6.5 CRITICALITY BENCHMARK EXPERIMENTS

Benchmark calculations have been made on selected critical experiments, chosen, insofar as possible, to bound the range of variables in the cask designs. The most important parameters are (1) the enrichment, (2) the water-gap size (MPC-24) or cell spacing (MPC-68), and (3) the ^{10}B loading of the neutron absorber panels. Other parameters, within the normal range of cask and fuel designs, have a smaller effect, but are also included. No significant trends were evident in the benchmark calculations or the derived bias. Detailed benchmark calculations are presented in Appendix 6.A.

The benchmark calculations were performed with the same computer codes and cross-section data, described in Section 6.4, that were used to calculate the k_{eff} values for the cask. Further, all calculations were performed on the same computer hardware, specifically, personal computers using the pentium processor.

Additional benchmark calculations performed for the burnup methodology for the MPC-32 are presented in Subsection 6.4.11.3.

6.6 REGULATORY COMPLIANCE

This chapter documents the criticality evaluation of the HI-STAR 100 System for the packaging and transportation of radioactive materials (spent nuclear fuel). This evaluation demonstrates that the HI-STAR 100 System is in full compliance with the criticality safety requirements of 10CFR71.

The criticality design is based on favorable geometry, fixed neutron poisons (Boral), and an administrative limit on the maximum allowable enrichment *and the minimum allowable burnup in the MPC-32*. The HI-STAR 100 System design structures and components important to criticality safety are described in sufficient detail in this chapter to identify the package accurately and provide a sufficient basis for the evaluation of the package, including the maximum allowable enrichments *and minimum allowable burnups*.

The HI-STAR 100 System is designed to be subcritical under both normal and hypothetical accident conditions of transport. The evaluations presented in the chapter address the criticality safety requirements of 10CFR71 and demonstrate that a single HI-STAR 100 System remains subcritical under the most reactive normal and hypothetical accident conditions of transport and that the most reactive infinite array of HI-STAR 100 Systems is subcritical under both normal and hypothetical accident conditions of transport. This corresponds to a transport index of zero (0) and demonstrates compliance with 10CFR71 criticality requirements.

Therefore, it is concluded that the criticality design features for the HI-STAR 100 System are in compliance with 10CFR71 and that the applicable design and acceptance criteria have been satisfied. This criticality evaluation provides reasonable assurance that the HI-STAR 100 System will allow safe transport of spent fuel.

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APPENDIX 6.A: BENCHMARK CALCULATIONS

6.A.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 cask designs. Two independent methods of analysis were used, differing in cross section libraries and in the treatment of the cross sections. MCNP4a [6.A.1] is a continuous energy Monte Carlo code and KENO5a [6.A.2] uses group-dependent cross sections. For the KENO5a analyses reported here, the 238-group library was chosen, processed through the NITAWL-II [6.A.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., [6.A.3 through 6.A.5]) for calculations with collapsed cross section sets.

The results of the benchmark calculations presented herein are separated into two parts. The first part (Sections 6.A.1 through 6.A.5) presents the calculational bias for fresh fuel calculations and encompasses the benchmark critical experiments numbered 1 through 62 in Table 6.A.1. The second part (Section 6.A.6) presents the calculational bias for burnup credit and encompasses all of the benchmark critical experiments presented in Table 6.A.1.

In cask 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 cask and fuel designs, have a smaller effect, but are also included in the analyses.

Table 6.A.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". 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 energy of the average lethargy causing fission determined (post-processing).

Figures 6.A.1 and 6.A.2 show the calculated k_{eff} for the benchmark critical experiments as a function of the "energy of the average lethargy causing fission" for MCNP4a and KENO5a, respectively (UO_2 fuel only). The scatter in the data (even for comparatively minor variation in

† 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.

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 6.A.1 and 6.A.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		
	Total	Truncated
MCNP4a	0.0009 ± 0.0011	0.0021 ± 0.0007
KENO5a	0.0030 ± 0.0012	0.0036 ± 0.0009

The values of bias shown in this table include both the bias derived directly from the calculated k_{eff} values in Table 6.A.1, and a more conservative value derived by arbitrarily truncating to 1.000 any calculated value that exceeds 1.000. The bias and standard error of the bias were calculated by 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 [6.A.18] (for the number of cases analyzed, the K-factor is ~2.05 or slightly more than 2).

$$\bar{k} = \frac{1}{n}\sum_{i=1}^{n} k_i \qquad (6.A.1)$$

$$\sigma_{\bar{k}}^2 = \frac{\sum_{i=1}^{n} k_i^2 - (\sum_{i=1}^{n} k_i)^2 / n}{n(n-1)} \qquad (6.A.2)$$

$$\text{Bias} = (1 - \bar{k}) \pm K\sigma_{\bar{k}} \qquad (6.A.3)$$

where k_i are the calculated reactivities for 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)); and K is the one-sided multiplier for 95% probability at the 95% confidence level (NBS Handbook 91 [6.A.18]).

[††] 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 [6.A.6] (or the MCNP4a manual) and is the same methodology used in MCNP4a and in KENO5a.

Formula 6.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 6.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, $K\sigma_{\bar{k}}$, which corresponds to σ_B in Section 6.4.3, 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 larger of the calculational biases (truncated bias) was used to evaluate the maximum k_{eff} values for the cask designs.

6.A.2 Effect of Enrichment

The benchmark critical experiments include those with enrichments ranging from 2.46% to 5.74% and therefore span the enrichment range for the MPC designs. Figures 6.A.3 and 6.A.4 show the calculated k_{eff} values (Table 6.A.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 (0.083 for MCNP4a and 0.378 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, the MPC-68 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 6.A.2 and Figure 6.A.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.

6.A.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 cask designs. Of these critical experiments, those performed by B&W are the most representative of the cask 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 6.A.3 lists the subset of experiments using thin neutron absorbers (from Table 6.A.1) and shows the reactivity worth (Δk) of the absorber.[†]

[†]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.

No trends with reactivity worth of the absorber are evident, although based on the calculations shown in Table 6.A.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 6.A.6 and Table 6.A.4 for the MPC-68 cask[††] 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).

6.A.4 Miscellaneous and Minor Parameters

6.A.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 6.A.5 (subset of data in Table 6.A.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 cask calculations may be slightly more conservative than otherwise.

6.A.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 cask designs, the fuel pellet diameters range from 0.303 to 0.3835 inches O.D. (0.496 to 0.580 inch lattice spacing) for PWR fuel and from 0.3224 to 0.498 inches O.D. (0.488 to 0.740 inch lattice spacing) for BWR fuel. Thus, the critical experiments analyzed provide a reasonable representation of the fuel in the MPC designs. Based on the data in Table 6.A.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 or the cask designs.

6.A.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 6.A.6. Analyses of the very high boron

[††]The MPC-68 geometry was chosen for this comparison since it contains the greater number of Boral panels and would therefore be expected to be the most sensitive to trends (errors) in calculations.

[†]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 cask design. A lead reflector is also not directly pertinent, but might be used in future designs.

concentration experiments (>1300 ppm) show a tendency to slightly overpredict reactivity for the three experiments exceeding 1300 ppm.

6.A.5 MOX Fuel *Critical Experiments*

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 6.A.7. Results of these analyses are generally above a k_{eff} of 1.00, indicating that when Pu is present, MCNP4a and KENO5a overpredict the reactivity.

This may indicate that calculation of k_{eff} 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, suggested that a small trend may exist with KENO5a. It is also possible that the overprediction in k_{eff} in 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).

6.A.6 Burnup Credit Benchmark Experiments

The use of burnup credit in a spent fuel transportation cask license requires benchmarking of the appropriate codes to spent fuel critical experiments. However, spent fuel critical experiments are not available, therefore benchmarking with an extended set of mixed oxide fuel critical experiments is performed. Thirty-nine MOX fuel critical experiments (31 from reference [6.A.21] and eight additional MOX critical experiments from Section 6.A.5) have been selected for validating MCNP4a for burnup credit. The total bias (systematic error, or mean of the deviation from a k_{eff} of exactly 1.000) for MCNP4a for the entire set of 87 critical experiments identified in Table 6.A.1 is shown in the table below.

Calculational Bias of MCNP4a and KENO5a		
	Total	*Truncated*
MCNP4a	*-0.0006 ± 0.0009*	*0.0015 ± 0.0005*

The values of bias shown in this table include both the bias derived directly from the calculated k_{eff} values in Table 6.A.1, and a more conservative value derived by arbitrarily truncating to 1.000 any calculated value that exceeds 1.000. The bias and standard error of the bias were calculated with the equations in Section 6.A.1, with the standard error multiplied by the one-sided K-factor for 95% probability at the 95% confidence level from NBS Handbook 91 [6.A.18] (for the number of cases analyzed, the K-factor is ~1.95 or slightly less than 2).

6.A.6.1 Effect of EALF

Figure 6.A.7 shows the MOX fuel calculated k_{eff} values as a function of the calculated EALF from MCNP4a during post-processing as described in Section 6.A.1. Linear regression analysis for this data confirms that the MCNP4a results do not exhibit any trends with respect to the

EALF as evidenced by the low value of the correlation coefficient (-0.34). Thus there is no correction to the bias as a function of the EALF.

6.A.6.2 *Effect of Cladding OD*

The MOX critical experiments selected for analysis cover a range of cladding outside diameters from 0.230 to 0.565 inches. In the Holtec cask designs, the allowable cladding outside diameters range from 0.342 to 0.440 inches O.D. for PWR fuel and from 0.378 to 0.563 inches O.D. for BWR and PWR fuel. Thus, the critical experiments analyzed provide a reasonable representation of the fuel in the MPC designs. Linear regression analysis for this data confirms that the MCNP4a results do not exhibit any trends with respect to the Cladding O.D. as evidenced by the low value of the correlation coefficient (-0.14). Thus there is no correction to the bias as a function of the Cladding O.D.

~~*6.A.6*~~*6.A.7* References

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

Table 6.A.1
Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF (eV) MCNP4a	EALF (eV) KENO5a
13	B&W-1484 (6.A.7)	Core XVIII	2.46	1.0036 ± 0.0012	0.9931 ± 0.0006	0.1705	0.1708
14	B&W-1484 (6.A.7)	Core XIX	2.46	0.9961 ± 0.0012	0.9971 ± 0.0005	0.2103	0.2011
15	B&W-1484 (6.A.7)	Core XX	2.46	1.0008 ± 0.0011	0.9932 ± 0.0006	0.1724	0.1701
16	B&W-1484 (6.A.7)	Core XXI	2.46	0.9994 ± 0.0010	0.9918 ± 0.0006	0.1544	0.1536
17	B&W-1645 (6.A.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 (6.A.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 (6.A.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 (6.A.9)	Case 1 1337 ppm B	2.46	1.0023 ± 0.0010	NC	0.1531	NC
21	B&W-1810 (6.A.9)	Case 12 1899 ppm B	2.46/4.02	1.0060 ± 0.0009	NC	0.4493	NC
22	French (6.A.10)	Water Moderator 0 gap	4.75	0.9966 ± 0.0013	NC	0.2172	NC
23	French (6.A.10)	Water Moderator 2.5 cm gap	4.75	0.9952 ± 0.0012	NC	0.1778	NC
24	French (6.A.10)	Water Moderator 5 cm gap	4.75	0.9943 ± 0.0010	NC	0.1677	NC

Table 6.A.1
Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF (eV) MCNP4a	EALF (eV) KENO5a
25	French (6.A.10)	Water Moderator 10 cm gap	4.75	0.9979 ± 0.0010	NC	0.1736	NC
26	PNL-3602 (6.A.11)	Steel Reflector, 0 cm separation	2.35	NC	1.0004 ± 0.0006	NC	0.1018
27	PNL-3602 (6.A.11)	Steel Reflector, 1.321 cm separation	2.35	0.9980 ± 0.0009	0.9992 ± 0.0006	0.1000	0.0909
28	PNL-3602 (6.A.11)	Steel Reflector, 2.616 cm separation	2.35	0.9968 ± 0.0009	0.9964 ± 0.0006	0.0981	0.0975
29	PNL-3602 (6.A.11)	Steel Reflector, 3.912 cm separation	2.35	0.9974 ± 0.0010	0.9980 ± 0.0006	0.0976	0.0970
30	PNL-3602 (6.A.11)	Steel Reflector, Infinite separation	2.35	0.9962 ± 0.0008	0.9939 ± 0.0006	0.0973	0.0968
31	PNL-3602 (6.A.11)	Steel Reflector, 0 cm separation	4.306	NC	1.0003 ± 0.0007	NC	0.3282
32	PNL-3602 (6.A.11)	Steel Reflector, 1.321 cm separation	4.306	0.9997 ± 0.0010	1.0012 ± 0.0007	0.3016	0.3039
33	PNL-3602 (6.A.11)	Steel Reflector, 2.616 cm separation	4.306	0.9994 ± 0.0012	0.9974 ± 0.0007	0.2911	0.2927
34	PNL-3602 (6.A.11)	Steel Reflector, 5.405 cm separation	4.306	0.9969 ± 0.0011	0.9951 ± 0.0007	0.2828	0.2860
35	PNL-3602 (6.A.11)	Steel Reflector, Infinite separation	4.306	0.9910 ± 0.0020	0.9947 ± 0.0007	0.2851	0.2864
36	PNL-3602 (6.A.11)	Steel Reflector, with Boral Sheets	4.306	0.9941 ± 0.0011	0.9970 ± 0.0007	0.3135	0.3150

Table 6.A.1
Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF (eV) MCNP4a	EALF (eV) KENO5a
37	PNL-3626 (6.A.12)	Lead Reflector, 0 cm sepn.	4.306	NC	1.0003 ± 0.0007	NC	0.3159
38	PNL-3626 (6.A.12)	Lead Reflector, 0.55 cm sepn.	4.306	1.0025 ± 0.0011	0.9997 ± 0.0007	0.3030	0.3044
39	PNL-3626 (6.A.12)	Lead Reflector, 1.956 cm sepn.	4.306	1.0000 ± 0.0012	0.9985 ± 0.0007	0.2883	0.2930
40	PNL-3626 (6.A.12)	Lead Reflector, 5.405 cm sepn.	4.306	0.9971 ± 0.0012	0.9946 ± 0.0007	0.2831	0.2854
41	PNL-2615 (6.A.13)	Experiment 004/032 – no absorber	4.306	0.9925 ± 0.0012	0.9950 ± 0.0007	0.1155	0.1159
42	PNL-2615 (6.A.13)	Experiment 030 – Zr plates	4.306	NC	0.9971 ± 0.0007	NC	0.1154
43	PNL-2615 (6.A.13)	Experiment 013 – Steel plates	4.306	NC	0.9965 ± 0.0007	NC	0.1164
44	PNL-2615 (6.A.13)	Experiment 014 – Steel plates	4.306	NC	0.9972 ± 0.0007	NC	0.1164
45	PNL-2615 (6.A.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 (6.A.13)	Exp. 009 1.62% Boron Steel plates	4.306	0.9996 ± 0.0012	0.9982 ± 0.0007	0.1161	0.1173
47	PNL-2615 (6.A.13)	Exp. 031 – Boral plates	4.306	0.9994 ± 0.0012	0.9969 ± 0.0007	0.1165	0.1171
48	PNL-7167 (6.A.14)	Experiment 214R – with flux traps	4.306	0.9991 ± 0.0011	0.9956 ± 0.0007	0.3722	0.3812

Table 6.A.1
Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF (eV) MCNP4a	EALF (eV) KENO5a
49	PNL-7167 (6.A.14)	Experiment 214V3 –with flux trap	4.306	0.9969 ± 0.0011	0.9963 ± 0.0007	0.3742	0.3826
50	PNL-4267 (6.A.15)	Case 173 – 0 ppm B	4.306	0.9974 ± 0.0012	NC	0.2893	NC
51	PNL-4267 (6.A.15)	Case 177 – 2550 ppm B	4.306	1.0057 ± 0.0010	NC	0.5509	NC
52	PNL-5803 (6.A.16)	MOX Fuel – Type 3.2 Exp. 21	20% Pu	1.0041 ± 0.0011	1.0046 ± 0.0006	0.9171	0.8868
53	PNL-5803 (6.A.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 (6.A.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 (6.A.16)	MOX Fuel – Type 3.2 Exp. 32	20% Pu	1.0079 ± 0.0011	0.9966 ± 0.0006	0.1339	0.1165
56	WCAP-3385 (6.A.17)	Saxton Case 52 PuO_2 0.52" pitch	6.6% Pu	0.9996 ± 0.0011	1.0005 ± 0.0006	0.8665	0.8417
57	WCAP-3385 (6.A.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 (6.A.17)	Saxton Case 56 PuO_2 0.56" pitch	6.6% Pu	1.0036 ± 0.0011	1.0047 ± 0.0006	0.5289	0.5197
59	WCAP-3385 (6.A.17)	Saxton Case 56 borated PuO_2	6.6% Pu	1.0008 ± 0.0010	NC	0.6389	NC
60	WCAP-3385 (6.A.17)	Saxton Case 56 U 0.56" pitch	5.74	0.9994 ± 0.0011	0.9967 ± 0.0007	0.2923	0.2954

Table 6.A.1
Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF (eV) MCNP4a	EALF (eV) KENO5a
61	WCAP-3385 (6.A.17)	Saxton Case 79 PuO_2 0.79" pitch	6.6% Pu	1.0063 ± 0.0011	1.0133 ± 0.0006	0.1520	0.1555
62	WCAP-3385 (6.A.17)	Saxton Case 79 U 0.79" pitch	5.74	1.0039 ± 0.0011	1.0008 ± 0.0006	0.1036	0.1047
		Additional MOX					
63	*EPRI Exp22 (6.A.19)*	*0.700-in. pitch 0 ppm B*	*2% Pu*	*1.0065 ± 0.0011*	*NC*	*0.5458*	*NC*
64	*EPRI Exp23 (6.A.19)*	*0.700-in. pitch 688 ppm B*	*2% Pu*	*1.0069 ± 0.0010*	*NC*	*0.7256*	*NC*
65	*EPRI Exp24 (6.A.19)*	*0.870-in. pitch 0 ppm B*	*2% Pu*	*1.0037 ± 0.0011*	*NC*	*0.1963*	*NC*
66	*EPRI Exp25 (6.A.19)*	*0.870-in. pitch 1090 ppm B*	*2% Pu*	*1.0073 ± 0.0011*	*NC*	*0.2880*	*NC*
67	*EPRI Exp26 (6.A.19)*	*0.990-in. pitch 0 ppm B*	*2% Pu*	*1.0057 ± 0.0010*	*NC*	*0.1386*	*NC*
68	*EPRI Exp27 (6.A.19)*	*0.990-in. pitch 767 ppm B*	*2% Pu*	*1.0079 ± 0.0010*	*NC*	*0.1849*	*NC*
69	*WCAP-3385 (6.A.17)*	*Saxton Case PuO_2 0.735" pitch*	*6.6% Pu*	*1.0081 ± 0.0012*	*NC*	*0.1843*	*NC*
70	*WCAP-3385 (6.A.17)*	*Saxton Case PuO_2 1.04" pitch*	*6.6% Pu*	*1.0085 ± 0.0011*	*NC*	*0.0999*	*NC*
71	*PUP Exp35 (6.A.20)*	*8 wt% ^{240}Pu 0.80" pitch*	*2% Pu*	*0.9971 ± 0.0010*	*NC*	*0.3582*	*NC*
72	*PUP Exp36 (6.A.20)*	*8 wt% ^{240}Pu 0.93" pitch*	*2% Pu*	*1.0018 ± 0.0011*	*NC*	*0.1883*	*NC*

Table 6.A.1
Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF (eV) MCNP4a	EALF (eV) KENO5a
73	*PUP Exp37 (6.A.20)*	*8 wt% ^{240}Pu 1.05" pitch*	*2% Pu*	*0.9959 ± 0.0011*	*NC*	*0.1377*	*NC*
74	*PUP Exp38 (6.A.20)*	*8 wt% ^{240}Pu 1.143" pitch*	*2% Pu*	*1.0017 ± 0.0010*	*NC*	*0.1170*	*NC*
75	*PUP Exp39 (6.A.20)*	*8 wt% ^{240}Pu 1.32" pitch*	*2% Pu*	*1.0000 ± 0.0010*	*NC*	*0.0956*	*NC*
76	*PUP Exp40 (6.A.20)*	*8 wt% ^{240}Pu 1.386" pitch*	*2% Pu*	*0.9994 ± 0.0009*	*NC*	*0.0908*	*NC*
77	*PUP Exp41 (6.A.20)*	*16 wt% ^{240}Pu 0.93" pitch*	*2% Pu*	*1.0042 ± 0.0010*	*NC*	*0.1981*	*NC*
78	*PUP Exp42 (6.A.20)*	*16 wt% ^{240}Pu 1.05" pitch*	*2% Pu*	*1.0018 ± 0.0010*	*NC*	*0.1408*	*NC*
79	*PUP Exp43 (6.A.20)*	*16 wt% ^{240}Pu 1.143" pitch*	*2% Pu*	*1.0029 ± 0.0009*	*NC*	*0.1200*	*NC*
80	*PUP Exp44 (6.A.20)*	*16 wt% ^{240}Pu 1.32" pitch*	*2% Pu*	*1.0019 ± 0.0008*	*NC*	*0.0970*	*NC*
81	*PUP Exp45 (6.A.20)*	*24 wt% ^{240}Pu 0.80" pitch*	*2% Pu*	*0.9947 ± 0.0010*	*NC*	*0.3988*	*NC*
82	*PUP Exp46 (6.A.20)*	*24 wt% ^{240}Pu 0.93" pitch*	*2% Pu*	*0.9993 ± 0.0008*	*NC*	*0.2006*	*NC*
83	*PUP Exp47 (6.A.20)*	*24 wt% ^{240}Pu 1.05" pitch*	*2% Pu*	*1.0014 ± 0.0008*	*NC*	*0.1414*	*NC*
84	*PUP Exp48 (6.A.20)*	*24 wt% ^{240}Pu 1.143" pitch*	*2% Pu*	*1.0019 ± 0.0009*	*NC*	*0.1196*	*NC*

