934	1.46346	1.0103	1.46505	1.01978	1.46197	1.01253	1.46716	1.02431	1.46385	1.01602
0.5	1.45339	1.00189	1.46101	1.00874	1.46261	1.0182	1.45952	1.01093	1.46472	1.02274	1.4614	1.01441
1.5	1.44139	0.99422	1.43962	0.99537	1.44162	1.00483	1.43795	0.99749	1.44372	1.00934	1.43948	1.00087
5	1.40904	0.9722	1.40797	0.97365	1.41066	0.98325	1.40598	0.97585	1.41268	0.98773	1.40672	0.97895
7.5	1.3859	0.95595	1.38526	0.95767	1.38829	0.96722	1.38316	0.95989	1.39024	0.97165	1.38345	0.96283
10	1.36307	0.93977	1.3628	0.94156	1.366	0.95106	1.36075	0.94402	1.36786	0.9554	1.36072	0.94684
12.5	1.3406	0.92373	1.34062	0.9256	1.34382	0.93481	1.33877	0.92828	1.3456	0.93908	1.33858	0.93113
15	1.31843	0.90788	1.31866	0.90973	1.32174	0.91851	1.31717	0.91268	1.32344	0.92273	1.31696	0.91565
17.5	1.29645	0.89202	1.29681	0.8939	1.29967	0.9022	1.29585	0.89724	1.30132	0.90636	1.29574	0.90045
20	1.27456	0.87632	1.27499	0.87803	1.2775	0.88579	1.27467	0.88189	1.27914	0.88986	1.2748	0.88536
25	1.23051	0.8448	1.2309	0.84608	1.2325	0.85248	1.23237	0.85115	1.23413	0.85649	1.2333	0.85547
30	1.18592	0.81302	1.1859	0.81367	1.18607	0.8183	1.18963	0.8203	1.18783	0.82223	1.1919	0.82573
35	1.1406	0.78099	1.13989	0.78077	1.13815	0.78334	1.14637	0.78918	1.14011	0.7873	1.1505	0.79615
40	1.0948	0.74884	1.09299	0.74745	1.08885	0.74754	1.10274	0.75804	1.09112	0.75163	1.10921	0.76676
K-inf in rack	**1.32**	**0.9090**	1.32	**0.9107**	1.32	**0.9172**	1.32	**0.9147**	1.32	**0.9202**	1.32	**0.9178**
	Burnup	14.792		14.824		15.185		14.635		15.375		14.598
	Required											
Design Basis Fuel Assembly												
Array Type	Burnup	k-inf	k-inf		Array Type	k-inf	k-inf	Burnup	5% of			
	GWD/MTU	in rack	in SCCG			in rack	in SCCG	GWD/MTU	reac. Dec.			
GE-6/6B	0	1.0093	1.4656		GE-6/6B	0.9090	1.32	14.792	0.0050			
GE9B	0	1.0103	1.4635		GE9B	0.9107	1.32	14.824	0.0050			
GE11/13	0	1.0125	1.4620		GE11/13	0.9147	1.32	14.635	0.0049			
GE11/13*	0	1.0198	1.4651		GE11/13*	0.9172	1.32	15.185	0.0051			
GE14	0	1.0160	1.4639		GE14	0.9178	1.32	14.598	0.0049			
GE14*	0	**1.0243**	1.4672		**GE14***	**0.9202**	1.32	15.375	0.0052			
									0.0052			
*Note: partial length fuel rods are replaced by water												