Table 6.A.1
Summary of Criticality Benchmark Calculations

	Reference	Identification	Enrich.	Calculated k_{eff} MCNP4a	Calculated k_{eff} KENO5a	EALF (eV) MCNP4a	EALF (eV) KENO5a
85	*PUP Exp49 (6.A.20)*	*24 wt% ^{240}Pu 1.32" pitch*	*2% Pu*	*1.0049 ± 0.0008*	*NC*	*0.0973*	*NC*
86	*PUP Exp50 (6.A.20)*	*24 wt% ^{240}Pu 1.386" pitch*	*2% Pu*	*1.0040 ± 0.0008*	*NC*	*0.0917*	*NC*
87	*PUP Exp51 (6.A.20)*	*18 wt% ^{240}Pu 0.85" pitch*	*4% Pu*	*0.9993 ± 0.0011*	*NC*	*0.3918*	*NC*
88	*PUP Exp52 (6.A.20)*	*18 wt% ^{240}Pu 0.93" pitch*	*4% Pu*	*0.9991 ± 0.0010*	*NC*	*0.2565*	*NC*
89	*PUP Exp53 (6.A.20)*	*18 wt% ^{240}Pu 1.05" pitch*	*4% Pu*	*1.0073 ± 0.0011*	*NC*	*0.1757*	*NC*
90	*PUP Exp54 (6.A.20)*	*18 wt% ^{240}Pu 1.143" pitch*	*4% Pu*	*1.0065 ± 0.0010*	*NC*	*0.1454*	*NC*
91	*PUP Exp55 (6.A.20)*	*18 wt% ^{240}Pu 1.386" pitch*	*4% Pu*	*1.0093 ± 0.0009*	*NC*	*0.1068*	*NC*
92	*PUP Exp56 (6.A.20)*	*18 wt% ^{240}Pu 1.60" pitch*	*4% Pu*	*1.0086 ± 0.0010*	*NC*	*0.0932*	*NC*
93	*PUP Exp57 (6.A.20)*	*18 wt% ^{240}Pu 1.70" pitch*	*4% Pu*	*1.0106 ± 0.0009*	*NC*	*0.0884*	*NC*

Notes: NC stands for not calculated.

† EALF is the energy of the average lethargy causing fission

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

Table 6.A.2

COMPARISON OF MCNP4a AND KENO5a CALCULATED REACTIVITIES†
FOR VARIOUS ENRICHMENTS (UO_2)

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 MPC-68 with the GE 8x8R

Table 6.A.3

MCNP4a CALCULATED REACTIVITIES FOR
CRITICAL EXPERIMENTS WITH NEUTRON ABSORBERS (UO_2)

Ref.	Experiment		Δk Worth of Absorber	MCNP4a Calculated k_{eff}	EALF† (eV)
6.A.13	PNL-2615	Boral Sheet	0.0139	0.9994 ± 0.0012	0.1165
6.A.7	BAW-1484	Core XX	0.0165	1.0008 ± 0.0011	0.1724
6.A.13	PNL-2615	1.62% Boron-steel	0.0165	0.9996 ± 0.0012	0.1161
6.A.7	BAW-1484	Core XIX	0.0202	0.9961 ± 0.0012	0.2103
6.A.7	BAW-1484	Core XXI	0.0243	0.9994 ± 0.0010	0.1544
6.A.7	BAW-1484	Core XVII	0.0519	0.9962 ± 0.0012	0.2083
6.A.11	PNL-3602	Boral Sheet	0.0708	0.9941 ± 0.0011	0.3135
6.A.7	BAW-1484	Core XV	0.0786	0.9910 ± 0.0011	0.2092
6.A.7	BAW-1484	Core XVI	0.0845	0.9935 ± 0.0010	0.1757
6.A.7	BAW-1484	Core XIV	0.1575	0.9953 ± 0.0011	0.2022
6.A.7	BAW-1484	Core XIII	0.1738	1.0020 ± 0.0011	0.1988
6.A.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 6.A.4
COMPARISON OF MCNP4a AND KENO5a
CALCULATED REACTIVITIES† FOR VARIOUS BORON LOADINGS (UO_2)

^{10}B, g/cm^2	**Calcualted 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
0.030	0.9325 ± 0.0011	0.9338 ± 0.0004
0.035	0.9234 ± 0.0011	0.9251 ± 0.0004
0.040	0.9173 ± 0.0011	0.9179 ± 0.0004

† based on 4.5% enrichment GE 8x8R in the MPC-68 cask.

Table 6.A.5

CALCULATIONS FOR CRITICAL EXPERIMENTS WITH THICK LEAD AND STEEL REFLECTORS† (UO_2)

Ref.	Case	Enrichment, wt%	Separation, cm	MCNP4a k_{eff}	KENO5a k_{eff}
6.A.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
6.A.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
6.A.11	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 6.A.6

CALCULATIONS FOR CRITICAL EXPERIMENTS WITH VARIOUS SOLUBLE BORON CONCENTRATIONS (UO_2)

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

Table 6.A.7

CALCULATIONS FOR CRITICAL EXPERIMENTS WITH MOX FUEL

Reference	Case†	MCNP4a		KENO 5a	
		k_{eff}	EALF†† (eV)	k_{eff}	EALF†† (eV)
PNL-5803 [6.A.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 [6.A.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

† Arranged in order of increasing lattice spacing.

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

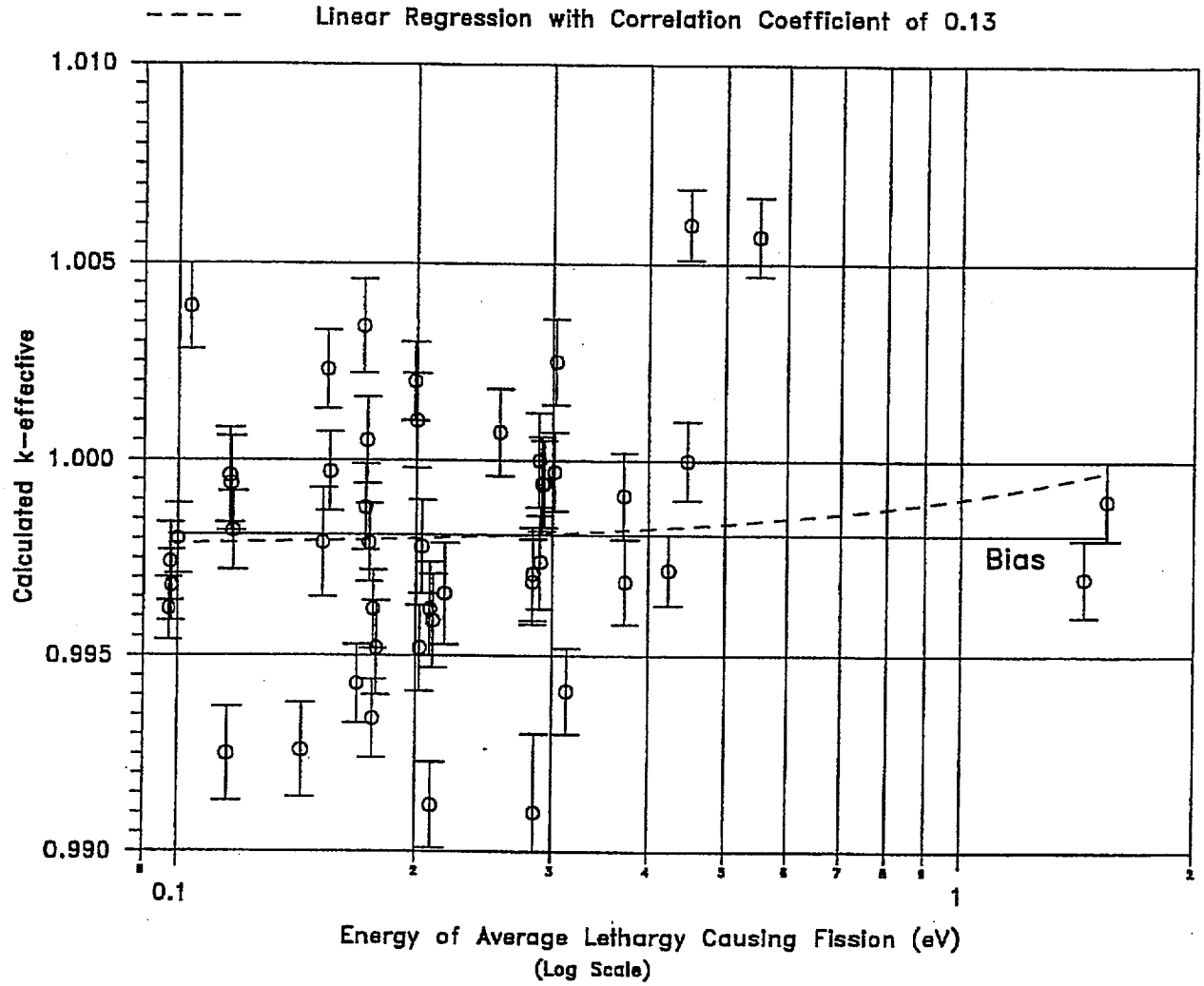

FIGURE 6.A.1 MCNP4a CALCULATED k-eff VALUES FOR VARIOUS VALUES OF THE SPECTRAL INDEX

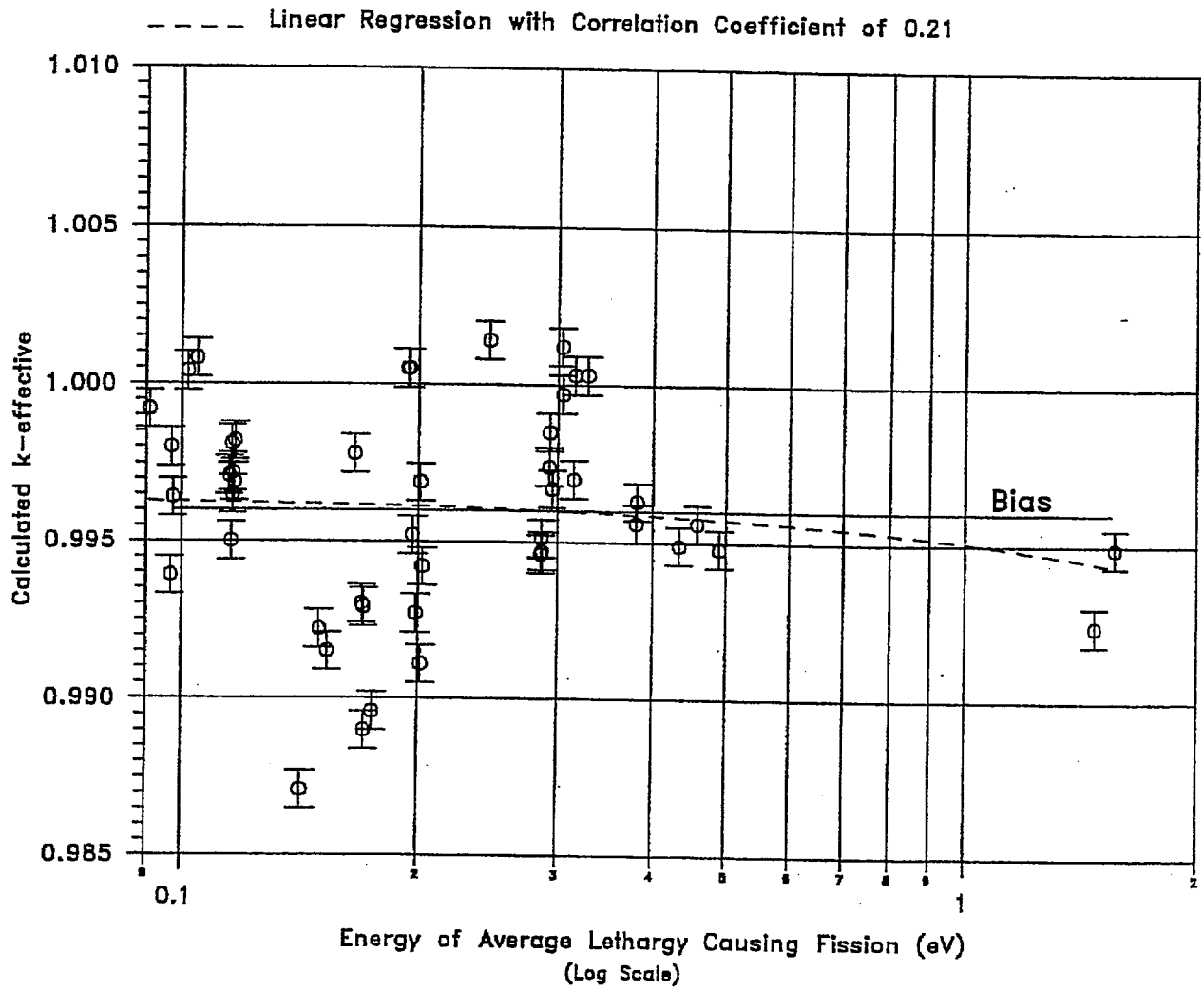

FIGURE 6.A.2 KENO5a CALCULATED k-eff VALUES FOR VARIOUS VALUES OF THE SPECTRAL INDEX

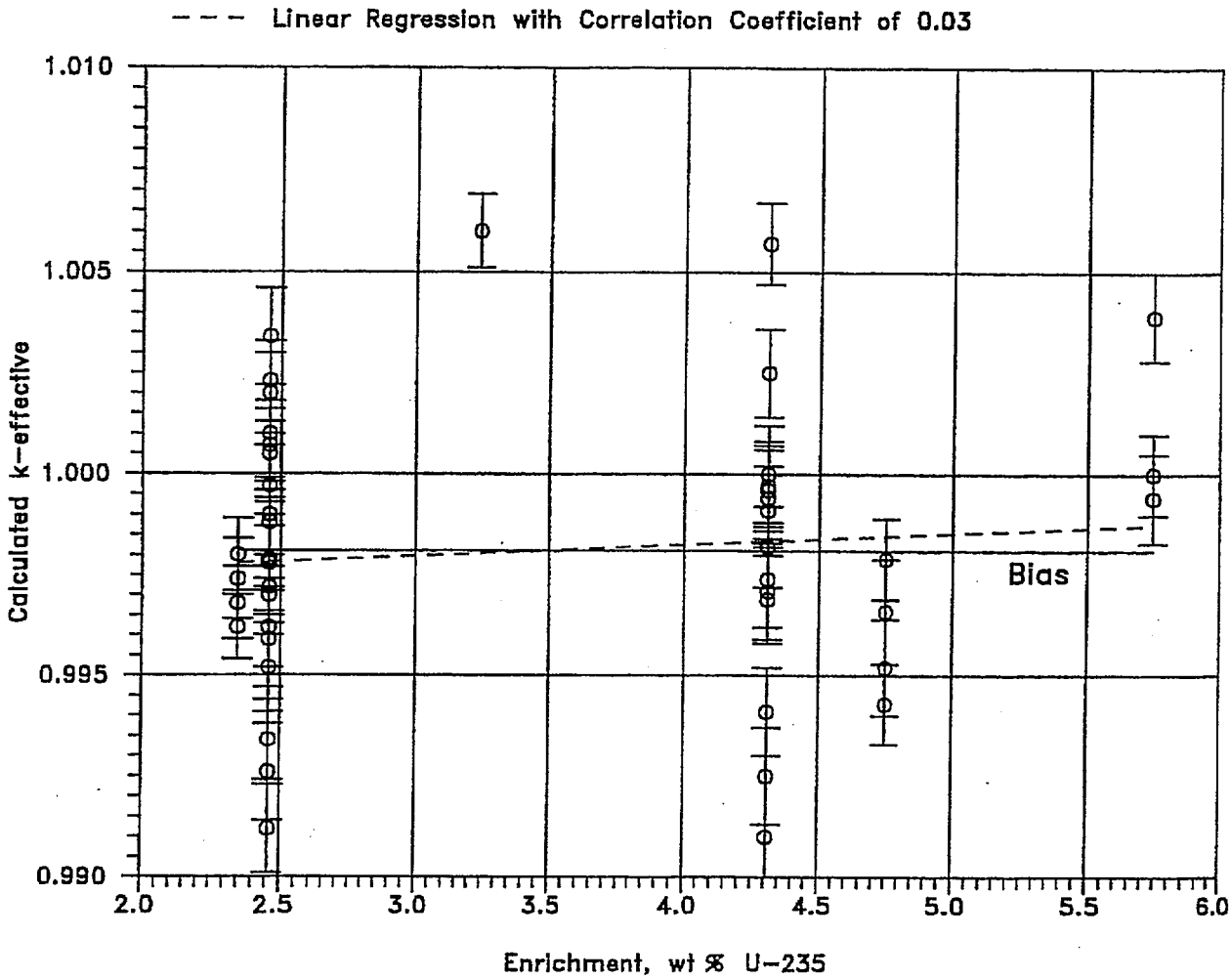

FIGURE 6.A.3 MCNP4a CALCULATED k-eff VALUES AT VARIOUS U-235 ENRICHMENTS

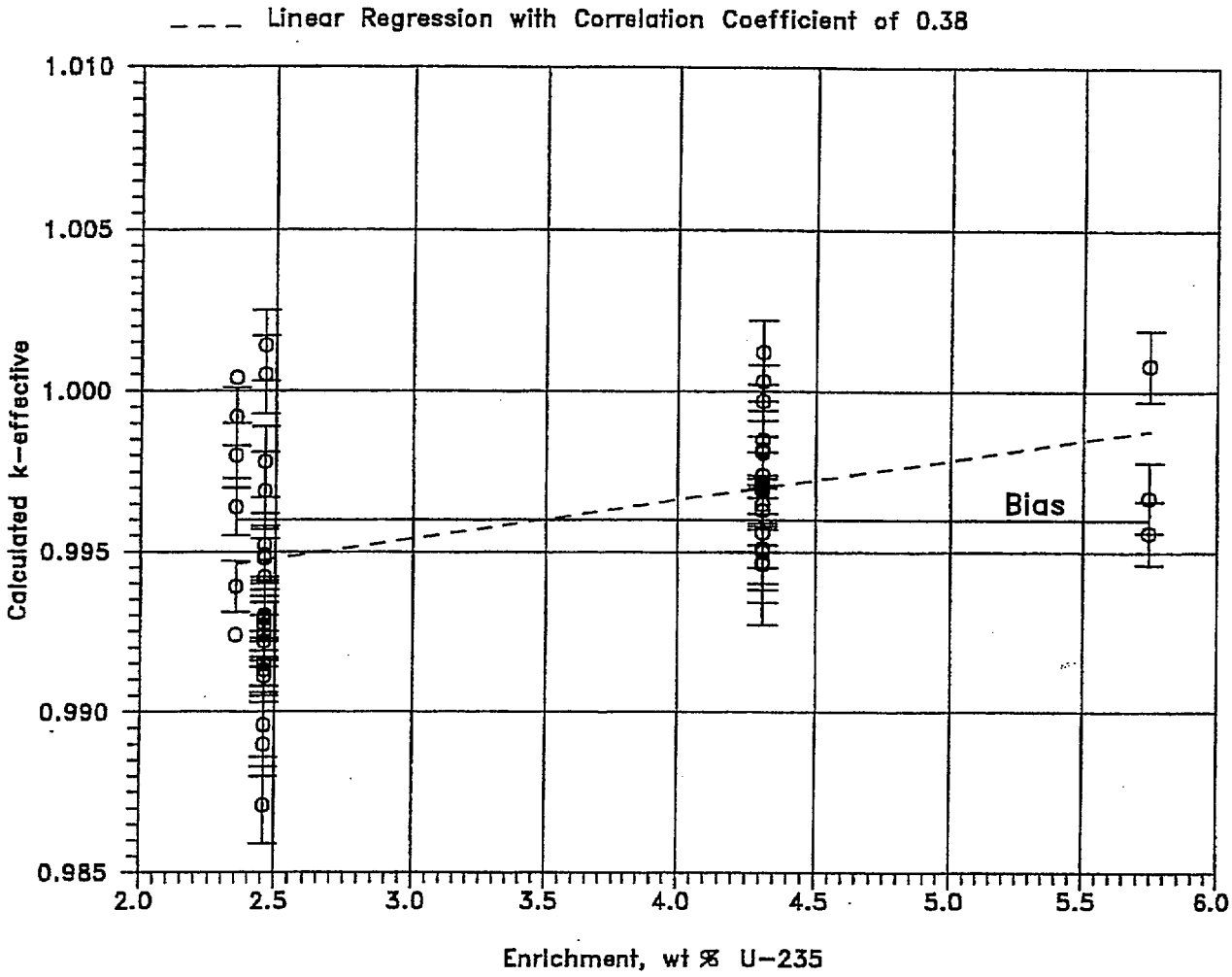

FIGURE 6.A.4 KENO5a CALCULATED k-eff VALUES AT VARIOUS U-235 ENRICHMENTS

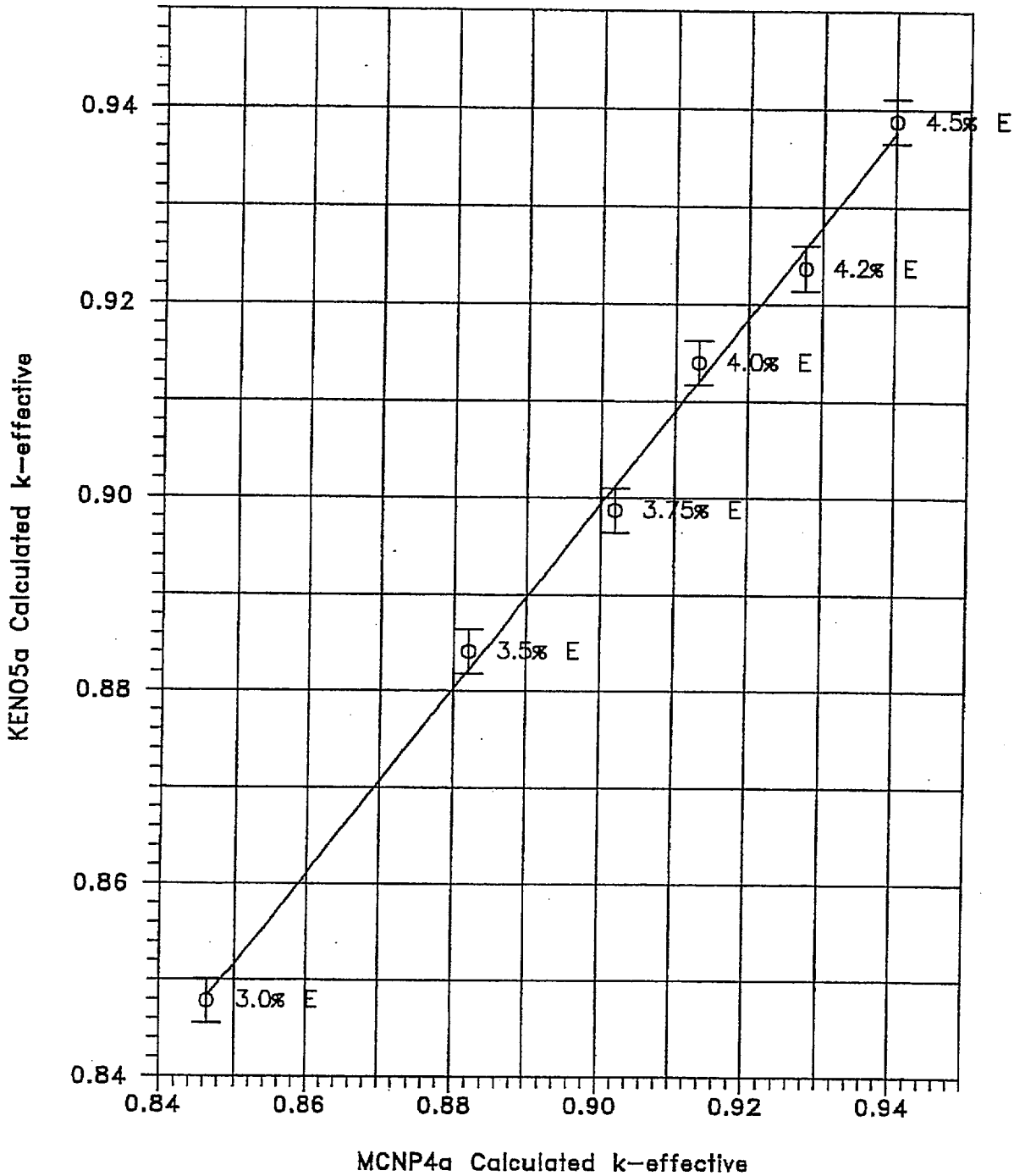

FIGURE 6.A.5 COMPARISON OF MCNP4a AND KENO5a CALCULATIONS FOR VARIOUS FUEL ENRICHMENTS

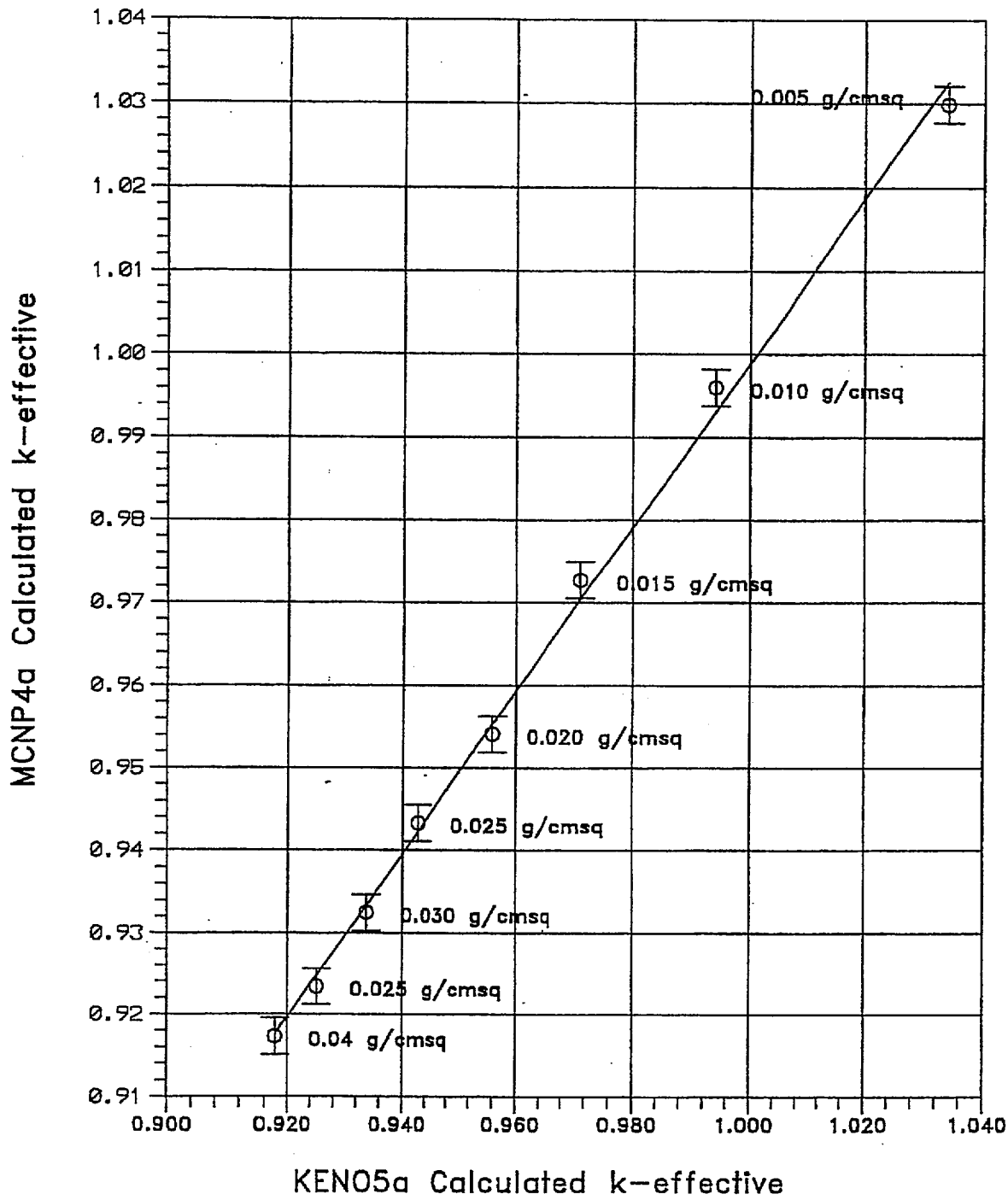

FIGURE 6.A.6 COMPARISON OF MCNP4a AND KENO5a CALCULATIONS FOR VARIOUS BORON-10 AREAL DENSITIES

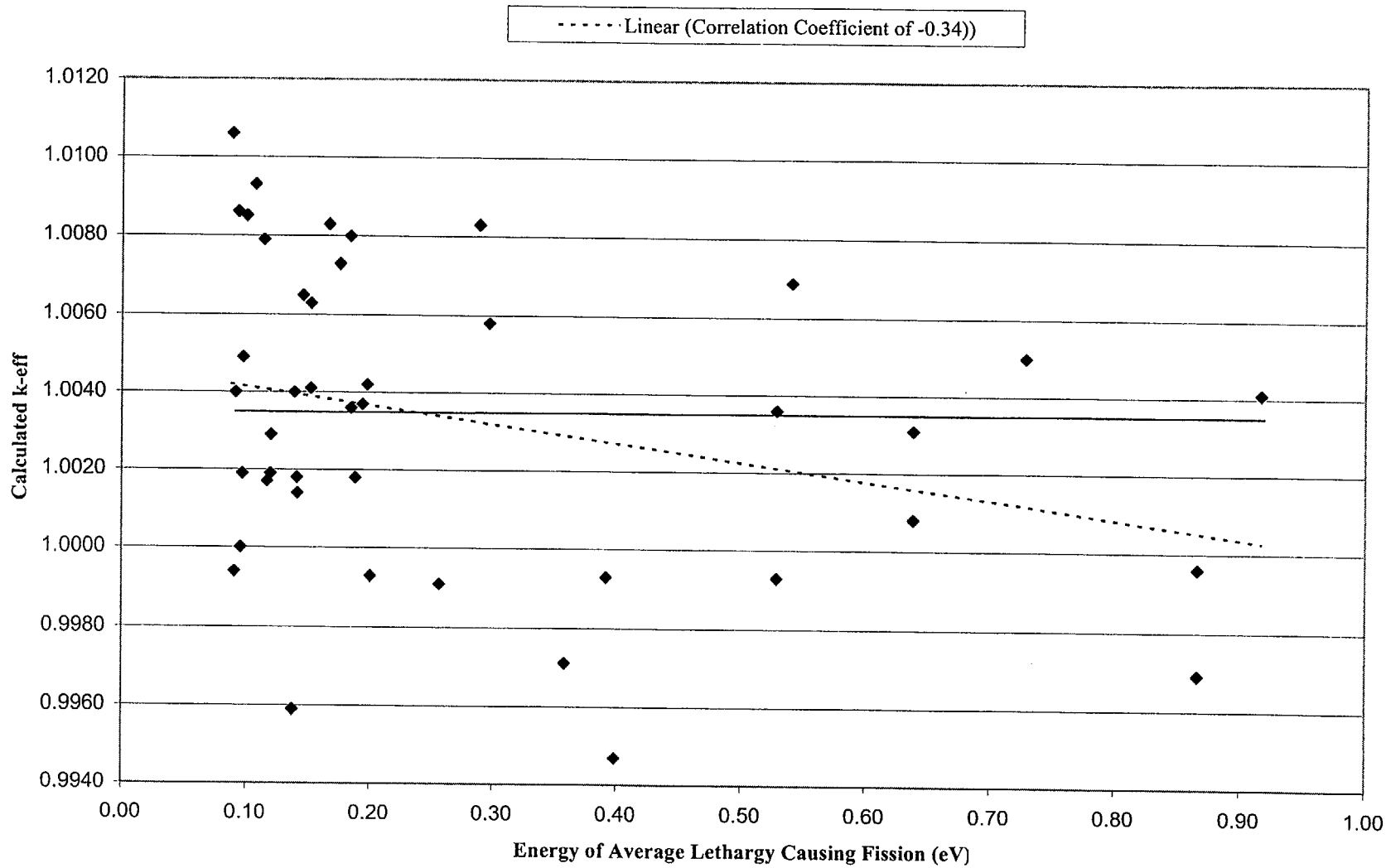

Figure 6.A.7: MCNP4a CALCULATED k-eff VALUES FOR VARIOUS VALUES OF THE SPECTRAL INDEX

APPENDIX 6.B: DISTRIBUTED ENRICHMENTS IN BWR FUEL

Fuel assemblies used in BWRs utilize fuel rods of varying enrichments as a means of controlling power peaking during in-core operation. For calculations involving BWR assemblies, the use of a uniform (planar-average) enrichment, as opposed to the distributed enrichments normally used in BWR fuel, produces conservative results. Calculations have been performed to confirm that this statement remains valid in the geometry of the MPC-68. These calculations are based on fuel assembly designs currently in use and two hypothetical distributions, all intended to illustrate that calculations with uniform average enrichments are conservative.

The average enrichment is calculated as the linear average of the various fuel rod enrichments, i.e.,

$$\overline{E} = \frac{1}{n} \sum_{i=1}^{n} E_i,$$

where E_i is the enrichment in each of the n rods, and $\overline{E}$ is the assembly average enrichment. This parameter conservatively characterizes the fuel assembly and is readily available for specific fuel assemblies in determining the acceptability of the assembly for placement in the MPC-68 cask.

The criticality calculations for average and distributed enrichment cases are compared in Table 6.B.1 to illustrate and confirm the conservatism inherent in using average enrichments. With two exceptions, the cases analyzed represent realistic designs currently in use and encompass fuel with different ratios of maximum pin enrichment to average assembly enrichment. The two exceptions are hypothetical cases intended to extend the models to higher enrichments and to demonstrate that using the average enrichment remains conservative.

Table 6.B.1 shows that, in all cases, the averaged enrichment yields conservative values of reactivity relative to distributed enrichments for both the actual fuel designs and the hypothetical higher enrichment cases. Thus, it is concluded that uniform average enrichments will always yield higher (more conservative) values for reactivity than the corresponding distributed enrichments.†

† This conclusion implicitly assumes the higher enrichment fuel rods are located internal to the assembly (as in BWR fuel), and the lower enriched rods are on the outside.

Table 6.B.1

COMPARISON CALCULATIONS FOR BWR FUEL WITH AVERAGE AND DISTRIBUTED ENRICHMENTS

Case	Average %E	Peak Rod E%	Calculated k_{eff}	
			Average E	Distributed E
8x8C04	3.01	3.80	0.8549	0.8429
8x8C04	3.934	4.9	0.9128	0.9029
8x8D05	3.42	3.95	0.8790	0.8708
8x8D05	3.78	4.40	0.9030	0.8974
8x8D05	3.90	4.90	0.9062	0.9042
9x9B01	4.34	4.71	0.9347	0.9285
9x9D01	3.35	4.34	0.8793	0.8583
Hypothetical #1 (48 outer rods of 3.967%E,14 inner rods of 5.0%)	4.20	5.00	0.9289	0.9151
Hypothetical #2 (48 outer rods of 4.354%E,14 inner rods of 5.0%)	4.50	5.00	0.9422	0.9384

APPENDIX 6.C: CALCULATIONAL SUMMARY

The following table lists the maximum k_{eff} (including bias, uncertainties, and calculational statistics), MCNP calculated k_{eff}, standard deviation, and energy of average lethargy causing fission (EALF) for each of the candidate fuel types and basket configurations.

Table 6.C.1
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-24				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
14x14A01	*0.9295*	*0.9252*	*0.0008*	*0.2084*
14x14A02	*0.9286*	*0.9242*	*0.0008*	*0.2096*
14x14A03	*0.9296*	*0.9253*	*0.0008*	*0.2093*
14x14B01	*0.9159*	*0.9117*	*0.0007*	*0.2727*
14x14B02	*0.9169*	*0.9126*	*0.0008*	*0.2345*
14x14B03	*0.9110*	*0.9065*	*0.0009*	*0.2545*
14x14B04	*0.9084*	*0.9039*	*0.0009*	*0.2563*
B14x14B01	*0.9228*	*0.9185*	*0.0008*	*0.2675*
14x14C01	*0.9258*	*0.9215*	*0.0008*	*0.2729*
14x14C02	*0.9265*	*0.9222*	*0.0008*	*0.2765*
14x14C03	*0.9287*	*0.9242*	*0.0009*	*0.2825*
14x14D01	*0.8507*	*0.8464*	*0.0008*	*0.3308*
14x14E01	*0.7598*	*0.7555*	*0.0008*	*0.3890*
14x14E01	*0.7627*	*0.7586*	*0.0007*	*0.3607*
14x14E01	*0.6952*	*0.6909*	*0.0008*	*0.2905*
15x15A01	*0.9204*	*0.9159*	*0.0009*	*0.2608*
15x15B01	*0.9369*	*0.9326*	*0.0008*	*0.2632*
15C15B02	*0.9338*	*0.9295*	*0.0008*	*0.2640*
15x15B03	*0.9362*	*0.9318*	*0.0008*	*0.2632*
15x15B04	*0.9370*	*0.9327*	*0.0008*	*0.2612*
15x15B05	*0.9356*	*0.9313*	*0.0008*	*0.2606*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-24				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
15x15B06	*0.9366*	*0.9324*	*0.0007*	*0.2638*
B15x15B01	*0.9388*	*0.9343*	*0.0009*	*0.2626*
15x15C01	*0.9255*	*0.9213*	*0.0007*	*0.2493*
15x15C02	*0.9297*	*0.9255*	*0.0007*	*0.2457*
15x15C03	*0.9297*	*0.9255*	*0.0007*	*0.2440*
15x15C04	*0.9311*	*0.9268*	*0.0008*	*0.2435*
B15x15C01	*0.9361*	*0.9316*	*0.0009*	*0.2385*
15x15D01	*0.9341*	*0.9298*	*0.0008*	*0.2822*
15x15D02	*0.9367*	*0.9324*	*0.0008*	*0.2802*
15x15D03	*0.9354*	*0.9311*	*0.0008*	*0.2844*
15x15D04	*0.9339*	*0.9292*	*0.0010*	*0.2958*
15x15E01	*0.9368*	*0.9325*	*0.0008*	*0.2826*
15x15F01	*0.9395*	*0.9350*	*0.0009*	*0.2903*
15x15G01	*0.8876*	*0.8833*	*0.0008*	*0.3357*
15x15H01	*0.9337*	*0.9292*	*0.0009*	*0.2349*
16x16A01	*0.9287*	*0.9244*	*0.0008*	*0.2704*
16x16A02	*0.9263*	*0.9221*	*0.0007*	*0.2702*
17x17A01	*0.9368*	*0.9325*	*0.0008*	*0.2131*
17x17A02	*0.9368*	*0.9325*	*0.0008*	*0.2131*
17x17A03	*0.9329*	*0.9286*	*0.0008*	*0.2018*
17x17B01	*0.9288*	*0.9243*	*0.0009*	*0.2607*
17x17B02	*0.9290*	*0.9247*	*0.0008*	*0.2596*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-24				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
17x17B03	*0.9243*	*0.9199*	*0.0008*	*0.2625*
17x17B04	*0.9324*	*0.9279*	*0.0009*	*0.2576*
17x17B05	*0.9266*	*0.9222*	*0.0008*	*0.2539*
17x17B06	*0.9311*	*0.9268*	*0.0008*	*0.2593*
17x17C01	*0.9293*	*0.9250*	*0.0008*	*0.2595*
17x17C02	*0.9336*	*0.9293*	*0.0008*	*0.2624*

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
6x6A01	0.7539	0.7498	0.0007	0.2754
6x6A02	0.7517	0.7476	0.0007	0.2510
6x6A03	0.7545	0.7501	0.0008	0.2494
6x6A04	0.7537	0.7494	0.0008	0.2494
6x6A05	0.7555	0.7512	0.0008	0.2470
6x6A06	0.7618	0.7576	0.0008	0.2298
6x6A07	0.7588	0.7550	0.0005	0.2360
6x6A08	0.7808	0.7766	0.0007	0.2527
B6x6A01	0.7888	0.7846	0.0007	0.2310
6x6B01	0.7604	0.7563	0.0007	0.2461
6x6B02	0.7618	0.7577	0.0006	0.2450
6x6B03	0.7619	0.7578	0.0007	0.2439