NMP2 Racks		Enrichment =4.95%			no Gadolinium present			
						k-inf in the rack		
Burnup	k-inf		max	min	max	min	min	min
GWD/MTU	SCCG	reference	box-id	box-id	box-wall	box-wall	boral width	boral loading
0	1.4671	1.0256	1.02324	1.02834	1.02593	1.02461	1.032	1.03082
0.1	1.46466	1.02402	1.02168	1.02676	1.02436	1.02312	1.0304	1.02921
0.5	1.4552	1.01818	1.01583	1.02092	1.01853	1.01729	1.02452	1.02334
1	1.44853	1.01383	1.01151	1.01658	1.0142	1.01292	1.02016	1.01901
2	1.43923	1.00756	1.00521	1.01031	1.00794	1.00667	1.01383	1.01269
3	1.43047	1.00152	0.99917	1.00426	1.00189	1.00061	1.00773	1.00659
4	1.42164	0.99531	0.99299	0.99808	0.99567	0.99442	1.00149	1.00036
5	1.41273	0.98904	0.98675	0.99169	0.9894	0.98815	0.99512	0.99401
6	1.40376	0.98261	0.98036	0.98528	0.98298	0.98176	0.98868	0.98761
7	1.39478	0.97616	0.97395	0.97882	0.97651	0.97531	0.98218	0.98111
8	1.3858	0.96969	0.9675	0.97227	0.97005	0.96882	0.97566	0.97459
9	1.37684	0.96319	0.96101	0.96572	0.96353	0.96231	0.96909	0.96806
10	1.36789	0.95667	0.95449	0.95918	0.957	0.95579	0.96255	0.9615
11	1.35897	0.95009	0.94798	0.9526	0.95042	0.94924	0.95597	0.95489
12	1.35006	0.94354	0.94145	0.94602	0.94387	0.94271	0.94933	0.9483
13	1.34116	0.93698	0.93492	0.93944	0.93731	0.93614	0.94272	0.94171
14	1.33228	0.93042	0.92837	0.93286	0.93074	0.9296	0.93611	0.93511
15.384	1.32	0.9213	0.9193	0.9237	0.9217	0.9205	0.9270	0.9260
15	1.32341	0.92386	0.92183	0.92627	0.92419	0.92303	0.92951	0.92851
17.5	1.30136	0.90751	0.90551	0.90986	0.90781	0.9067	0.91304	0.91208
20	1.27918	0.89102	0.88906	0.89328	0.8913	0.89024	0.89643	0.89549
Delta-k values								
			manufacturing tolerance					
		min	min	min	min			
		box-id	box wall	boral width	boral loading			
Burnup								
0		0.0027	0.0003	0.0064	0.0052			
15.384		0.0024	0.0003	0.0056	0.0046			
Fresh Assemblies			k-inf in					
Array Type	Description		rack					
GE14*	reference		1.0256	reference				
	(E=4.95% D=10.631g/cc)							
GE14*	D=10.412		1.0228	-0.0028				
GE14*	D=10.850		1.0283	0.0027				
GE14*	E=4.90%		1.0233	-0.0023				
GE14*	E=5.00%		1.0279	0.0023				
Summary								
B-10 Loading						0.0052		
Lattice Spacing						0.0027		
SS Thickness						0.0003		
Fuel Enrichment						0.0023		
Fuel Density						0.0027		
Statistical Combination of tolerance uncertainties						**0.0069**		

Worksheet C.4: Temperature Effects

Reference GE-14 assembly w. partial rods replaced by water at 4.95 wt% enrichment and density of 10.631 g/cc								
The reactivity effect of temperature and void was determined for fresh fuel with No Gadolinia								
CASMO	degrees	degrees		**fresh**	delta-k			
run	C	F	void %	k-inf	rel to 4C			
nmp2t01	4			1.0256	reference			
nmp2t01	20			1.0235	-0.0021			
nmp2t01	40			1.0201	-0.0055			
nmp2t01	60			1.0168	-0.0088			
nmp2t01	80			1.0125	-0.0131			
nmp2t01	100			1.0072	-0.0184			
nmp2t01	120			1.0029	-0.0228			
nmp2t01	120		10	0.9819	-0.0437			

Comparison of CASMO-4 to MCNP-4A								
Adjustments for MCNP values								
Bias from Appendix A				0.0009				
Bias uncertainty from Appendix A			0.0011					
MCNP Statistics			0.0017					
Total Calculational Statistics				0.0020				
			Fresh Fuel, No Burnup, No Gad					
	MCNP	CASMO	MCNP		CASMO			
Array Type	run	run	result		result			
GE-6/6B	nmp201	nmp2d01	1.0102	0.0008	1.0093	0.0028		
GE-9B	nmp202	nmp2d02	1.0103	0.0008	1.0103	0.0020		
GE11/GE13	nmp203	nmp2d05	1.0114	0.0007	1.0125	0.0008		
GE-14	nmp204	nmp2d06	1.0136	0.0008	1.0160	-0.0004		
GE11/GE13*	nmp205	nmp2d03	1.0183	0.0008	1.0198	0.0005		
GE-14*	nmp206	nmp2d04	1.0219	0.0008	1.0243	-0.0004		
				0.0008		**0.0028**		
*partial rods replaced by water								