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
6x6B04	0.7686	0.7644	0.0008	0.2286
6x6B05	0.7824	0.7785	0.0006	0.2184
B6x6B01	0.7822	0.7783	0.0006	0.2190
6x6C01	0.8021	0.7980	0.0007	0.2139
7x7A01	0.7973	0.7930	0.0008	0.2015
7x7B01	0.9372	0.9330	0.0007	0.3658
7x7B02	0.9301	0.9260	0.0007	0.3524
7x7B03	0.9313	0.9271	0.0008	0.3438
7x7B04	0.9311	0.9270	0.0007	0.3816
7x7B05	0.9350	0.9306	0.0008	0.3382
7x7B06	0.9298	0.9260	0.0006	0.3957
B7x7B01	0.9375	0.9332	0.0008	0.3887
B7x7B02	0.9386	0.9344	0.0007	0.3983
8x8A01	0.7685	0.7644	0.0007	0.2227
8x8A02	0.7697	0.7656	0.0007	0.2158
8x8B01	0.9310	0.9265	0.0009	0.2935
8x8B02	0.9227	0.9185	0.0007	0.2993
8x8B03	0.9299	0.9257	0.0008	0.3319
8x8B04	0.9236	0.9194	0.0008	0.3700
B8x8B01	0.9346	0.9301	0.0009	0.3389
B8x8B02	0.9385	0.9343	0.0008	0.3329
B8x8B03	0.9416	0.9375	0.0007	0.3293

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
8x8C01	0.9315	0.9273	0.0007	0.2822
8x8C02	0.9313	0.9268	0.0009	0.2716
8x8C03	0.9329	0.9286	0.0008	0.2877
8x8C04	0.9348	0.9307	0.0007	0.2915
8x8C05	0.9353	0.9312	0.0007	0.2971
8x8C06	0.9353	0.9312	0.0007	0.2944
8x8C07	0.9314	0.9273	0.0007	0.2972
8x8C08	0.9339	0.9298	0.0007	0.2915
8x8C09	0.9301	0.9260	0.0007	0.3183
8x8C10	0.9317	0.9275	0.0008	0.3018
8x8C11	0.9328	0.9287	0.0007	0.3001
8x8C12	0.9285	0.9242	0.0008	0.3062
B8x8C01	0.9357	0.9313	0.0009	0.3141
B8x8C02	0.9425	0.9384	0.0007	0.3081
B8x8C03	0.9418	0.9375	0.0008	0.3056
8x8D01	0.9342	0.9302	0.0006	0.2733
8x8D02	0.9325	0.9284	0.0007	0.2750
8x8D03	0.9351	0.9309	0.0008	0.2731
8x8D04	0.9338	0.9296	0.0007	0.2727
8x8D05	0.9339	0.9294	0.0009	0.2700
8x8D06	0.9365	0.9324	0.0007	0.2777
8x8D07	0.9341	0.9297	0.0009	0.2694

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
8x8D08	0.9376	0.9332	0.0009	0.2841
B8x8D01	0.9403	0.9363	0.0007	0.2778
8x8E01	0.9312	0.9270	0.0008	0.2831
8x8F01	*0.9411*	*0.9366*	*0.0009*	*0.2264*
9x9A01	0.9353	0.9310	0.0008	0.2875
9x9A02	0.9388	0.9345	0.0008	0.2228
9x9A03	0.9351	0.9310	0.0007	0.2837
9x9A04	0.9396	0.9355	0.0007	0.2262
B9x9A01	0.9417	0.9374	0.0008	0.2236
9x9B01	*0.9380*	*0.9336*	*0.0008*	*0.2576*
9x9B02	*0.9373*	*0.9329*	*0.0009*	*0.2578*
9x9B03	*0.9417*	*0.9374*	*0.0008*	*0.2545*
B9x9B01	*0.9436*	*0.9394*	*0.0008*	*0.2506*
9x9C01	0.9395	0.9352	0.0008	0.2698
9x9D01	0.9394	0.9350	0.0009	0.2625
9x9E01	*0.9334*	*0.9293*	*0.0007*	*0.2227*
9x9E02	*0.9401*	*0.9359*	*0.0008*	*0.2065*
9x9F01	*0.9307*	*0.9265*	*0.0007*	*0.2899*
9x9F02	*0.9401*	*0.9359*	*0.0008*	*0.2065*
9x9G01	*0.9309*	*0.9265*	*0.0008*	*0.2191*
10x10A01	0.9377	0.9335	0.0008	0.3170
10x10A02	0.9426	0.9386	0.0007	0.2159

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-68				
Fuel Assembly Designation	**Maximum k_{eff}**	**Calculated k_{eff}**	**Std. Dev. (1-sigma)**	**EALF (eV)**
10x10A03	0.9396	0.9356	0.0007	0.3169
B10x10A01	0.9457	0.9414	0.0008	0.2212
10x10B01	0.9384	0.9341	0.0008	0.2881
10x10B02	0.9416	0.9373	0.0008	0.2333
10x10B03	0.9375	0.9334	0.0007	0.2856
B10x10B01	0.9436	0.9395	0.0007	0.2366
10x10C01	*0.9433*	*0.9392*	*0.0007*	*0.2416*
10x10D01	0.9376	0.9333	0.0008	0.3355
10x10E01	0.9185	0.9144	0.0007	0.2936

MPC-24E				
Fuel Assembly Designation	***Maximum k_{eff}***	***Calculated k_{eff}***	***Std. Dev. (1-sigma)***	***EALF (eV)***
14x14A03	*0.9380*	*0.9337*	*0.0008*	*0.2277*
B14x14B01	*0.9312*	*0.9269*	*0.0008*	*0.2927*
14x14C01	*0.9356*	*0.9311*	*0.0009*	*0.3161*
14x14D01	*0.8875*	*0.8830*	*0.0009*	*0.4026*
14x14E02	*0.7651*	*0.7610*	*0.0007*	*0.3645*
15x15A01	*0.9336*	*0.9292*	*0.0008*	*0.2879*
B15x15B01	*0.9465*	*0.9421*	*0.0008*	*0.2924*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES AND BASKET CONFIGURATIONS

MPC-24E				
Fuel Assembly Designation	***Maximum k_{eff}***	***Calculated k_{eff}***	***Std. Dev. (1-sigma)***	***EALF (eV)***
B15x15C01	*0.9462*	*0.9419*	*0.0008*	*0.2631*
15x15D04	*0.9440*	*0.9395*	*0.0009*	*0.3316*
15x15E01	*0.9455*	*0.9411*	*0.0009*	*0.3178*
15x15F01	*0.9468*	*0.9424*	*0.0008*	*0.3270*
15x15G01	*0.9054*	*0.9012*	*0.0007*	*0.3781*
15x15H01	*0.9423*	*0.9381*	*0.0008*	*0.2628*
16x16A01	*0.9341*	*0.9297*	*0.0009*	*0.3019*
17x17A02	*0.9447*	*0.9406*	*0.0007*	*0.2374*
17x17B06	*0.9421*	*0.9377*	*0.0008*	*0.2888*
17x17C02	*0.9433*	*0.9390*	*0.0008*	*0.2932*

MPC-24E/EF TROJAN				
Fuel Assembly Class	***Maximum k_{eff}***	***Calculated k_{eff}***	***Std. Dev. (1-sigma)***	***EALF (eV)***
17x17B (Intact)	*0.9161*	*0.9118*	*0.0008*	*0.2520*
17x17B (Intact and Damaged)	*0.9377*	*0.9333*	*0.0008*	*n/c*[†]

[†] *n/c = not calculated*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
15x15D	*2*	*2.5*	*const*	*0.9486*	*0.9447*	*0.0006*	*n/c*
15x15D	*2*	*2.5*	*profile*	*0.9524*	*0.9485*	*0.0006*	*n/c*
15x15D	*2*	*5*	*const*	*0.9365*	*0.9324*	*0.0007*	*n/c*
15x15D	*2*	*5*	*profile*	*0.9406*	*0.9368*	*0.0005*	*n/c*
15x15D	*2.5*	*15*	*const*	*0.9242*	*0.9201*	*0.0007*	*n/c*
15x15D	*2.5*	*15*	*profile*	*0.9507*	*0.9468*	*0.0006*	*n/c*
15x15D	*2.5*	*17.5*	*const*	*0.9095*	*0.9053*	*0.0007*	*n/c*
15x15D	*2.5*	*17.5*	*profile*	*0.9386*	*0.9347*	*0.0006*	*n/c*
15x15D	*3*	*22.5*	*const*	*0.9231*	*0.9190*	*0.0007*	*n/c*
15x15D	*3*	*22.5*	*profile*	*0.9558*	*0.9519*	*0.0006*	*n/c*
15x15D	*3*	*25*	*const*	*0.9078*	*0.9037*	*0.0007*	*n/c*
15x15D	*3*	*25*	*profile*	*0.9438*	*0.9397*	*0.0007*	*n/c*
15x15D	*3.5*	*30*	*const*	*0.9192*	*0.9150*	*0.0007*	*n/c*
15x15D	*3.5*	*30*	*profile*	*0.9532*	*0.9493*	*0.0006*	*n/c*
15x15D	*3.5*	*32.5*	*const*	*0.9044*	*0.9003*	*0.0007*	*n/c*
15x15D	*3.5*	*32.5*	*profile*	*0.9368*	*0.9328*	*0.0006*	*n/c*
15x15D	*4*	*35*	*const*	*0.9260*	*0.9218*	*0.0007*	*n/c*
15x15D	*4*	*35*	*profile*	*0.9554*	*0.9513*	*0.0007*	*n/c*
15x15D	*4*	*37.5*	*const*	*0.9130*	*0.9088*	*0.0007*	*n/c*
15x15D	*4*	*37.5*	*profile*	*0.9390*	*0.9351*	*0.0006*	*n/c*
15x15D	*4.5*	*40*	*const*	*0.9313*	*0.9273*	*0.0006*	*n/c*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
15x15D	*4.5*	*40*	*profile*	*0.9546*	*0.9505*	*0.0007*	*n/c*
15x15D	*4.5*	*42.5*	*const*	*0.9185*	*0.9144*	*0.0007*	*n/c*
15x15D	*4.5*	*42.5*	*profile*	*0.9390*	*0.9349*	*0.0007*	*n/c*
15x15D	*5*	*45*	*const*	*0.9372*	*0.9331*	*0.0007*	*n/c*
15x15D	*5*	*45*	*profile*	*0.9498*	*0.9459*	*0.0006*	*n/c*
15x15D	*5*	*47.5*	*const*	*0.9250*	*0.9209*	*0.0007*	*n/c*
15x15D	*5*	*47.5*	*profile*	*0.9383*	*0.9342*	*0.0007*	*n/c*
15x15E	*2*	*2.5*	*const*	*0.9487*	*0.9446*	*0.0007*	*n/c*
15x15E	*2*	*2.5*	*profile*	*0.9504*	*0.9465*	*0.0006*	*n/c*
15x15E	*2*	*5*	*const*	*0.9353*	*0.9314*	*0.0006*	*n/c*
15x15E	*2*	*5*	*profile*	*0.9409*	*0.9370*	*0.0006*	*n/c*
15x15E	*2.5*	*15*	*const*	*0.9264*	*0.9223*	*0.0007*	*n/c*
15x15E	*2.5*	*15*	*profile*	*0.9507*	*0.9469*	*0.0005*	*n/c*
15x15E	*2.5*	*17.5*	*const*	*0.9080*	*0.9041*	*0.0006*	*n/c*
15x15E	*2.5*	*17.5*	*profile*	*0.9399*	*0.9360*	*0.0006*	*n/c*
15x15E	*3*	*22.5*	*const*	*0.9233*	*0.9192*	*0.0007*	*n/c*
15x15E	*3*	*22.5*	*profile*	*0.9584*	*0.9545*	*0.0006*	*n/c*
15x15E	*3*	*25*	*const*	*0.9072*	*0.9033*	*0.0006*	*n/c*
15x15E	*3*	*25*	*profile*	*0.9434*	*0.9395*	*0.0006*	*n/c*
15x15E	*3.5*	*30*	*const*	*0.9179*	*0.9138*	*0.0007*	*n/c*
15x15E	*3.5*	*30*	*profile*	*0.9525*	*0.9486*	*0.0006*	*n/c*
15x15E	*3.5*	*32.5*	*const*	*0.9043*	*0.9002*	*0.0007*	*n/c*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
15x15E	*3.5*	*32.5*	*profile*	*0.9387*	*0.9348*	*0.0006*	*n/c*
15x15E	*4*	*35*	*const*	*0.9264*	*0.9225*	*0.0006*	*n/c*
15x15E	*4*	*35*	*profile*	*0.9550*	*0.9511*	*0.0006*	*n/c*
15x15E	*4*	*37.5*	*const*	*0.9123*	*0.9082*	*0.0007*	*n/c*
15x15E	*4*	*37.5*	*profile*	*0.9396*	*0.9357*	*0.0006*	*n/c*
15x15E	*4.5*	*40*	*const*	*0.9322*	*0.9281*	*0.0007*	*n/c*
15x15E	*4.5*	*40*	*profile*	*0.9526*	*0.9486*	*0.0006*	*n/c*
15x15E	*4.5*	*42.5*	*const*	*0.9191*	*0.9151*	*0.0006*	*n/c*
15x15E	*4.5*	*42.5*	*profile*	*0.9367*	*0.9328*	*0.0006*	*n/c*
15x15E	*5*	*45*	*const*	*0.9362*	*0.9320*	*0.0007*	*n/c*
15x15E	*5*	*45*	*profile*	*0.9492*	*0.9452*	*0.0006*	*n/c*
15x15E	*5*	*47.5*	*const*	*0.9228*	*0.9187*	*0.0007*	*n/c*
15x15E	*5*	*47.5*	*profile*	*0.9414*	*0.9375*	*0.0006*	*n/c*
15x15F	*2*	*2.5*	*const*	*0.9508*	*0.9466*	*0.0007*	*0.2424*
15x15F	*2*	*2.5*	*profile*	*0.9548*	*0.9509*	*0.0006*	*0.2355*
15x15F	*2*	*5*	*const*	*0.9385*	*0.9346*	*0.0006*	*0.2671*
15x15F	*2*	*5*	*profile*	*0.9440*	*0.9401*	*0.0006*	*0.2547*
15x15F	*2.5*	*15*	*const*	*0.9281*	*0.9240*	*0.0007*	*n/c*
15x15F	*2.5*	*15*	*profile*	*0.9518*	*0.9477*	*0.0007*	*n/c*
15x15F	*2.5*	*17.5*	*const*	*0.9121*	*0.9082*	*0.0006*	*n/c*
15x15F	*2.5*	*17.5*	*profile*	*0.9412*	*0.9373*	*0.0006*	*n/c*
15x15F	*3*	*25*	*const*	*0.9119*	*0.9078*	*0.0007*	*0.3797*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
15x15F	*3*	*25*	*profile*	*0.9471*	*0.9431*	*0.0006*	*0.3397*
15x15F	*3*	*27.5*	*const*	*0.8977*	*0.8936*	*0.0007*	*0.3890*
15x15F	*3*	*27.5*	*profile*	*0.9324*	*0.9283*	*0.0007*	*0.3493*
15x15F	*3.5*	*30*	*const*	*0.9202*	*0.9162*	*0.0006*	*n/c*
15x15F	*3.5*	*30*	*profile*	*0.9552*	*0.9512*	*0.0006*	*n/c*
15x15F	*3.5*	*32.5*	*const*	*0.9065*	*0.9024*	*0.0007*	*n/c*
15x15F	*3.5*	*32.5*	*profile*	*0.9412*	*0.9373*	*0.0006*	*n/c*
15x15F	*4*	*35*	*const*	*0.9288*	*0.9247*	*0.0007*	*0.4302*
15x15F	*4*	*35*	*profile*	*0.9572*	*0.9533*	*0.0006*	*0.3983*
15x15F	*4*	*37.5*	*const*	*0.9166*	*0.9125*	*0.0007*	*0.4376*
15x15F	*4*	*37.5*	*profile*	*0.9409*	*0.9369*	*0.0006*	*0.4069*
15x15F	*4.5*	*40*	*const*	*0.9347*	*0.9307*	*0.0006*	*n/c*
15x15F	*4.5*	*40*	*profile*	*0.9562*	*0.9522*	*0.0006*	*n/c*
15x15F	*4.5*	*42.5*	*const*	*0.9228*	*0.9185*	*0.0008*	*n/c*
15x15F	*4.5*	*42.5*	*profile*	*0.9401*	*0.9361*	*0.0006*	*n/c*
15x15F	*5*	*45*	*const*	*0.9389*	*0.9348*	*0.0007*	*0.4813*
15x15F	*5*	*45*	*profile*	*0.9499*	*0.9461*	*0.0005*	*0.4637*
15x15F	*5*	*47.5*	*const*	*0.9264*	*0.9223*	*0.0007*	*0.4884*
15x15F	*5*	*47.5*	*profile*	*0.9410*	*0.9370*	*0.0006*	*0.4631*
15x15H	*2*	*2.5*	*const*	*0.9485*	*0.9446*	*0.0006*	*n/c*
15x15H	*2*	*2.5*	*profile*	*0.9516*	*0.9477*	*0.0006*	*n/c*
15x15H	*2*	*5*	*const*	*0.9349*	*0.9308*	*0.0007*	*n/c*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
15x15H	*2*	*5*	*profile*	*0.9409*	*0.9370*	*0.0006*	*n/c*
15x15H	*2.5*	*15*	*const*	*0.9226*	*0.9185*	*0.0007*	*n/c*
15x15H	*2.5*	*15*	*profile*	*0.9520*	*0.9481*	*0.0006*	*n/c*
15x15H	*2.5*	*17.5*	*const*	*0.9054*	*0.9013*	*0.0007*	*n/c*
15x15H	*2.5*	*17.5*	*profile*	*0.9405*	*0.9364*	*0.0007*	*n/c*
15x15H	*3*	*22.5*	*const*	*0.9195*	*0.9156*	*0.0006*	*n/c*
15x15H	*3*	*22.5*	*profile*	*0.9601*	*0.9560*	*0.0007*	*n/c*
15x15H	*3*	*25*	*const*	*0.9035*	*0.8995*	*0.0006*	*n/c*
15x15H	*3*	*25*	*profile*	*0.9442*	*0.9403*	*0.0006*	*n/c*
15x15H	*3.5*	*30*	*const*	*0.9128*	*0.9089*	*0.0006*	*n/c*
15x15H	*3.5*	*30*	*profile*	*0.9520*	*0.9481*	*0.0006*	*n/c*
15x15H	*3.5*	*32.5*	*const*	*0.8987*	*0.8946*	*0.0007*	*n/c*
15x15H	*3.5*	*32.5*	*profile*	*0.9384*	*0.9345*	*0.0006*	*n/c*
15x15H	*4*	*35*	*const*	*0.9202*	*0.9160*	*0.0007*	*n/c*
15x15H	*4*	*35*	*profile*	*0.9572*	*0.9533*	*0.0006*	*n/c*
15x15H	*4*	*37.5*	*const*	*0.9077*	*0.9036*	*0.0007*	*n/c*
15x15H	*4*	*37.5*	*profile*	*0.9399*	*0.9358*	*0.0007*	*n/c*
15x15H	*4.5*	*40*	*const*	*0.9266*	*0.9225*	*0.0007*	*n/c*
15x15H	*4.5*	*40*	*profile*	*0.9551*	*0.9510*	*0.0007*	*n/c*
15x15H	*4.5*	*42.5*	*const*	*0.9127*	*0.9086*	*0.0007*	*n/c*
15x15H	*4.5*	*42.5*	*profile*	*0.9398*	*0.9358*	*0.0006*	*n/c*
15x15H	*5*	*45*	*const*	*0.9325*	*0.9284*	*0.0007*	*n/c*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
15x15H	*5*	*45*	*profile*	*0.9509*	*0.9469*	*0.0006*	*n/c*
15x15H	*5*	*47.5*	*const*	*0.9184*	*0.9143*	*0.0007*	*n/c*
15x15H	*5*	*47.5*	*profile*	*0.9407*	*0.9368*	*0.0006*	*n/c*
17x17A	*2*	*1*	*const*	*0.9456*	*0.9416*	*0.0006*	*n/c*
17x17A	*2*	*1*	*profile*	*0.9440*	*0.9400*	*0.0006*	*n/c*
17x17A	*2*	*2.5*	*const*	*0.9406*	*0.9367*	*0.0006*	*0.1855*
17x17A	*2*	*2.5*	*profile*	*0.9397*	*0.9360*	*0.0005*	*0.1863*
17x17A	*2*	*5*	*const*	*0.9282*	*0.9242*	*0.0006*	*0.2027*
17x17A	*2*	*5*	*profile*	*0.9276*	*0.9237*	*0.0006*	*0.2017*
17x17A	*2.5*	*10*	*const*	*0.9529*	*0.9488*	*0.0007*	*n/c*
17x17A	*2.5*	*10*	*profile*	*0.9552*	*0.9513*	*0.0006*	*n/c*
17x17A	*2.5*	*12.5*	*const*	*0.9365*	*0.9324*	*0.0007*	*n/c*
17x17A	*2.5*	*12.5*	*profile*	*0.9407*	*0.9370*	*0.0005*	*n/c*
17x17A	*2.5*	*15*	*const*	*0.9195*	*0.9155*	*0.0006*	*n/c*
17x17A	*2.5*	*15*	*profile*	*0.9292*	*0.9253*	*0.0006*	*n/c*
17x17A	*3*	*20*	*const*	*0.9362*	*0.9319*	*0.0008*	*0.2649*
17x17A	*3*	*20*	*profile*	*0.9492*	*0.9453*	*0.0006*	*0.2495*
17x17A	*3*	*22.5*	*const*	*0.9201*	*0.9158*	*0.0008*	*0.2730*
17x17A	*3*	*22.5*	*profile*	*0.9379*	*0.9342*	*0.0005*	*0.2534*
17x17A	*3.5*	*27.5*	*const*	*0.9306*	*0.9265*	*0.0007*	*n/c*
17x17A	*3.5*	*27.5*	*profile*	*0.9502*	*0.9463*	*0.0006*	*n/c*
17x17A	*3.5*	*30*	*const*	*0.9169*	*0.9128*	*0.0007*	*n/c*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
17x17A	*3.5*	*30*	*profile*	*0.9373*	*0.9333*	*0.0006*	*n/c*
17x17A	*4*	*35*	*const*	*0.9258*	*0.9218*	*0.0006*	*0.3137*
17x17A	*4*	*35*	*profile*	*0.9461*	*0.9422*	*0.0006*	*0.2940*
17x17A	*4*	*37.5*	*const*	*0.9139*	*0.9100*	*0.0006*	*0.3171*
17x17A	*4*	*37.5*	*profile*	*0.9321*	*0.9280*	*0.0007*	*0.2996*
17x17A	*4.5*	*40*	*const*	*0.9331*	*0.9288*	*0.0008*	*n/c*
17x17A	*4.5*	*40*	*profile*	*0.9504*	*0.9465*	*0.0006*	*n/c*
17x17A	*4.5*	*42.5*	*const*	*0.9202*	*0.9162*	*0.0006*	*n/c*
17x17A	*4.5*	*42.5*	*profile*	*0.9352*	*0.9311*	*0.0007*	*n/c*
17x17A	*5*	*45*	*const*	*0.9370*	*0.9328*	*0.0007*	*0.3460*
17x17A	*5*	*45*	*profile*	*0.9492*	*0.9452*	*0.0006*	*0.3325*
17x17A	*5*	*47.5*	*const*	*0.9261*	*0.9220*	*0.0007*	*0.3511*
17x17A	*5*	*47.5*	*profile*	*0.9425*	*0.9386*	*0.0006*	*0.3349*
17x17A	*2*	*2.5*	*const*	*0.9406*	*0.9367*	*0.0006*	*0.1855*
17x17A	*2*	*2.5*	*profile*	*0.9397*	*0.9360*	*0.0005*	*0.1863*
17x17A	*2*	*5*	*const*	*0.9282*	*0.9242*	*0.0006*	*0.2027*
17x17A	*2*	*5*	*profile*	*0.9276*	*0.9237*	*0.0006*	*0.2017*
17x17A	*2.5*	*12.5*	*const*	*0.9365*	*0.9324*	*0.0007*	*n/c*
17x17A	*2.5*	*12.5*	*profile*	*0.9407*	*0.9370*	*0.0005*	*n/c*
17x17A	*2.5*	*15*	*const*	*0.9195*	*0.9155*	*0.0006*	*n/c*
17x17A	*2.5*	*15*	*profile*	*0.9292*	*0.9253*	*0.0006*	*n/c*
17x17B	*2*	*2.5*	*const*	*0.9469*	*0.9429*	*0.0006*	*n/c*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
17x17B	*2*	*2.5*	*profile*	*0.9465*	*0.9428*	*0.0005*	*n/c*
17x17B	*2*	*5*	*const*	*0.9378*	*0.9337*	*0.0007*	*n/c*
17x17B	*2*	*5*	*profile*	*0.9379*	*0.9340*	*0.0006*	*n/c*
17x17B	*2.5*	*12.5*	*const*	*0.9462*	*0.9421*	*0.0007*	*n/c*
17x17B	*2.5*	*12.5*	*profile*	*0.9489*	*0.9450*	*0.0006*	*n/c*
17x17B	*2.5*	*15*	*const*	*0.9327*	*0.9286*	*0.0007*	*n/c*
17x17B	*2.5*	*15*	*profile*	*0.9374*	*0.9336*	*0.0005*	*n/c*
17x17B	*3*	*22.5*	*const*	*0.9314*	*0.9271*	*0.0008*	*n/c*
17x17B	*3*	*22.5*	*profile*	*0.9459*	*0.9418*	*0.0007*	*n/c*
17x17B	*3*	*25*	*const*	*0.9206*	*0.9166*	*0.0006*	*n/c*
17x17B	*3*	*25*	*profile*	*0.9352*	*0.9313*	*0.0006*	*n/c*
17x17B	*3.5*	*30*	*const*	*0.9313*	*0.9271*	*0.0007*	*n/c*
17x17B	*3.5*	*30*	*profile*	*0.9464*	*0.9425*	*0.0006*	*n/c*
17x17B	*3.5*	*32.5*	*const*	*0.9190*	*0.9149*	*0.0007*	*n/c*
17x17B	*3.5*	*32.5*	*profile*	*0.9335*	*0.9294*	*0.0007*	*n/c*
17x17B	*4*	*35*	*const*	*0.9386*	*0.9347*	*0.0006*	*n/c*
17x17B	*4*	*35*	*profile*	*0.9509*	*0.9470*	*0.0006*	*n/c*
17x17B	*4*	*37.5*	*const*	*0.9277*	*0.9238*	*0.0006*	*n/c*
17x17B	*4*	*37.5*	*profile*	*0.9400*	*0.9361*	*0.0006*	*n/c*
17x17B	*4.5*	*40*	*const*	*0.9453*	*0.9412*	*0.0007*	*n/c*
17x17B	*4.5*	*40*	*profile*	*0.9563*	*0.9524*	*0.0006*	*n/c*
17x17B	*4.5*	*42.5*	*const*	*0.9325*	*0.9285*	*0.0006*	*n/c*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
17x17B	*4.5*	*42.5*	*profile*	*0.9437*	*0.9398*	*0.0006*	*n/c*
17x17B	*5*	*47.5*	*const*	*0.9397*	*0.9356*	*0.0007*	*n/c*
17x17B	*5*	*47.5*	*profile*	*0.9477*	*0.9436*	*0.0007*	*n/c*
17x17B	*5*	*50*	*const*	*0.9285*	*0.9244*	*0.0007*	*n/c*
17x17B	*5*	*50*	*profile*	*0.9408*	*0.9367*	*0.0007*	*n/c*
17x17C	*2*	*2.5*	*const*	*0.9490*	*0.9450*	*0.0006*	*n/c*
17x17C	*2*	*2.5*	*profile*	*0.9506*	*0.9467*	*0.0006*	*n/c*
17x17C	*2*	*5*	*const*	*0.9401*	*0.9361*	*0.0006*	*n/c*
17x17C	*2*	*5*	*profile*	*0.9398*	*0.9359*	*0.0006*	*n/c*
17x17C	*2.5*	*12.5*	*const*	*0.9484*	*0.9443*	*0.0007*	*n/c*
17x17C	*2.5*	*12.5*	*profile*	*0.9505*	*0.9466*	*0.0006*	*n/c*
17x17C	*2.5*	*15*	*const*	*0.9339*	*0.9298*	*0.0007*	*n/c*
17x17C	*2.5*	*15*	*profile*	*0.9395*	*0.9356*	*0.0006*	*n/c*
17x17C	*3*	*22.5*	*const*	*0.9345*	*0.9303*	*0.0007*	*n/c*
17x17C	*3*	*22.5*	*profile*	*0.9455*	*0.9416*	*0.0006*	*n/c*
17x17C	*3*	*25*	*const*	*0.9227*	*0.9187*	*0.0006*	*n/c*
17x17C	*3*	*25*	*profile*	*0.9351*	*0.9312*	*0.0006*	*n/c*
17x17C	*3.5*	*30*	*const*	*0.9325*	*0.9286*	*0.0006*	*n/c*
17x17C	*3.5*	*30*	*profile*	*0.9468*	*0.9429*	*0.0006*	*n/c*
17x17C	*3.5*	*32.5*	*const*	*0.9197*	*0.9157*	*0.0006*	*n/c*
17x17C	*3.5*	*32.5*	*profile*	*0.9370*	*0.9329*	*0.0007*	*n/c*
17x17C	*4*	*35*	*const*	*0.9403*	*0.9361*	*0.0007*	*n/c*

Table 6.C.1 (continued)
CALCULATIONAL SUMMARY FOR ALL CANDIDATE FUEL TYPES
AND BASKET CONFIGURATIONS

MPC-32							
Assembly Class	***Enrich-ment (wt%)***	***Burnup (GWd/MTU)***	***Axial Burnup Distr.***	***Max. k_{eff}***	***Calc'd k_{eff}***	***Std. Deviation (1-sigma)***	***EALF (eV)***
17x17C	*4*	*35*	*profile*	*0.9552*	*0.9513*	*0.0006*	*n/c*
17x17C	*4*	*37.5*	*const*	*0.9286*	*0.9245*	*0.0007*	*n/c*
17x17C	*4*	*37.5*	*profile*	*0.9435*	*0.9395*	*0.0006*	*n/c*
17x17C	*4.5*	*42.5*	*const*	*0.9357*	*0.9316*	*0.0007*	*n/c*
17x17C	*4.5*	*42.5*	*profile*	*0.9469*	*0.9430*	*0.0006*	*n/c*
17x17C	*4.5*	*45*	*const*	*0.9255*	*0.9212*	*0.0008*	*n/c*
17x17C	*4.5*	*45*	*profile*	*0.9332*	*0.9291*	*0.0007*	*n/c*
17x17C	*5*	*47.5*	*const*	*0.9410*	*0.9369*	*0.0007*	*n/c*
17x17C	*5*	*47.5*	*profile*	*0.9519*	*0.9478*	*0.0007*	*n/c*
17x17C	*5*	*50*	*const*	*0.9308*	*0.9266*	*0.0007*	*n/c*
17x17C	*5*	*50*	*profile*	*0.9429*	*0.9388*	*0.0007*	*n/c*

Note: Maximum k_{eff} = Calculated k_{eff} + $K_c \times \sigma_c$ + Bias + σ_B
where:

K_c = 2.0
σ_c = Std. Dev. (1-sigma)
Bias = 0.0021
σ_B = 0.0006

See Subsection 6.4.3 for further explanation.

APPENDIX 6.D: SAMPLE INPUT FILES

(Total number of pages in this appendix : *46*~~44~~)