Worksheet C.6: Determination of Minimum Gd_2O_3 Loading

	6 @ 2%	6 @ 3%	6 @ 4%	6 @ 5%	8 @ 2%	8 @ 3%	8 @ 4%	8 @ 5%
Burnup								
0	0.9208	0.9151	0.9110	0.9077	0.8882	0.8808	0.8754	0.8711
0.1	0.9200	0.9141	0.9099	0.9066	0.8877	0.8800	0.8746	0.8702
1	0.9186	0.9107	0.9054	0.9014	0.8888	0.8785	0.8717	0.8666
2	0.9230	0.9121	0.9054	0.9005	0.8962	0.8822	0.8735	0.8672
3	0.9286	0.9145	0.9061	0.9002	0.9052	0.8870	0.8761	0.8685
4	0.9351	0.9172	0.9070	0.9000	0.9151	0.8922	0.8791	0.8701
5	0.9422	0.9204	0.9082	0.9000	0.9260	0.8980	0.8823	0.8719
6	0.9492	0.9241	0.9097	0.9003	0.9367	0.9044	0.8860	0.8739
7	0.9541	0.9284	0.9115	0.9007	0.9451	0.9116	0.8901	0.8762
8	0.9559	0.9329	0.9137	0.9013	0.9498	0.9193	0.8946	0.8788
9	0.9549	0.9368	0.9163	0.9022	0.9509	0.9262	0.8997	0.8817
10	0.9516	0.9389	0.9192	0.9034	0.9490	0.9311	0.9052	0.8850
11	0.9468	0.9387	0.9219	0.9049	0.9451	0.9332	0.9105	0.8887
12	0.9411	0.9364	0.9236	0.9067	0.9399	0.9326	0.9147	0.8928
13	0.9349	0.9323	0.9236	0.9084	0.9341	0.9298	0.9170	0.8968
14	0.9286	0.9270	0.9216	0.9095	0.9278	0.9253	0.9169	0.9001
15	0.9221	0.9211	0.9180	0.9093	0.9215	0.9199	0.9148	0.9020
16	0.9156	0.9149	0.9131	0.9075	0.9150	0.9139	0.9110	0.9021
17	0.9091	0.9085	0.9074	0.9041	0.9085	0.9076	0.9058	0.9003
18	0.9026	0.9020	0.9013	0.8994	0.9020	0.9011	0.9000	0.8968
19	0.8960	0.8954	0.8949	0.8938	0.8954	0.8946	0.8938	0.8919
20	0.8894	0.8889	0.8884	0.8877	0.8888	0.8881	0.8874	0.8862
22.5	0.8729	0.8724	0.8720	0.8716	0.8724	0.8717	0.8711	0.8704
25	0.8562	0.8557	0.8553	0.8549	0.8556	0.8550	0.8544	0.8539
MAX	**0.9559**	**0.9389**	**0.9236**	**0.9095**	**0.9509**	**0.9332**	**0.9170**	**0.9021**
MAX SCCG	1.3659	1.3420	1.3208	1.3013	1.3594	1.3348	1.3123	1.2917
Summary								
6 rods								
Gadolinia	Rack							
content	k-inf							
2.0%	0.9559							
3.0%	0.9389							
4.0%	0.9236							
5.0%	0.9095							
Target:	0.9210	**4.17%**	Min. Loading					
8 rods								
Gadolinia	Rack							
content	k-inf							
2.0%	0.9509							
3.0%	0.9332							
4.0%	0.9170							
5.0%	0.9021							
Target:	0.9210	**3.75%**	Min. Loading					

Channel ID		5.278						
Channel OD		5.518						
BOX ID		5.985						
Midpoint of Channel					5.398			
Midpoint between Channel and Box ID					5.6915			
Channel Area					2.59104			
Equation to determine half thickness					(5.6915+t)^2-(5.6915-t)^2=2.59104			
Simplified Equation					22.764t=2.59104			
Result t=					0.1138			
New Channel ID					5.5777			
New Channel OD					5.8053			
Confirm Area					2.5913			
MCNP Input								
New Channel ID					7.08365			
New Channel OD					7.37276			

Worksheet C.8: Summary of Criticality Analysis - For Limiting k_{inf} in the SCCG

Summary of Criticality Safety Analyses				
For limiting keff in the Standard Cold Core Geometry	1.32			
Temperature used for this analysis	4 C			
Initial Fuel Enrichment	5			
Maximum k-inf in SCCG	1.32			
Reference CASMO4 k-inf		CASMO	MCNP	
GE-6/6B Fuel		0.9090		
GE9B Fuel		0.9107		
GE11/GE13 Fuel		0.9147		
GE11/GE13 Fuel w/ partial rods replaced by water		0.9172		
GE14 Fuel		0.9178		
GE14 Fuel with partial rods replaced by water		0.9202		
Uncertainties				
Removal of flow channel		negative		
Eccentric assembly location		negative		
Tolerances		0.0069		
Uncertainty in depletion calculations		0.0052		
Statistical Combination		**0.0086**		
Effect of Channel Bulge		0.0052		
Comparison to Vendor Calculations		0.0100		
CASMO to MCNP Correction		0.0028		
Total Adjustment		**0.0266**		
Maximum Reactivity				
BP8x8 Fuel		**0.9356**		
GE9B Fuel		**0.9373**		
GE11/GE13 Fuel		**0.9413**		
GE11/GE13 Fuel w/ partial rods replaced by water		**0.9438**		
GE14 Fuel		**0.9444**		
GE14 Fuel with partial rods replaced by water		**0.9468**		

Worksheet C.9: Summary of Criticality Analysis - For Minimum Gd_2O_3 Loading

Summary of Criticality Safety Analyses								
For minimum Gd2O3		4.17%						
Temperature used for this analysis					4 C			
Initial Fuel Enrichment					4.95			
GD2O3 loading %					4.17%			
Reference CASMO4 k-inf						CASMO		
GE14 Fuel with partial rods replaced by water						0.9210		
Uncertainties								
Removal of flow channel						negative		
Eccentric assembly location						negative		
Tolerances						0.0069		
Uncertainty in depletion calculations						0.0052		
Statistical Combination						**0.0086**		
Effect of Channel Bulge						0.0052		
Comparison to Vendor Calculations						0.0100		
CASMO to MCNP Correction						0.0028		
Total Adjustment						**0.0266**		
Maximum Reactivity								
GE14 Fuel with partial rods replaced by water						**0.9476**		

Appendix D
List of Computer Runs

(total number of pages: 3 including this page)

Project:	1101		
Report:	2012621		
Input ID	Code	Computer	Description
			BWR CALCULATIONS
nmp201	MCNP4a	PC	4.95% BP8x8 - reference
nmp202	MCNP4a	PC	4.95% GE9B - reference
nmp203	MCNP4a	PC	4.95% GE11 & GE13 - reference partial rods replaced with fuel
nmp204	MCNP4a	PC	4.95% GE14 - reference partial rods replaced with fuel
nmp205	MCNP4a	PC	4.95% GE11 & GE13 - reference partial rods replaced with water
nmp206	MCNP4a	PC	4.95% GE14 - reference, partial rods replaced with water
nmp207	MCNP4a	PC	4.95% GE14 - reference, eccentric fuel positioning
nmp208	MCNP4a	PC	4.95% GE14 - reference, fuel channel removed
nmp209	MCNP4a	PC	4.95% GE14 - reference, thiner channel 0.100"
nmp210	MCNP4a	PC	4.95% GE14 - reference, fuel channel bulge included
nmp211	MCNP4a	PC	
nmp212	MCNP4a	PC	
nmp213	MCNP4a	PC	
nmp214	MCNP4a	PC	4.95% GE14 - misplaced assembly between Rack I &J, with misplaced assembly
nmp215	MCNP4a	PC	4.95% GE14 - misplaced assembly between Rack I &J, without misplaced assembly
nmp216	MCNP4a	PC	3.2% GE14 - reference, partial rods replaced with water
nmp217	MCNP4a	PC	3.2% GE14 - misplaced assembly between Rack I &J, with misplaced assembly
nmp218	MCNP4a	PC	3.2% GE14 - misplaced assembly between Rack I &J, without misplaced assembly
nmp219	MCNP4a	PC	4.95% GE14 - misplaced assembly between Rack I &J, with misplaced assembly - no Channel
nmp220	MCNP4a	PC	4.95% GE14 - misplaced assembly between Rack I &J, with misplaced assembly source redistributed
nmp221	MCNP4a	PC	3.2% GE14 - misplaced assembly between Rack I &J, with misplaced assembly of 4.95% enrichment
nmp2d01	CASMO	Dec 500	4.95% BP8x8 depletion, SCCG and rack, 0.100" channel
nmp2d02	CASMO	Dec 500	4.95% GE9B depletion, SCCG and rack, 0.100" channel
nmp2d03	CASMO	Dec 500	4.95% GE11/13 depletion, SCCG and rack - partial rods replaced by water, 0.120" channel
nmp2d04	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water, 0.120" channel
nmp2d05	CASMO	Dec 500	4.95% GE11/13 depletion, SCCG and rack - partial rods replaced by fuel, 0.120" channel
nmp2d06	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by fuel, 0.120" channel
nmp2d07	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water 6 Gad rods of 2%
nmp2d08	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water 6 Gad rods of 3%
nmp2d09	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water 6 Gad rods of 4%
nmp2d10	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water 6 Gad rods of 5%
nmp2d11	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water 8 Gad rods of 2%

nmp2d12	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water 8 Gad rods of 3%
nmp2d13	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water 8 Gad rods of 4%
nmp2d14	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water 8 Gad rods of 5%
nmp2t01	CASMO	Dec 500	4.95% GE14 depletion, SCCG and rack - partial rods replaced by water, 0.120" channel calculation of manufacturing tolerances and temperature effects