File Description	Starting Page
MCNP4a input file for MPC-24	Appendix 6.D-2
MCNP4a input file for MPC-68	Appendix 6.D-*13*~~12~~
MCNP4a input file for MPC-68F	Appendix 6.D-*19*~~18~~
MCNP4a input file for MPC-68F with Dresden damaged fuel in the Damaged Fuel Container	Appendix 6.D-*25*~~24~~
MCNP4a input file for MPC-68F with Humbolt Bay damaged fuel in the Damaged Fuel Container	Appendix 6.D-*31*~~30~~
KENO5a input file for MPC-24	Appendix 6.D-*37*~~36~~
KENO5a input file for MPC-68	Appendix 6.D-*42*~~40~~

```
 message:   outp=4rf5f45o  srctp=4rf5f45s  runtpe=4rf5f45r

4rf5f45
c
c
c Bounding Assembly in Class 15x15F
c
c MPC-24/24E cell configuration
c
c HI-STAR with active length 150 inch
c
c Cask Input Preprocessor
c cskinp 15f 15f mpc24n mpc24n histar star150 4.1 4rf5f45 pure
c ------     10580 30-Jul-101 09:38 cpp\15f.bat
c   added 15f.co
c   added 15f.ce
c   added 15f.su
c   added 15f.sp
c ------     37966 21-Aug-101 10:10 cpp\mpc24n.bat
c   added mpc24n.co
c   added mpc24n.ce
c   added mpc24n.su
c   added mpc24n.sp
c ------      5620 22-Aug-101 14:05 cpp\histar.bat
c   added histar.co
c   added histar.ce
c   added histar.su
c   added histar.sp
c end of comments
c
c start of cells
c
c 15x15f
c
c number of cells: 6
c cell numbers:      1 to 7 and 201 to 299
c univers numbers:   1 to 3 and 201 to 299
c surface numbers:   1 to 9 and 201 to 299
c
c number of cells: 1
1     1 -10.522     -1  u=2       $ fuel
2     4 -1.0     1  -2  u=2       $ gap
3     3 -6.55    2  -3  u=2       $ Zr Clad
4     4 -1.0        3  u=2       $ water in fuel region
5     4 -1.0  -4:5     u=3       $ water in guide tubes
6     3 -6.55   4 -5    u=3       $ guide tubes
7     4 -1.0  -6   +7   -8   +9   u=1  lat=1
      fill= -8:8    -8:8   0:0
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
      1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
      1 2 2 2 2 2 3 2 2 2 3 2 2 2 2 2 1
      1 2 2 2 3 2 2 2 2 2 2 2 3 2 2 2 1
      1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
      1 2 2 3 2 2 3 2 2 2 3 2 2 3 2 2 1
      1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
      1 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 1
      1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
```

```
      1 2 2 3 2 2 3 2 2 2 3 2 2 3 2 2 1
      1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
      1 2 2 2 3 2 2 2 2 2 2 2 3 2 2 2 1
      1 2 2 2 2 2 3 2 2 2 3 2 2 2 2 2 1
      1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
      1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
c
c     MPC-24
c
c number of cells: 102
c cell numbers :       400   to  699
c universe numbers :     4   to    9
c surface numbers :    400   to  699
c
c     Right Side
c
408     0          -410   411  -412   413    u=4 fill=1 (1)
409     5  -7.84    410  -424   413  -426    u=4
410    4 -1.0      424  -428   448  -445    u=4
411    7  -2.7      428  -528  448  -445    u=4
412    6  -2.66    528  -532  448  -445    u=4
413    7  -2.7     532  -432   448  -445    u=4
414    4 -1.0      432  -436   448  -445    u=4
415    5  -7.84     436  -440   448  -445    u=4
416    4 -1.0      440        413         u=4
417    4 -1.0      424  -440   413  -447    u=4
418    4 -1.0      424  -440   446         u=4
419    5  -7.84     424  -440   447  -448    u=4
420    5  -7.84     424  -440   445  -446    u=4
c
c    Left Side
c
421    5  -7.84     425  -411   413         u=4
422    4 -1.0      429  -425   448  -445    u=4
423    7  -2.7     529  -429   448  -445    u=4
424    6  -2.66    533 -529   448  -445    u=4
425    7  -2.7      433 -533   448  -445    u=4
426    4 -1.0      437  -433   448  -445    u=4
427    5  -7.84     441  -437   448  -445    u=4
428    4 -1.0          -441   413         u=4
429    4 -1.0      441  -425   413  -447    u=4
430    4 -1.0      441  -425   446         u=4
431    5  -7.84     441  -425   447  -448    u=4
432    5  -7.84     441  -425   445  -446    u=4
c
c     Top
c
433    5  -7.84     411  -410   412  -426    u=4
434    4 -1.0      451  -452   426  -430    u=4
435    7  -2.7      451  -452   430 -530    u=4
436    6  -2.66     451  -452  530 -534    u=4
437    7  -2.7      451  -452  534  -434    u=4
438    4 -1.0      451  -452   434  -438    u=4
439    5  -7.84     451  -452   438  -442    u=4
440    4 -1.0      411  -424   442         u=4
441    4 -1.0      411  -450   426  -442    u=4
442    4 -1.0      453  -424   426  -442    u=4
```

```
443     5  -7.84     450  -451   426  -442     u=4
444     5  -7.84     452  -453   426  -442     u=4
c
c     Bottom
c
445     5  -7.84     427              -413     u=4
446     4 -1.0      451  -452   431  -427     u=4
447     7  -2.7      451  -452  531  -431     u=4
448     6  -2.66     451  -452  535 -531     u=4
449     7  -2.7      451  -452   435 -535     u=4
450     4 -1.0      451  -452   439  -435     u=4
451     5  -7.84     451  -452   443  -439     u=4
452     4 -1.0      411              -443     u=4
453     4 -1.0      411  -450   443  -427     u=4
454     4 -1.0      453         443  -427     u=4
455     5  -7.84     450  -451   443  -427     u=4
456     5  -7.84     452  -453   443  -427     u=4
457     5  -7.84     425  -411        -427     u=4
458     4 -1.0          -425        -427     u=4
c
c     TYPE B CELL  -  Short Boral on top and right
c
c     Right Side
c
459     0           -410   411  -412   413     u=5 fill=1 (1)
460     5  -7.84     410  -424   413  -426     u=5
470     4 -1.0      424  -428  548 -545     u=5
471     7  -2.7      428  -528 548 -545     u=5
472     6  -2.66    528  -532 548 -545     u=5
473     7  -2.7     532  -432  548 -545     u=5
474     4 -1.0      432  -436  548 -545     u=5
475     5  -7.84     436  -440  548 -545     u=5
476     4 -1.0      440         413         u=5
477     4 -1.0      424  -440   413 -547     u=5
478     4 -1.0      424  -440  546         u=5
479     5  -7.84     424  -440  547 -548     u=5
480     5  -7.84     424  -440  545 -546     u=5
c
c    Left Side
c
481     5  -7.84     425  -411   413          u=5
482     4 -1.0      429  -425   448  -445     u=5
483     7  -2.7      529  -429   448  -445     u=5
484     6  -2.66    533 -529   448  -445     u=5
485     7  -2.7      433 -533   448  -445     u=5
486     4 -1.0      437  -433   448  -445     u=5
487     5  -7.84     441  -437   448  -445     u=5
488     4 -1.0          -441   413         u=5
489     4 -1.0      441  -425   413  -447     u=5
490     4 -1.0      441  -425   446         u=5
491     5  -7.84     441  -425   447  -448     u=5
492     5  -7.84     441  -425   445  -446     u=5
c
c     Top
c
493     5  -7.84     411  -410   412  -426     u=5
494     4 -1.0     551 -552   426  -430     u=5
495     7  -2.7     551 -552   430 -530     u=5
```

```
496    6  -2.66   551 -552  530 -534    u=5
497    7  -2.7    551 -552  534  -434    u=5
498    4 -1.0    551 -552   434  -438    u=5
499    5  -7.84   551 -552   438  -442    u=5
500   4 -1.0     411  -424   442         u=5
501   4 -1.0     411 -550   426  -442    u=5
502   4 -1.0    553  -424   426  -442    u=5
503   5  -7.84   550 -551   426  -442    u=5
504   5  -7.84   552 -553   426  -442    u=5
c
c     Bottom
c
505   5  -7.84    427            -413    u=5
506   4 -1.0     451  -452   431  -427    u=5
507   7  -2.7     451  -452  531  -431    u=5
508   6  -2.66    451  -452  535 -531    u=5
509   7  -2.7     451  -452   435 -535    u=5
510   4 -1.0     451  -452   439  -435    u=5
511   5  -7.84    451  -452   443  -439    u=5
512   4 -1.0     411            -443    u=5
513   4 -1.0     411  -450   443  -427    u=5
514   4 -1.0     453         443  -427    u=5
515   5  -7.84    450  -451   443  -427    u=5
516   5  -7.84    452  -453   443  -427    u=5
517   5  -7.84    425  -411        -427    u=5
518   4 -1.0         -425       -427    u=5
c
c
c
c     TYPE D CELL  -  Short Boral on left and bottom, different cell ID
c
c number of cells: 51
c
c     Right Side
c
1570   0          -1410   1411  -1412   1413    u=17 fill=1 (1)
1571   5  -7.84    1410  -1424   1413  -1426    u=17
1572   4 -1.0     1424  -1428   1448  -1445    u=17
1573   7  -2.7     1428  -1528  1448  -1445    u=17
1574   6  -2.66   1528  -1532  1448  -1445    u=17
1575   7  -2.7    1532  -1432   1448  -1445    u=17
1576   4 -1.0     1432  -1436   1448  -1445    u=17
1577   5  -7.84    1436  -1440   1448  -1445    u=17
1578   4 -1.0     1440         1413         u=17
1579   4 -1.0     1424  -1440   1413  -1447    u=17
1580   4 -1.0     1424  -1440   1446         u=17
1581   5  -7.84    1424  -1440   1447  -1448    u=17
1582   5  -7.84    1424  -1440   1445  -1446    u=17
c
c    Left Side
c
1583   5  -7.84    1425  -1411   1413         u=17
1584   4 -1.0     1429  -1425  1548 -1545    u=17
1585   7  -2.7    1529  -1429  1548 -1545    u=17
1586   6  -2.66   1533 -1529  1548 -1545    u=17
1587   7  -2.7     1433 -1533  1548 -1545    u=17
1588   4 -1.0     1437  -1433  1548 -1545    u=17
1589   5  -7.84    1441  -1437  1548 -1545    u=17
```

```
1590   4 -1.0          -1441   1413          u=17
1591   4 -1.0     1441  -1425   1413 -1547    u=17
1592   4 -1.0     1441  -1425  1546          u=17
1593   5  -7.84    1441  -1425  1547 -1548    u=17
1594   5  -7.84    1441  -1425  1545 -1546    u=17
c
c     Top
c
1595   5  -7.84    1411  -1410   1412  -1426    u=17
1596   4 -1.0     1451  -1452   1426  -1430    u=17
1597   7  -2.7     1451  -1452   1430 -1530    u=17
1598   6  -2.66    1451  -1452  1530 -1534    u=17
1599   7  -2.7     1451  -1452  1534  -1434    u=17
1600   4 -1.0     1451  -1452   1434  -1438    u=17
1601   5  -7.84    1451  -1452   1438  -1442    u=17
1602   4 -1.0     1411  -1424   1442          u=17
1603   4 -1.0     1411  -1450   1426  -1442    u=17
1604   4 -1.0     1453  -1424   1426  -1442    u=17
1605   5  -7.84    1450  -1451   1426  -1442    u=17
1606   5  -7.84    1452  -1453   1426  -1442    u=17
c
c     Bottom
c
1607   5  -7.84    1427            -1413    u=17
1608   4 -1.0    1551 -1552   1431  -1427    u=17
1609   7  -2.7    1551 -1552  1531  -1431    u=17
1610   6  -2.66   1551 -1552  1535 -1531    u=17
1611   7  -2.7    1551 -1552   1435 -1535    u=17
1612   4 -1.0    1551 -1552   1439  -1435    u=17
1613   5  -7.84   1551 -1552   1443  -1439    u=17
1614   4 -1.0     1411             -1443    u=17
1615   4 -1.0     1411 -1550   1443  -1427    u=17
1616   4 -1.0    1553         1443  -1427    u=17
1617   5  -7.84   1550 -1551   1443  -1427    u=17
1618   5  -7.84   1552 -1553   1443  -1427    u=17
1619   5  -7.84    1425  -1411        -1427    u=17
1620   4 -1.0          -1425        -1427    u=17
c
c number of cells: 29
c
c empty cell no boral, no top
c
c
751     4 -1.0   -410   411  -412   413     u=14
752     5  -7.84    410  -424   413  -426    u=14
753    5  -7.84    425  -411   413          u=14
754    4 -1.0     411  -410   412  -426     u=14
755    5  -7.84    427             -413     u=14
756    5  -7.84    425  -411       -427     u=14
757    4 -1.0     411   426                u=14
758    4 -1.0     411  -427                u=14
759    4 -1.0    -425   413                u=14
760    4 -1.0     424   413   -426         u=14
761    4 -1.0    -425  -427                u=14
c
c
701   5   -7.84   701 -702 711 -713      u=9   $ steel post
702   5   -7.84   702 -703 711 -712      u=9   $ steel post
```

```
c
711   0            701 -705 711 -715 (702:713) (703:712)
                   fill=4 (13.8506 13.8506 0) u=9
712   0            704 (-706:-716) (705:715) -717 -710
                   fill=4 (17.9489 41.5518 0  0 1 0  -1 0 0   0 0 1) u=9
713   0            (705:715) -707 714 (-706:-716)  710
                   fill=4 (41.5518 17.9489 0  0 -1 0  1 0 0   0 0 1) u=9
714   0            701 -705 717 -719
                   fill=5 (13.8506 69.253 0) u=9
715   0            707 -709 711 -715
                   fill=5 (69.253 13.8506 0) u=9
716   0            706 -708 716 -718
                   fill=17 (45.6501 45.6501 0  -1 0 0  0 -1 0  0 0 1) u=9
717   0            705 -706 717 -719
                   fill=14 (41.5518 69.253 0) u=9
718   0            707 -709 715 -716
                   fill=14 (69.253 41.5518 0 0 1 0   1 0 0   0 0 1) u=9
719   0            701 -704 715 -717
                   fill=14 (-9.75233 41.5518 0  -1 0 0  0 1 0   0 0 1) u=9
720   0            705 -707 711 -714
                   fill=14 (41.5518 -9.75233 0   0 -1 0  1 0 0   0 0 1) u=9
721   4 -1.0      (706:719) (708:718) (709:716) u=9
c
c
c q-offset  0 inch
c
731   4 -1.0       720  721   fill=9 (0 0 0) u=19
732   4 -1.0      -720  721   fill=9 (0 0 0
                               -1 0 0  0  1 0  0 0 1) u=19
733   4 -1.0       720 -721   fill=9 (0 0 0
                                1 0 0  0 -1 0  0 0 1) u=19
734   4 -1.0      -720 -721   fill=9 (0 0 0
                               -1 0 0  0 -1 0  0 0 1) u=19
c
673   0            -41                39  -40  fill=19
c
c number of cells: 6
102   4  -1.0    -41       40  -44            $ 6.0" Water above Fuel
103   5  -7.84   -41       44  -45            $ 15.5" Steel above Fuel
104   4  -1.0    -41      -39   43            $ 7.3" Water below Fuel
105   5  -7.84   -41      -43   46            $ 8.5" Steel below Fuel
106   5  -7.84   46  -45 41 -42               $ 6.0" Radial Steel Shield
107   0            -46:45:42                  $ Outside world
c end of cells
c --- empty line

c --- empty line
c start of surfaces
1     cz         0.4752    $ fuel
2     cz         0.4851    $ clad ID
3     cz         0.5436    $ clad OD
4     cz         0.6350    $ guide ID
5     cz         0.6706    $ guide OD
6     px         0.7214    $ pin pitch
7     px        -0.7214
8     py         0.7214
9     py        -0.7214
c
```

```
c
c cell-id       8.98
c cell-pitch    10.906
c wall-thkns    5/16
c angle-thkns   5/16
c boral-gap     0.0035
c boral-gap-o   0.0035
c boral-thkns   0.075
c boral-clad    0.01
c sheathing     0.0235
c boral-wide    7.5
c boral-narrow  6.25
c
c gap size      1.09
c basket-od     67.335
c
410    px         11.40460 $x 8.98/2
411    px        -11.40460 $x {410} *-1
412    py         11.40460 $x {410}
413    py        -11.40460 $x {411}
416    px         13.85062 $x (10.906 + 5/16 - 5/16) /2
417    px        -13.85062 $x -10.906 + {416}
418    py         13.85062 $x {416}
419    py        -13.85062 $x {417}
424    px         12.19835 $x {410} + 5/16     $ angle
425    px        -12.19835 $x {411} - 5/16     $ box wall
426    py         12.19835 $x {412} + 5/16
427    py        -12.19835 $x {413} - 5/16
428    px         12.20724 $x {424} + 0.0035   $ wall to boral gap
429    px        -12.20724 $x {425} - 0.0035
430    py         12.20724 $x {426} + 0.0035
431    py        -12.20724 $x {427} - 0.0035
432    px         12.39774 $x {428} + 0.075    $ boral
433    px        -12.39774 $x {429} - 0.075
434    py         12.39774 $x {430} + 0.075
435    py        -12.39774 $x {431} - 0.075
436    px         12.40663 $x {432} + 0.0035   $ boral to sheathing gap
437    px        -12.40663 $x {433} - 0.0035
438    py         12.40663 $x {434} + 0.0035
439    py        -12.40663 $x {435} - 0.0035
440    px         12.46632 $x {436} + 0.0235   $ sheathing
441    px        -12.46632 $x {437} - 0.0235
442    py         12.46632 $x {438} + 0.0235
443    py        -12.46632 $x {439} - 0.0235
445    py          9.52500 $x 7.5/2
446    py          9.58469 $x {445} + 0.0235   $ sheathing
447    py         -9.58469 $x {446} *-1
448    py         -9.52500 $x {445} *-1
450    px         -9.58469 $x {447}
451    px         -9.52500 $x {448}
452    px          9.52500 $x {445}
453    px          9.58469 $x {446}
528   px         12.23264 $x {428} + 0.01  $ Aluminum on the outside of boral
529   px        -12.23264 $x {429} - 0.01
530   py         12.23264 $x {430} + 0.01
531   py        -12.23264 $x {431} - 0.01
532   px         12.37234 $x {432} - 0.01
533   px        -12.37234 $x {433} + 0.01
```

```
534   py        12.37234 $x {434} - 0.01
535   py       -12.37234 $x {435} + 0.01
545   py        7.93750 $x 6.25/2
546   py        7.99719 $x {545} + 0.0235   $ sheathing
547   py       -7.99719 $x {546} *-1
548   py       -7.93750 $x {545} *-1
550   px       -7.99719 $x {547}
551   px       -7.93750 $x {548}
552   px        7.93750 $x {545}
553   px        7.99719 $x {546}
c
c cell-id-2 8.98
c gap-o     1.09
c
701   px       -5.0
702   px       1.90627 $x (10.906 - 8.98)/2 - 5/16 + 0.1
703   px       3.45694 $x 2.722/2
704   px       4.09829 $x 10.906 - 8.98 - 5/16
705   px       27.70124 $x 10.906
706   px       31.79953 $x 2 * 10.906 - (8.98+8.98)/2 - 5/16
707   px       55.40248 $x 2 * 10.906
708   px       59.50077 $x {707} + {704}
709   px       83.10372 $x 3 * 10.906
710   p     1  -1  0  0.1 $ diagonal x=y, offset by 0.1 to avoid intersecting corners
711   py       -4.99999 $x {701}
712   py       1.90627 $x {702}
713   py       3.45694 $x {703}
714   py       4.09829 $x {704}
715   py       27.70124 $x {705}
716   py       31.79953 $x {706}
717   py       55.40248 $x {707}
718   py       59.50077 $x {708}
719   py       83.10372 $x {709}
720   px       0.0
721   py       0.0
1410    px        11.40460 $x 8.98/2
1411    px       -11.40460 $x {1410} *-1
1412    py        11.40460 $x {1410}
1413    py       -11.40460 $x {1411}
1424    px        12.19835 $x {1410} + 5/16     $ angle
1425    px       -12.19835 $x {1411} - 5/16     $ box wall
1426    py        12.19835 $x {1412} + 5/16
1427    py       -12.19835 $x {1413} - 5/16
1428    px        12.20724 $x {1424} + 0.0035   $ wall to boral gap
1429    px       -12.20724 $x {1425} - 0.0035
1430    py        12.20724 $x {1426} + 0.0035
1431    py       -12.20724 $x {1427} - 0.0035
1432    px        12.39774 $x {1428} + 0.075    $ boral
1433    px       -12.39774 $x {1429} - 0.075
1434    py        12.39774 $x {1430} + 0.075
1435    py       -12.39774 $x {1431} - 0.075
1436    px        12.40663 $x {1432} + 0.0035   $ boral to sheathing gap
1437    px       -12.40663 $x {1433} - 0.0035
1438    py        12.40663 $x {1434} + 0.0035
1439    py       -12.40663 $x {1435} - 0.0035
1440    px        12.46632 $x {1436} + 0.0235   $ sheathing
1441    px       -12.46632 $x {1437} - 0.0235
1442    py        12.46632 $x {1438} + 0.0235
```

```
1443    py        -12.46632 $x {1439} - 0.0235
1445    py          9.52500 $x 7.5/2
1446    py          9.58469 $x {1445} + 0.0235   $ sheathing
1447    py         -9.58469 $x {1446} *-1
1448    py         -9.52500 $x {1445} *-1
1450    px         -9.58469 $x {1447}
1451    px         -9.52500 $x {1448}
1452    px          9.52500 $x {1445}
1453    px          9.58469 $x {1446}
1528   px         12.23264 $x {1428} + 0.01  $ Aluminum on the outside of boral
1529   px        -12.23264 $x {1429} - 0.01
1530   py         12.23264 $x {1430} + 0.01
1531   py        -12.23264 $x {1431} - 0.01
1532   px         12.37234 $x {1432} - 0.01
1533   px        -12.37234 $x {1433} + 0.01
1534   py         12.37234 $x {1434} - 0.01
1535   py        -12.37234 $x {1435} + 0.01
1545   py         7.93750 $x 6.25/2
1546   py         7.99719 $x {1545} + 0.0235   $ sheathing
1547   py        -7.99719 $x {1546} *-1
1548   py        -7.93750 $x {1545} *-1
1550   px        -7.99719 $x {1547}
1551   px        -7.93750 $x {1548}
1552   px         7.93750 $x {1545}
1553   px         7.99719 $x {1546}
46    pz         -31.75       $ 8.5"  lower steel thickness
43    pz         -10.16       $ lower water thickness
39    pz           0.0        $ bottom of active fuel assembly
40    pz         381.0        $ top of active fuel assembly
44    pz         396.24       $ upper water thickness
45    pz         435.61       $ 15.5" upper steel thickness
41    cz          85.57       $ mpc steel ID
42    cz         108.43       $ mpc water
c end of surfaces
c --- empty line

c --- empty line
tr1 0 0 0
kcode    10000  .94  20  120
sdef  par=1  erg=d1 axs=0 0 1 x=d4 y=fx d5 z=d3
c
sp1  -2 1.2895
c
sp3  0 1
c
si4  s          13 14
             12 13 14 15
          11 12 13 14 15 16
          11 12 13 14 15 16
             12 13 14 15
                13 14
sp4  1 23r
c
ds5  s                26 26
                   25 25 25 25
                24 24 24 24 24 24
                23 23 23 23 23 23
                   22 22 22 22
```

```
                    21 21
c
si11  -79.25435 -57.61355
si12  -51.88077 -30.23997
si13  -24.50719 -2.86639
si14   2.86639   24.50719
si15   30.23997  51.88077
si16   57.61355  79.25435
c
si21  -79.25435 -57.61355
si22  -51.88077 -30.23997
si23  -24.50719 -2.86639
si24   2.86639   24.50719
si25   30.23997  51.88077
si26   57.61355  79.25435
c
sp11  0 1
sp12  0 1
sp13  0 1
sp14  0 1
sp15  0 1
sp16  0 1
sp21  0 1
sp22  0 1
sp23  0 1
sp24  0 1
sp25  0 1
sp26  0 1
c
m3            40000.56c   1.            $ Zr Clad
m4            1001.50c    0.6667        $ Water
              8016.50c    0.3333
m5            24000.50c   0.01761       $ Steel
              25055.50c   0.001761
              26000.55c   0.05977
              28000.50c   0.008239
m6            5010.50c   -0.054427      $ Boral Central Section @ 0.02 g/cmsq
              5011.50c   -0.241373
              13027.50c  -0.6222
              6000.50c   -0.0821
m7            13027.50c   1.0
mt4          lwtr.01t
prdmp     j   -120   j   2
fm4       1000   1   -6
f4:n   1
sd4       1000
e4     1.000E-11   1.000E-10   5.000E-10   7.500E-10   1.000E-09   1.200E-09
       1.500E-09   2.000E-09   2.500E-09   3.000E-09
       4.700E-09   5.000E-09   7.500E-09   1.000E-08   2.530E-08
       3.000E-08   4.000E-08   5.000E-08   6.000E-08   7.000E-08
       8.000E-08   9.000E-08   1.000E-07   1.250E-07   1.500E-07
       1.750E-07   2.000E-07   2.250E-07   2.500E-07   2.750E-07
       3.000E-07   3.250E-07   3.500E-07   3.750E-07   4.000E-07
       4.500E-07   5.000E-07   5.500E-07   6.000E-07   6.250E-07
       6.500E-07   7.000E-07   7.500E-07   8.000E-07   8.500E-07
       9.000E-07   9.250E-07   9.500E-07   9.750E-07   1.000E-06
       1.010E-06   1.020E-06   1.030E-06   1.040E-06   1.050E-06
       1.060E-06   1.070E-06   1.080E-06   1.090E-06   1.100E-06
```

```
      1.110E-06   1.120E-06   1.130E-06   1.140E-06   1.150E-06
      1.175E-06   1.200E-06   1.225E-06   1.250E-06   1.300E-06
      1.350E-06   1.400E-06   1.450E-06   1.500E-06   1.590E-06
      1.680E-06   1.770E-06   1.860E-06   1.940E-06   2.000E-06
      2.120E-06   2.210E-06   2.300E-06   2.380E-06   2.470E-06
      2.570E-06   2.670E-06   2.770E-06   2.870E-06   2.970E-06
      3.000E-06   3.050E-06   3.150E-06   3.500E-06   3.730E-06
      4.000E-06   4.750E-06   5.000E-06   5.400E-06   6.000E-06
      6.250E-06   6.500E-06   6.750E-06   7.000E-06   7.150E-06
      8.100E-06   9.100E-06   1.000E-05   1.150E-05   1.190E-05
      1.290E-05   1.375E-05   1.440E-05   1.510E-05   1.600E-05
      1.700E-05   1.850E-05   1.900E-05   2.000E-05   2.100E-05
      2.250E-05   2.500E-05   2.750E-05   3.000E-05   3.125E-05
      3.175E-05   3.325E-05   3.375E-05   3.460E-05   3.550E-05
      3.700E-05   3.800E-05   3.910E-05   3.960E-05   4.100E-05
      4.240E-05   4.400E-05   4.520E-05   4.700E-05   4.830E-05
      4.920E-05   5.060E-05   5.200E-05   5.340E-05   5.900E-05
      6.100E-05   6.500E-05   6.750E-05   7.200E-05   7.600E-05
      8.000E-05   8.200E-05   9.000E-05   1.000E-04   1.080E-04
      1.150E-04   1.190E-04   1.220E-04   1.860E-04   1.925E-04
      2.075E-04   2.100E-04   2.400E-04   2.850E-04   3.050E-04
      5.500E-04   6.700E-04   6.830E-04   9.500E-04   1.150E-03
      1.500E-03   1.550E-03   1.800E-03   2.200E-03   2.290E-03
      2.580E-03   3.000E-03   3.740E-03   3.900E-03   6.000E-03
      8.030E-03   9.500E-03   1.300E-02   1.700E-02   2.500E-02
      3.000E-02   4.500E-02   5.000E-02   5.200E-02   6.000E-02
      7.300E-02   7.500E-02   8.200E-02   8.500E-02   1.000E-01
      1.283E-01   1.500E-01   2.000E-01   2.700E-01   3.300E-01
      4.000E-01   4.200E-01   4.400E-01   4.700E-01   4.995E-01
      5.500E-01   5.730E-01   6.000E-01   6.700E-01   6.790E-01
      7.500E-01   8.200E-01   8.611E-01   8.750E-01   9.000E-01
      9.200E-01   1.010E+00   1.100E+00   1.200E+00   1.250E+00
      1.317E+00   1.356E+00   1.400E+00   1.500E+00   1.850E+00
      2.354E+00   2.479E+00   3.000E+00   4.304E+00   4.800E+00
      6.434E+00   8.187E+00   1.000E+01   1.284E+01   1.384E+01
      1.455E+01   1.568E+01   1.733E+01   2.000E+01
si3  h 0 381.00
imp:n 1 193r 0
c fuel enrichment 4.1 %
m1       92235.50c      -0.03614
         92238.50c      -0.84536
          8016.50c      -0.11850
c end of file
c
```

```
HI-STAR containing MPC68, 08x08 @ 4.2 wt% Enrich.
c     4.20 % uniform enrichment,  unreflected cask, 0.0279 g/cmsq B-10 in Boral
c
c
1     1 -10.522      -1  u=2        $ fuel
2     4 -1.0      1  -2  u=2        $ gap
3     3 -6.55     2  -3  u=2        $ Zr Clad
4     4 -1.0          3  u=2        $ water in fuel region
5     4 -1.0   -4:5      u=3        $ water in guide tubes
6     3 -6.55   4 -5     u=3        $ guide tubes
7     4 -1.0   -6   +7   -8   +9   u=1  lat=1
      fill= -5:4    -5:4   0:0
      1  1 1 1 1 1 1 1 1  1
      1  2 2 2 2 2 2 2 2  1
      1  2 2 2 2 2 2 2 2  1
      1  2 2 2 2 2 2 2 2  1
      1  2 2 2 3 2 2 2 2  1
      1  2 2 2 2 3 2 2 2  1
      1  2 2 2 2 2 2 2 2  1
      1  2 2 2 2 2 2 2 2  1
      1  2 2 2 2 2 2 2 2  1
      1  1 1 1 1 1 1 1 1  1
c
C  BOX TYPE R
c
8     0  -10   11  -12   13          u=4 fill=1 (0.8128  0.8128  0)
9     3  -6.55    60   -61    62   -63  #8       u=4     $ Zr flow channel
10    4  -1.      64   -65    66   -67  #8 #9    u=4     $ water
11    5  -7.84    20   -23    67   -14           u=4     $ 0.075" STEEL
12    4  -1.      20   -23    14   -15           u=4     $ WATER POCKET
13    7  -2.7     20   -23    15   -16           u=4     $ Al CLAD
14    6  -2.66    20   -23    16   -17           u=4     $ BORAL Absorber
15    7  -2.7     20   -23    17   -18           u=4     $ Al Clad
16    4  -1.      20   -23    18  -118           u=4     $ Water
17    5  -7.84    118:-129:65:-66                u=4     $ Steel
18    4  -1.      64   -21    67   -118          u=4     $ Water
19    4  -1.      24   -65    67   -118          u=4     $ water
20    5  -7.84    21   -20    67   -118          u=4     $ Steel
21    5  -7.84    23   -24    67   -118          u=4     $ Steel
22    4  -1.     129   -64    33   -118          u=4     $ Water
c
23    5  -7.84    25   -64    30   -31           u=4     $ Steel
24    4  -1.      26   -25    30   -31           u=4     $ Water
25    7  -2.7     27   -26    30   -31           u=4     $ Al clad
26    6  -2.66    28   -27    30   -31           u=4     $ Boral
27    7  -2.7     29   -28    30   -31           u=4     $ Al clad
28    4  -1.     129   -29    30   -31           u=4     $ water
29    5  -7.84   129   -64    32   -30           u=4     $ Steel ends
30    5  -7.84   129   -64    31   -33           u=4     $ Steel ends
31    4  -1.     129   -64    66   -32           u=4     $ Water
c
c    Type A box - Boral only on left side
c
32    0  -10   11  -12   13          u=6 fill=1 (0.8128  0.8128  0)
33    3  -6.55    60   -61    62   -63  #8       u=6     $ Zr flow channel
34    4  -1.      64   -65    66  -118  #8 #9    u=6     $ water
35    5  -7.84    118:-129:65:-66                u=6     $ Steel
36    4  -1.     129   -64    67   -118          u=6     $ Water
c
37    5  -7.84    25   -64    30   -31           u=6     $ Steel
```

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38    4  -1.      26   -25    30   -31          u=6     $ Water
39    7  -2.7     27   -26    30   -31          u=6     $ Al clad
40    6  -2.66    28   -27    30   -31          u=6     $ Boral
41    7  -2.7     29   -28    30   -31          u=6     $ Al clad
42    4  -1.     129   -29    30   -31          u=6     $ water
43    4  -1.     129   -64    33   -67          u=6     $ Water
44    5  -7.84   129   -64    32   -30          u=6     $ Steel ends
45    5  -7.84   129   -64    31   -33          u=6     $ Steel ends
46    4  -1.     129   -64    66   -32          u=6     $ Water
c
c    Type B box -  Boral on Top only
c
47    0  -10   11  -12   13         u=7 fill=1 (0.8128  0.8128  0)
48    3  -6.55    60   -61    62   -63  #8      u=7     $ Zr flow channel
49    4  -1.      64   -65    66   -67  #8 #9   u=7     $ water
50    5  -7.84    20   -23    67   -14          u=7     $ 0.075" STEEL
51    4  -1.      20   -23    14   -15          u=7     $ WATER POCKET
52    7  -2.7     20   -23    15   -16          u=7     $ Al CLAD
53    6  -2.66    20   -23    16   -17          u=7     $ BORAL Absorber
54    7  -2.7     20   -23    17   -18          u=7     $ water
55    4  -1.      20   -23    18  -118          u=7     $ Water
56    5  -7.84    118:-129:65:-66               u=7     $ Steel
57    4  -1.      64   -21    67   -118         u=7     $ Water
58    4  -1.      24   -65    67   -118         u=7     $ water
59    5  -7.84    21   -20    67   -118         u=7     $ Steel
60    5  -7.84    23   -24    67   -118         u=7     $ Steel
61    4  -1.     129   -64    66   -118         u=7     $ Water
c
c    Type E box  - No Boral Panels
c
62    0  -10   11  -12   13         u=8 fill=1 (0.8128  0.8128  0)
63    3  -6.55    60   -61    62   -63  #8      u=8     $ Zr flow channel
64    4  -1.     129   -65    66  -118  #8 #9   u=8     $ water
65    5  -7.84    118:-129:65:-66               u=8     $ Steel
c
c    Type F box  - No Boral Panels or fuel
c
66    4  -1.     129   -65    66  -118          u=9     $ water
67    5  -7.84    118:-129:65:-66               u=9     $ Steel
c
68    4  -1.0    -34  35  -36  37  u=5  lat=1  fill=-7:6  -7:6  0:0
               5 5 5 5 5 5 5 5 5 5 5 5 5 5
               5 9 9 9 9 9 9 9 9 9 9 9 9 5
               5 9 9 9 9 9 7 4 9 9 9 9 9 5
               5 9 9 9 7 4 4 4 4 4 9 9 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 7 4 4 4 4 4 4 4 4 4 9 5
               5 9 8 4 4 4 4 4 4 4 4 6 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 9 8 4 4 4 4 4 4 6 9 9 5
               5 9 9 9 8 4 4 4 6 6 9 9 9 5
               5 9 9 9 9 9 8 6 9 9 9 9 9 5
               5 9 9 9 9 9 9 9 9 9 9 9 9 5
               5 5 5 5 5 5 5 5 5 5 5 5 5 5
69    0          -41                 50  -49  fill=5 (8.1661  8.1661  0)
70    4  -1.0    -41       43  -50             $ Water below Fuel
71    4  -1.0    -41       49  -44             $ Water above Fuel
72    5  -7.84   -42       68  -43             $ Steel below Fuel
73    5  -7.84   -42       44  -69             $ Steel above Fuel
```

```
74     5  -7.84    41  -42  43  -44              $ Radial Steel
75     0            42 :-68:  69                  $ outside world

1      cz          0.5207      $ Fuel OD
2      cz          0.5321      $ Clad ID
3      cz          0.6134      $ Clad OD
4      cz          0.6744      $ Thimble ID
5      cz          0.7506      $ Thimble OD
6      px          0.8128      $ Pin Pitch
7      px         -0.8128
8      py          0.8128
9      py         -0.8128
10     px          6.7031      $ Channel ID
11     px         -6.7031
12     py          6.7031
13     py         -6.7031
14     py          7.8016
15     py          7.8155
16     py          7.8410
17     py          8.0467
18     py          8.0721
118    py          8.0861
20     px         -6.0325
21     px         -6.2230
23     px          6.0325
24     px          6.2230
25     px         -7.8016
26     px         -7.8155
27     px         -7.8410
28     px         -8.0467
29     px         -8.0721
129    px         -8.0861
30     py         -6.0325
31     py          6.0325
32     py         -6.2230
33     py          6.2230
34     px          7.6111
35     px         -8.7211
36     py          8.7211
37     py         -7.6111
41     cz          85.57
42     cz          108.43
43     pz         -18.54
44     pz          402.5
49     pz          381.        $ Top of Active Fuel
50     pz            0         $ Start of Active Fuel
60     px         -6.9571      $ Channel OD
61     px          6.9571
62     py         -6.9571
63     py          6.9571
64     px         -7.6111      $ Cell Box ID
65     px          7.6111
66     py         -7.6111
67     py          7.6111
68     pz         -40.13
69     pz          441.9

imp:n     1 73r 0
kcode   10000  0.94   20  120
c
```

```
sdef  par=1  erg=d1 axs=0 0 1 x=d4 y=fx d5 z=d3
c
sp1 -2 1.2895
c
c
si3  h 0 365.76
sp3  0 1
c
c
si4  s                15 16
                 13 14 15 16 17 18
              12 13 14 15 16 17 18 19
              12 13 14 15 16 17 18 19
           11 12 13 14 15 16 17 18 19 20
           11 12 13 14 15 16 17 18 19 20
              12 13 14 15 16 17 18 19
              12 13 14 15 16 17 18 19
                 13 14 15 16 17 18
                       15 16
sp4  1 67r
c
ds5  s                30 30
                 29 29 29 29 29 29
              28 28 28 28 28 28 28 28
              27 27 27 27 27 27 27 27
           26 26 26 26 26 26 26 26 26 26
           25 25 25 25 25 25 25 25 25 25
              24 24 24 24 24 24 24 24
              23 23 23 23 23 23 23 23
                 22 22 22 22 22 22
                       21 21
c
si11  -80.6831 -67.6783
si12  -64.1985 -51.1937
si13  -47.7139 -34.7091
si14  -31.2293 -18.2245
si15  -14.7447 -1.7399
si16   1.7399   14.7447
si17   18.2245  31.2293
si18   34.7091  47.7139
si19   51.1937  64.1985
si20   67.6783  80.6831
c
si21  -80.6831 -67.6783
si22  -64.1985 -51.1937
si23  -47.7139 -34.7091
si24  -31.2293 -18.2245
si25  -14.7447 -1.7399
si26   1.7399   14.7447
si27   18.2245  31.2293
si28   34.7091  47.7139
si29   51.1937  64.1985
si30   67.6783  80.6831
sp11  0 1
sp12  0 1
sp13  0 1
sp14  0 1
sp15  0 1
sp16  0 1
sp17  0 1
```

```
sp18   0 1
sp19   0 1
sp20   0 1
sp21   0 1
sp22   0 1
sp23   0 1
sp24   0 1
sp25   0 1
sp26   0 1
sp27   0 1
sp28   0 1
sp29   0 1
sp30   0 1
c
m1            92235.50c   9.98343E-04  $ 4.20% E Fuel
              92238.50c   0.022484
              8016.50c    0.046965
m2            8016.50c    1.           $ Void
m3            40000.56c   1.           $ Zr Clad
m4            1001.50c    0.6667       $ Water
              8016.50c    0.3333
m5            24000.50c   0.01761      $ Steel
              25055.50c   0.001761
              26000.55c   0.05977
              28000.50c   0.008239
m6            5010.50c    8.0707E-03   $ Boral
              5011.50c    3.2553E-02
              6000.50c    1.0146E-02
              13027.50c   3.8054E-02
m7            13027.50c    1.           $ Al Clad
mt4          lwtr.01t
prdmp     j   -30   1   2
fm4       1000   1   -6
f4:n    1
sd4       1000
e4     1.000E-11   1.000E-10   5.000E-10   7.500E-10   1.000E-09   1.200E-09
       1.500E-09   2.000E-09   2.500E-09   3.000E-09
       4.700E-09   5.000E-09   7.500E-09   1.000E-08   2.530E-08
       3.000E-08   4.000E-08   5.000E-08   6.000E-08   7.000E-08
       8.000E-08   9.000E-08   1.000E-07   1.250E-07   1.500E-07
       1.750E-07   2.000E-07   2.250E-07   2.500E-07   2.750E-07
       3.000E-07   3.250E-07   3.500E-07   3.750E-07   4.000E-07
       4.500E-07   5.000E-07   5.500E-07   6.000E-07   6.250E-07
       6.500E-07   7.000E-07   7.500E-07   8.000E-07   8.500E-07
       9.000E-07   9.250E-07   9.500E-07   9.750E-07   1.000E-06
       1.010E-06   1.020E-06   1.030E-06   1.040E-06   1.050E-06
       1.060E-06   1.070E-06   1.080E-06   1.090E-06   1.100E-06
       1.110E-06   1.120E-06   1.130E-06   1.140E-06   1.150E-06
       1.175E-06   1.200E-06   1.225E-06   1.250E-06   1.300E-06
       1.350E-06   1.400E-06   1.450E-06   1.500E-06   1.590E-06
       1.680E-06   1.770E-06   1.860E-06   1.940E-06   2.000E-06
       2.120E-06   2.210E-06   2.300E-06   2.380E-06   2.470E-06
       2.570E-06   2.670E-06   2.770E-06   2.870E-06   2.970E-06
       3.000E-06   3.050E-06   3.150E-06   3.500E-06   3.730E-06
       4.000E-06   4.750E-06   5.000E-06   5.400E-06   6.000E-06
       6.250E-06   6.500E-06   6.750E-06   7.000E-06   7.150E-06
       8.100E-06   9.100E-06   1.000E-05   1.150E-05   1.190E-05
       1.290E-05   1.375E-05   1.440E-05   1.510E-05   1.600E-05
       1.700E-05   1.850E-05   1.900E-05   2.000E-05   2.100E-05
       2.250E-05   2.500E-05   2.750E-05   3.000E-05   3.125E-05
```

3.175E-05	3.325E-05	3.375E-05	3.460E-05	3.550E-05
3.700E-05	3.800E-05	3.910E-05	3.960E-05	4.100E-05
4.240E-05	4.400E-05	4.520E-05	4.700E-05	4.830E-05
4.920E-05	5.060E-05	5.200E-05	5.340E-05	5.900E-05
6.100E-05	6.500E-05	6.750E-05	7.200E-05	7.600E-05
8.000E-05	8.200E-05	9.000E-05	1.000E-04	1.080E-04
1.150E-04	1.190E-04	1.220E-04	1.860E-04	1.925E-04
2.075E-04	2.100E-04	2.400E-04	2.850E-04	3.050E-04
5.500E-04	6.700E-04	6.830E-04	9.500E-04	1.150E-03
1.500E-03	1.550E-03	1.800E-03	2.200E-03	2.290E-03
2.580E-03	3.000E-03	3.740E-03	3.900E-03	6.000E-03
8.030E-03	9.500E-03	1.300E-02	1.700E-02	2.500E-02
3.000E-02	4.500E-02	5.000E-02	5.200E-02	6.000E-02
7.300E-02	7.500E-02	8.200E-02	8.500E-02	1.000E-01
1.283E-01	1.500E-01	2.000E-01	2.700E-01	3.300E-01
4.000E-01	4.200E-01	4.400E-01	4.700E-01	4.995E-01
5.500E-01	5.730E-01	6.000E-01	6.700E-01	6.790E-01
7.500E-01	8.200E-01	8.611E-01	8.750E-01	9.000E-01
9.200E-01	1.010E+00	1.100E+00	1.200E+00	1.250E+00
1.317E+00	1.356E+00	1.400E+00	1.500E+00	1.850E+00
2.354E+00	2.479E+00	3.000E+00	4.304E+00	4.800E+00
6.434E+00	8.187E+00	1.000E+01	1.284E+01	1.384E+01
1.455E+01	1.568E+01	1.733E+01	2.000E+01	

```
HI-STAR containing MPC68F, 06x06 @ 3.0 wt% Enrich.
c     3.00 % uniform enrichment, unreflected cask, 0.0067 g/cmsq B-10 in Boral
c     Dresden-1 6x6
c
c
1     1 -10.522      -1  u=2        $ fuel
2     4 -1.0      1  -2  u=2        $ gap
3     3 -6.55     2  -3  u=2        $ Zr Clad
4     4 -1.0          3  u=2        $ water in fuel region
5     4 -1.0   -4:5      u=3        $ water in guide tubes
6     3 -6.55   4 -5     u=3        $ guide tubes
7     4 -1.0   -6   +7   -8   +9   u=1  lat=1
      fill= -4:3    -4:3   0:0
      1  1 1 1 1 1 1  1
      1  2 2 2 2 2 2  1
      1  2 2 2 2 2 2  1
      1  2 2 2 2 2 2  1
      1  2 2 2 2 2 2  1
      1  2 2 2 2 2 2  1
      1  2 2 2 2 2 2  1
      1  1 1 1 1 1 1  1
c
C  BOX TYPE R
c
8     0  -10   11  -12   13          u=4 fill=1 (0.8814  0.8814  0)
9     3  -6.55    60   -61    62   -63  #8      u=4      $ Zr flow channel
10    4  -1.      64   -65    66   -67  #8 #9   u=4      $ water
11    5  -7.84    20   -23    67   -14          u=4      $ 0.075" STEEL
12    4  -1.      20   -23    14   -15          u=4      $ WATER POCKET
13    7  -2.7     20   -23    15   -16          u=4      $ Al CLAD
14    6  -2.66    20   -23    16   -17          u=4      $ BORAL Absorber
15    7  -2.7     20   -23    17   -18          u=4      $ Al Clad
16    4  -1.      20   -23    18  -118          u=4      $ Water
17    5  -7.84    118:-129:65:-66               u=4      $ Steel
18    4  -1.      64   -21    67   -118         u=4      $ Water
19    4  -1.      24   -65    67   -118         u=4      $ water
20    5  -7.84    21   -20    67   -118         u=4      $ Steel
21    5  -7.84    23   -24    67   -118         u=4      $ Steel
22    4  -1.     129   -64    33   -118         u=4      $ Water
c
23    5  -7.84    25   -64    30   -31          u=4      $ Steel
24    4  -1.      26   -25    30   -31          u=4      $ Water
25    7  -2.7     27   -26    30   -31          u=4      $ Al clad
26    6  -2.66    28   -27    30   -31          u=4      $ Boral
27    7  -2.7     29   -28    30   -31          u=4      $ Al clad
28    4  -1.     129   -29    30   -31          u=4      $ water
29    5  -7.84   129   -64    32   -30          u=4      $ Steel ends
30    5  -7.84   129   -64    31   -33          u=4      $ Steel ends
31    4  -1.     129   -64    66   -32          u=4      $ Water
c
c    Type A box - Boral only on left side
c
32    0  -10   11  -12   13          u=6 fill=1 (0.8814  0.8814  0)
33    3  -6.55    60   -61    62   -63  #8      u=6      $ Zr flow channel
34    4  -1.      64   -65    66  -118  #8 #9   u=6      $ water
35    5  -7.84    118:-129:65:-66               u=6      $ Steel
36    4  -1.     129   -64    67   -118         u=6      $ Water
c
37    5  -7.84    25   -64    30   -31          u=6      $ Steel
38    4  -1.      26   -25    30   -31          u=6      $ Water
```

```
39    7  -2.7     27   -26    30   -31          u=6     $ Al clad
40    6  -2.66    28   -27    30   -31          u=6     $ Boral
41    7  -2.7     29   -28    30   -31          u=6     $ Al clad
42    4  -1.     129   -29    30   -31          u=6     $ water
43    4  -1.     129   -64    33   -67          u=6     $ Water
44    5  -7.84   129   -64    32   -30          u=6     $ Steel ends
45    5  -7.84   129   -64    31   -33          u=6     $ Steel ends
46    4  -1.     129   -64    66   -32          u=6     $ Water
c
c    Type B box -  Boral on Top only
c
47    0  -10   11  -12   13          u=7 fill=1 (0.8814  0.8814  0)
48    3  -6.55    60   -61    62   -63  #8      u=7     $ Zr flow channel
49    4  -1.      64   -65    66   -67  #8 #9   u=7     $ water
50    5  -7.84    20   -23    67   -14          u=7     $ 0.075" STEEL
51    4  -1.      20   -23    14   -15          u=7     $ WATER POCKET
52    7  -2.7     20   -23    15   -16          u=7     $ Al CLAD
53    6  -2.66    20   -23    16   -17          u=7     $ BORAL Absorber
54    7  -2.7     20   -23    17   -18          u=7     $ water
55    4  -1.      20   -23    18  -118          u=7     $ Water
56    5  -7.84    118:-129:65:-66               u=7     $ Steel
57    4  -1.      64   -21    67   -118         u=7     $ Water
58    4  -1.      24   -65    67   -118         u=7     $ water
59    5  -7.84    21   -20    67   -118         u=7     $ Steel
60    5  -7.84    23   -24    67   -118         u=7     $ Steel
61    4  -1.     129   -64    66   -118         u=7     $ Water
c
c    Type E box  - No Boral Panels
c
62    0  -10   11  -12   13          u=8 fill=1 (0.8814  0.8814  0)
63    3  -6.55    60   -61    62   -63  #8      u=8     $ Zr flow channel
64    4  -1.     129   -65    66  -118  #8 #9   u=8     $ water
65    5  -7.84    118:-129:65:-66               u=8     $ Steel
c
c    Type F box  - No Boral Panels or fuel
c
66    4  -1.     129   -65    66  -118          u=9     $ water
67    5  -7.84    118:-129:65:-66               u=9     $ Steel
c
68    4  -1.0    -34  35  -36  37  u=5  lat=1  fill=-7:6  -7:6  0:0
               5 5 5 5 5 5 5 5 5 5 5 5 5 5
               5 9 9 9 9 9 9 9 9 9 9 9 9 5
               5 9 9 9 9 9 7 4 9 9 9 9 9 5
               5 9 9 9 7 4 4 4 4 4 9 9 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 7 4 4 4 4 4 4 4 4 4 9 5
               5 9 8 4 4 4 4 4 4 4 4 6 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 9 8 4 4 4 4 4 4 6 9 9 5
               5 9 9 9 8 4 4 4 6 6 9 9 9 5
               5 9 9 9 9 9 8 6 9 9 9 9 9 5
               5 9 9 9 9 9 9 9 9 9 9 9 9 5
               5 5 5 5 5 5 5 5 5 5 5 5 5 5
69    0           -41                 50  -49  fill=5 (8.1661  8.1661  0)
70    4  -1.0    -41        43  -50             $ Water below Fuel
71    4  -1.0    -41        49  -44             $ Water above Fuel
72    5  -7.84   -42        68  -43             $ Steel below Fuel
73    5  -7.84   -42        44  -69             $ Steel above Fuel
74    5  -7.84    41  -42   43  -44             $ Radial Steel
```