Appendix E
Email Correspondence

PROPRIETARY

ATTACHMENT 3

AFFIDAVIT FROM HOLTEC JUSTIFYING WITHHOLDING PROPRIETARY INFORMATION

Nine Mile Point Nuclear Station, LLC
December 13, 2010

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk

AFFIDAVIT PURSUANT TO 10 CFR 2.390

I, Savit Sinha, 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 the Attachment 4 and 5 of Letter from Nine Mile Point to Document Control Desk (NRC) dated December 13, 2010: "Response to Request for Additional Information Regarding Nine Mile Point Nuclear Station, Unit No. 2 – Re: The License Amendment Request for Extended Power Uprate Operation (TAC No. ME1476) – Spent Fuel Pool Criticality Analysis"

(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 paragraphs 4.a and 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 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.

(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)

Mr. Savit Sinha, being duly sworn, deposes and says:

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

Executed at Marlton, New Jersey, this 07th day of December, 2010.

Savit Sinha
Holtec International

Subscribed and sworn before me this 7th day of December, 2010.

MARIA C. MASSI
NOTARY PUBLIC OF NEW JERSEY
My Commission Expires April 25, 2015

ATTACHMENT 4

AFFIDAVIT FROM GLOBAL NUCLEAR FUEL JUSTIFYING WITHHOLDING PROPRIETARY INFORMATION

Nine Mile Point Nuclear Station, LLC
December 13, 2010

Global Nuclear Fuel - Americas LLC

AFFIDAVIT

I, Anthony P. Reese, state as follows:

(1) I am the Manager, Reload Design and Analysis, Global Nuclear Fuel – Americas, LLC (GNF-A), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Table 1 of Appendix E of Holtec Report No. HI-2012621, Criticality Safety Evaluation for the Nine Mile Point 2 Rack Installation Project. Table 1 is entitled NMP2 SPENT FUEL POOL RERACK PROJECT. Table 1 is proprietary in its entirety. The header of the page containing Table 1 carries the notation "GEH Proprietary Information{3}." The superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GNF-A 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 10 CFR 9.17(a)(4), and 2.390(a)(4) for trade secrets (Exemption 4). The material for which exemption from disclosure is here sought also qualifies 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, 975 F2d 871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704 F2d 1280 (DC Cir. 1983).

(4) The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. Some examples of categories of information that fit into the definition of proprietary information are:

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

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

c. Information that reveals aspects of past, present, or future GNF-A customer-funded development plans and programs, that may include potential products of GNF-A.

d. Information that discloses trade secret and/or potentially patentable subject matter for which it may be desirable to obtain patent protection.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to the NRC in confidence. The information is of a sort customarily held in confidence by GNF-A, 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 GNF-A, not been disclosed publicly, and not been made available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary and/or confidentiality agreements that provide for maintaining the information in confidence. The initial designation of this information as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure are as set forth in the following paragraphs (6) and (7).

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, who is the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or who is the person most likely to be subject to the terms under which it was licensed to GNF-A. Access to such documents within GNF-A is limited to 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 for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GNF-A 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 and/or confidentiality agreements.

(8) The information identified in paragraph (2) above is classified as proprietary because it contains details of GNF-A's fuel design and licensing methodology for the Boiling Water Reactor (BWR). Development of these methods, techniques, and information and their application for the design, modification, and analyses methodologies and processes was achieved at a significant cost to GNF-A. The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GNF-A asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GNF-A's competitive position and foreclose or reduce the availability of profit-making opportunities. The fuel design and licensing methodology is part of GNF-A's comprehensive BWR safety and 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. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GNF-A. 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. GNF-A's competitive advantage will be lost if its competitors are able to use the results of the GNF-A 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 GNF-A 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 GNF-A of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 9th day of December, 2010.

Anthony P. Reese
Manager, Reload Design and Analysis
Global Nuclear Fuel - Americas LLC
3901 Castle Hayne Rd.
Wilmington, NC 28401