```
75     0            42 :-68:  69                $ outside world

1      cz          0.6274       $ Fuel OD
2      cz          0.6280       $ Clad ID
3      cz          0.7169       $ Clad OD
4      cz          0.6280       $ Thimble ID
5      cz          0.7169       $ Thimble OD
6      px          0.8814       $ Pin Pitch
7      px         -0.8814
8      py          0.8814
9      py         -0.8814
10     px          5.4483       $ Channel ID
11     px         -5.4483
12     py          5.4483
13     py         -5.4483
14     py          7.8016
15     py          7.8155
16     py          7.8410
17     py          8.0467
18     py          8.0721
118    py          8.0861
20     px         -6.0325
21     px         -6.2230
23     px          6.0325
24     px          6.2230
25     px         -7.8016
26     px         -7.8155
27     px         -7.8410
28     px         -8.0467
29     px         -8.0721
129    px         -8.0861
30     py         -6.0325
31     py          6.0325
32     py         -6.2230
33     py          6.2230
34     px          7.6111
35     px         -8.7211
36     py          8.7211
37     py         -7.6111
41     cz          85.57
42     cz          108.43
43     pz          11.46
44     pz          331.0
49     pz          309.4        $ Top of Active F
50     pz           30.         $ Start of Active
60     px         -5.6007       $ Channel OD
61     px          5.6007
62     py         -5.6007
63     py          5.6007
64     px         -7.6111       $ Cell Box ID
65     px          7.6111
66     py         -7.6111
67     py          7.6111
68     pz         -10.13
69     pz          370.36

imp:n     1 73r 0
kcode    10000  0.94   20  120
c
sdef  par=1  erg=d1 axs=0 0 1 x=d4 y=fx d5 z=d3
```

```
c
sp1 -2 1.2895
c
si3  h 30. 309.
sp3  0 1
c
c
si4  s                 15 16
                 13 14 15 16 17 18
              12 13 14 15 16 17 18 19
              12 13 14 15 16 17 18 19
           11 12 13 14 15 16 17 18 19 20
           11 12 13 14 15 16 17 18 19 20
              12 13 14 15 16 17 18 19
              12 13 14 15 16 17 18 19
                 13 14 15 16 17 18
                       15 16
sp4  1 67r
c
ds5  s                 30 30
                 29 29 29 29 29 29
              28 28 28 28 28 28 28 28
              27 27 27 27 27 27 27 27
           26 26 26 26 26 26 26 26 26 26
           25 25 25 25 25 25 25 25 25 25
              24 24 24 24 24 24 24 24
              23 23 23 23 23 23 23 23
                 22 22 22 22 22 22
                       21 21
c
si11  -80.6831 -67.6783
si12  -64.1985 -51.1937
si13  -47.7139 -34.7091
si14  -31.2293 -18.2245
si15  -14.7447 -1.7399
si16   1.7399   14.7447
si17   18.2245  31.2293
si18   34.7091  47.7139
si19   51.1937  64.1985
si20   67.6783  80.6831
c
si21  -80.6831 -67.6783
si22  -64.1985 -51.1937
si23  -47.7139 -34.7091
si24  -31.2293 -18.2245
si25  -14.7447 -1.7399
si26   1.7399   14.7447
si27   18.2245  31.2293
si28   34.7091  47.7139
si29   51.1937  64.1985
si30   67.6783  80.6831
sp11  0 1
sp12  0 1
sp13  0 1
sp14  0 1
sp15  0 1
sp16  0 1
sp17  0 1
sp18  0 1
sp19  0 1
```

```
sp20  0 1
sp21  0 1
sp22  0 1
sp23  0 1
sp24  0 1
sp25  0 1
sp26  0 1
sp27  0 1
sp28  0 1
sp29  0 1
sp30  0 1
c
m1          92235.50c   -0.02644      $ 3.00% E Fuel
            92238.50c   -0.85504
            8016.50c    -0.11852
m3          40000.56c   1.            $ Zr Clad
m4          1001.50c    0.6667        $ Water
            8016.50c    0.3333
m5          24000.50c   0.01761       $ Steel
            25055.50c   0.001761
            26000.55c   0.05977
            28000.50c   0.008239
m6          5010.50c  1.9592E-03       $ Boral 0.0067 gm/cm2
            5011.50c  8.1175E-03
            6000.50c  2.5176E-03
            13027.50c 5.4933E-02
m7          13027.50c    1.           $ Al Clad
mt4        lwtr.01t
prdmp    j   -120   j   2
fm4      1000   1   -6
f4:n   1
sd4      1000
e4    1.000E-11   1.000E-10   5.000E-10   7.500E-10   1.000E-09   1.200E-09
      1.500E-09   2.000E-09   2.500E-09   3.000E-09
      4.700E-09   5.000E-09   7.500E-09   1.000E-08   2.530E-08
      3.000E-08   4.000E-08   5.000E-08   6.000E-08   7.000E-08
      8.000E-08   9.000E-08   1.000E-07   1.250E-07   1.500E-07
      1.750E-07   2.000E-07   2.250E-07   2.500E-07   2.750E-07
      3.000E-07   3.250E-07   3.500E-07   3.750E-07   4.000E-07
      4.500E-07   5.000E-07   5.500E-07   6.000E-07   6.250E-07
      6.500E-07   7.000E-07   7.500E-07   8.000E-07   8.500E-07
      9.000E-07   9.250E-07   9.500E-07   9.750E-07   1.000E-06
      1.010E-06   1.020E-06   1.030E-06   1.040E-06   1.050E-06
      1.060E-06   1.070E-06   1.080E-06   1.090E-06   1.100E-06
      1.110E-06   1.120E-06   1.130E-06   1.140E-06   1.150E-06
      1.175E-06   1.200E-06   1.225E-06   1.250E-06   1.300E-06
      1.350E-06   1.400E-06   1.450E-06   1.500E-06   1.590E-06
      1.680E-06   1.770E-06   1.860E-06   1.940E-06   2.000E-06
      2.120E-06   2.210E-06   2.300E-06   2.380E-06   2.470E-06
      2.570E-06   2.670E-06   2.770E-06   2.870E-06   2.970E-06
      3.000E-06   3.050E-06   3.150E-06   3.500E-06   3.730E-06
      4.000E-06   4.750E-06   5.000E-06   5.400E-06   6.000E-06
      6.250E-06   6.500E-06   6.750E-06   7.000E-06   7.150E-06
      8.100E-06   9.100E-06   1.000E-05   1.150E-05   1.190E-05
      1.290E-05   1.375E-05   1.440E-05   1.510E-05   1.600E-05
      1.700E-05   1.850E-05   1.900E-05   2.000E-05   2.100E-05
      2.250E-05   2.500E-05   2.750E-05   3.000E-05   3.125E-05
      3.175E-05   3.325E-05   3.375E-05   3.460E-05   3.550E-05
      3.700E-05   3.800E-05   3.910E-05   3.960E-05   4.100E-05
      4.240E-05   4.400E-05   4.520E-05   4.700E-05   4.830E-05
```

4.920E-05	5.060E-05	5.200E-05	5.340E-05	5.900E-05
6.100E-05	6.500E-05	6.750E-05	7.200E-05	7.600E-05
8.000E-05	8.200E-05	9.000E-05	1.000E-04	1.080E-04
1.150E-04	1.190E-04	1.220E-04	1.860E-04	1.925E-04
2.075E-04	2.100E-04	2.400E-04	2.850E-04	3.050E-04
5.500E-04	6.700E-04	6.830E-04	9.500E-04	1.150E-03
1.500E-03	1.550E-03	1.800E-03	2.200E-03	2.290E-03
2.580E-03	3.000E-03	3.740E-03	3.900E-03	6.000E-03
8.030E-03	9.500E-03	1.300E-02	1.700E-02	2.500E-02
3.000E-02	4.500E-02	5.000E-02	5.200E-02	6.000E-02
7.300E-02	7.500E-02	8.200E-02	8.500E-02	1.000E-01
1.283E-01	1.500E-01	2.000E-01	2.700E-01	3.300E-01
4.000E-01	4.200E-01	4.400E-01	4.700E-01	4.995E-01
5.500E-01	5.730E-01	6.000E-01	6.700E-01	6.790E-01
7.500E-01	8.200E-01	8.611E-01	8.750E-01	9.000E-01
9.200E-01	1.010E+00	1.100E+00	1.200E+00	1.250E+00
1.317E+00	1.356E+00	1.400E+00	1.500E+00	1.850E+00
2.354E+00	2.479E+00	3.000E+00	4.304E+00	4.800E+00
6.434E+00	8.187E+00	1.000E+01	1.284E+01	1.384E+01
1.455E+01	1.568E+01	1.733E+01	2.000E+01	

```
HI-STAR containing MPC68F, 06x06 in DFC with 08 missing rods
c     3.00 % uniform enrichment, unreflected cask, 0.0067 g/cmsq B-10 in Boral
c
c
1     1 -10.522      -1  u=2        $ fuel
2     4 -1.0      1  -2  u=2        $ gap
3     3 -6.55     2  -3  u=2        $ Zr Clad
4     4 -1.0          3  u=2        $ water in fuel region
5     4 -1.0   -4:5      u=3        $ water in guide tubes
6     3 -6.55   4 -5     u=3        $ guide tubes
7     4 -1.0   -6   +7   -8   +9   u=1  lat=1
      fill= -4:3    -4:3   0:0
      1  1 1 1 1 1 1  1
      1  2 2 2 2 2 2  1
      1  2 1 2 1 2 2  1
      1  2 2 1 2 1 2  1
      1  2 1 2 1 2 2  1
      1  2 2 1 2 1 2  1
      1  2 2 2 2 2 2  1
      1  1 1 1 1 1 1  1
c
C  BOX TYPE R
c
8     0  -10   11  -12   13          u=4 fill=1 (0.8814  0.8814  0)
9     3  -6.55    60   -61    62   -63  #8      u=4      $ Zr flow channel
100   5  -7.84   74 -75 76 -77 (-70:71:-72:73)  u=4      $ DFC
10    4  -1.      64   -65    66   -67  #8 #9 #100  u=4 $ water
11    5  -7.84    20   -23    67   -14          u=4      $ 0.075" STEEL
12    4  -1.      20   -23    14   -15          u=4      $ WATER POCKET
13    7  -2.7     20   -23    15   -16          u=4      $ Al CLAD
14    6  -2.66    20   -23    16   -17          u=4      $ BORAL Absorber
15    7  -2.7     20   -23    17   -18          u=4      $ Al Clad
16    4  -1.      20   -23    18  -118          u=4      $ Water
17    5  -7.84    118:-129:65:-66               u=4      $ Steel
18    4  -1.      64   -21    67   -118         u=4      $ Water
19    4  -1.      24   -65    67   -118         u=4      $ water
20    5  -7.84    21   -20    67   -118         u=4      $ Steel
21    5  -7.84    23   -24    67   -118         u=4      $ Steel
22    4  -1.     129   -64    33   -118         u=4      $ Water
c
23    5  -7.84    25   -64    30   -31          u=4      $ Steel
24    4  -1.      26   -25    30   -31          u=4      $ Water
25    7  -2.7     27   -26    30   -31          u=4      $ Al clad
26    6  -2.66    28   -27    30   -31          u=4      $ Boral
27    7  -2.7     29   -28    30   -31          u=4      $ Al clad
28    4  -1.     129   -29    30   -31          u=4      $ water
29    5  -7.84   129   -64    32   -30          u=4      $ Steel ends
30    5  -7.84   129   -64    31   -33          u=4      $ Steel ends
31    4  -1.     129   -64    66   -32          u=4      $ Water
c
c    Type A box - Boral only on left side
c
32    0  -10   11  -12   13          u=6 fill=1 (0.8814  0.8814  0)
33    3  -6.55    60   -61    62   -63  #8      u=6      $ Zr flow channel
101   5  -7.84   74 -75 76 -77 (-70:71:-72:73)  u=6      $ DFC
34    4  -1.      64   -65    66  -118  #8 #9 #101 u=6  $ water
35    5  -7.84    118:-129:65:-66               u=6      $ Steel
36    4  -1.     129   -64    67   -118         u=6      $ Water
c
37    5  -7.84    25   -64    30   -31          u=6      $ Steel
```

```
38    4  -1.      26    -25    30    -31          u=6      $ Water
39    7  -2.7     27    -26    30    -31          u=6      $ Al clad
40    6  -2.66    28    -27    30    -31          u=6      $ Boral
41    7  -2.7     29    -28    30    -31          u=6      $ Al clad
42    4  -1.     129    -29    30    -31          u=6      $ water
43    4  -1.     129    -64    33    -67          u=6      $ Water
44    5  -7.84   129    -64    32    -30          u=6      $ Steel ends
45    5  -7.84   129    -64    31    -33          u=6      $ Steel ends
46    4  -1.     129    -64    66    -32          u=6      $ Water
c
c    Type B box -  Boral on Top only
c
47    0  -10   11  -12   13          u=7 fill=1 (0.8814  0.8814  0)
48    3  -6.55    60    -61    62    -63  #8      u=7      $ Zr flow channel
102   5  -7.84   74 -75 76 -77 (-70:71:-72:73)  u=7      $ DFC
49    4  -1.      64    -65    66    -67  #8 #9 #102 u=7  $ water
50    5  -7.84    20    -23    67    -14          u=7      $ 0.075" STEEL
51    4  -1.      20    -23    14    -15          u=7      $ WATER POCKET
52    7  -2.7     20    -23    15    -16          u=7      $ Al CLAD
53    6  -2.66    20    -23    16    -17          u=7      $ BORAL Absorber
54    7  -2.7     20    -23    17    -18          u=7      $ water
55    4  -1.      20    -23    18   -118          u=7      $ Water
56    5  -7.84    118:-129:65:-66                 u=7      $ Steel
57    4  -1.      64    -21    67    -118         u=7      $ Water
58    4  -1.      24    -65    67    -118         u=7      $ water
59    5  -7.84    21    -20    67    -118         u=7      $ Steel
60    5  -7.84    23    -24    67    -118         u=7      $ Steel
61    4  -1.     129    -64    66    -118         u=7      $ Water
c
c    Type E box  - No Boral Panels
c
62    0  -10   11  -12   13          u=8 fill=1 (0.8814  0.8814  0)
63    3  -6.55    60    -61    62    -63  #8      u=8      $ Zr flow channel
103   5  -7.84   74 -75 76 -77 (-70:71:-72:73)  u=8      $ DFC
64    4  -1.     129    -65    66   -118  #8 #9 #103 u=8  $ water
65    5  -7.84    118:-129:65:-66                 u=8      $ Steel
c
c    Type F box  - No Boral Panels or fuel
c
66    4  -1.     129    -65    66   -118          u=9      $ water
67    5  -7.84    118:-129:65:-66                 u=9      $ Steel
c
68    4  -1.0    -34  35  -36  37  u=5  lat=1  fill=-7:6  -7:6  0:0
               5 5 5 5 5 5 5 5 5 5 5 5 5 5
               5 9 9 9 9 9 9 9 9 9 9 9 9 5
               5 9 9 9 9 9 7 4 9 9 9 9 9 5
               5 9 9 9 7 4 4 4 4 4 9 9 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 7 4 4 4 4 4 4 4 4 4 9 5
               5 9 8 4 4 4 4 4 4 4 4 6 9 5
               5 9 9 7 4 4 4 4 4 4 4 9 9 5
               5 9 9 8 4 4 4 4 4 4 6 9 9 5
               5 9 9 9 8 4 4 4 6 6 9 9 9 5
               5 9 9 9 9 9 8 6 9 9 9 9 9 5
               5 9 9 9 9 9 9 9 9 9 9 9 9 5
               5 5 5 5 5 5 5 5 5 5 5 5 5 5
69    0           -41                 50  -49  fill=5 (8.1661  8.1661  0)
70    4  -1.0    -41        43  -50              $ Water below Fuel
71    4  -1.0    -41        49  -44              $ Water above Fuel
```

```
72    5  -7.84   -42        68  -43              $ Steel below Fuel
73    5  -7.84   -42        44  -69              $ Steel above Fuel
74    5  -7.84    41  -42   43  -44              $ Radial Steel
75    0             42 :-68:  69                  $ outside world

1     cz         0.6274       $ Fuel OD
2     cz         0.6280       $ Clad ID
3     cz         0.7169       $ Clad OD
4     cz         0.6280       $ Thimble ID
5     cz         0.7169       $ Thimble OD
6     px         0.8814       $ Pin Pitch
7     px        -0.8814
8     py         0.8814
9     py        -0.8814
10    px         5.4483       $ Channel ID
11    px        -5.4483
12    py         5.4483
13    py        -5.4483
14    py         7.8016
15    py         7.8155
16    py         7.8410
17    py         8.0467
18    py         8.0721
118   py         8.0861
20    px        -6.0325
21    px        -6.2230
23    px         6.0325
24    px         6.2230
25    px        -7.8016
26    px        -7.8155
27    px        -7.8410
28    px        -8.0467
29    px        -8.0721
129   px        -8.0861
30    py        -6.0325
31    py         6.0325
32    py        -6.2230
33    py         6.2230
34    px         7.6111
35    px        -8.7211
36    py         8.7211
37    py        -7.6111
41    cz         85.57
42    cz         108.43
43    pz         11.46
44    pz         331.0
49    pz         309.4        $ Top of Active F
50    pz          30.         $ Start of Active
60    px        -5.6007       $ Channel OD
61    px         5.6007
62    py        -5.6007
63    py         5.6007
64    px        -7.6111       $ Cell Box ID
65    px         7.6111
66    py        -7.6111
67    py         7.6111
68    pz        -10.13
69    pz         370.36
70    px        -6.2611       $ DFC ID
71    px         6.2611
```

```
72     py          -6.2611
73     py           6.2611
74     px          -6.5659        $ DFC OD
75     px           6.5659
76     py          -6.5659
77     py           6.5659

imp:n      1 77r 0
kcode     10000  0.94   20  120
c
sdef  par=1  erg=d1 axs=0 0 1 x=d4 y=fx d5 z=d3
c
sp1 -2 1.2895
c
si3  h 30. 309.
sp3  0 1
c
c
si4  s                 15 16
                 13 14 15 16 17 18
              12 13 14 15 16 17 18 19
              12 13 14 15 16 17 18 19
           11 12 13 14 15 16 17 18 19 20
           11 12 13 14 15 16 17 18 19 20
              12 13 14 15 16 17 18 19
              12 13 14 15 16 17 18 19
                 13 14 15 16 17 18
                       15 16
sp4  1 67r
c
ds5  s                 30 30
                 29 29 29 29 29 29
              28 28 28 28 28 28 28 28
              27 27 27 27 27 27 27 27
           26 26 26 26 26 26 26 26 26 26
           25 25 25 25 25 25 25 25 25 25
              24 24 24 24 24 24 24 24
              23 23 23 23 23 23 23 23
                 22 22 22 22 22 22
                       21 21
c
si11  -80.6831 -67.6783
si12  -64.1985 -51.1937
si13  -47.7139 -34.7091
si14  -31.2293 -18.2245
si15  -14.7447 -1.7399
si16   1.7399   14.7447
si17   18.2245  31.2293
si18   34.7091  47.7139
si19   51.1937  64.1985
si20   67.6783  80.6831
c
si21  -80.6831 -67.6783
si22  -64.1985 -51.1937
si23  -47.7139 -34.7091
si24  -31.2293 -18.2245
si25  -14.7447 -1.7399
si26   1.7399   14.7447
si27   18.2245  31.2293
si28   34.7091  47.7139
```

```
si29   51.1937  64.1985
si30   67.6783  80.6831
sp11  0 1
sp12  0 1
sp13  0 1
sp14  0 1
sp15  0 1
sp16  0 1
sp17  0 1
sp18  0 1
sp19  0 1
sp20  0 1
sp21  0 1
sp22  0 1
sp23  0 1
sp24  0 1
sp25  0 1
sp26  0 1
sp27  0 1
sp28  0 1
sp29  0 1
sp30  0 1
c
m1          92235.50c   -0.02644      $ 3.00% E Fuel
            92238.50c   -0.85504
            8016.50c    -0.11852
m3          40000.56c   1.            $ Zr Clad
m4          1001.50c    0.6667        $ Water
            8016.50c    0.3333
m5          24000.50c   0.01761       $ Steel
            25055.50c   0.001761
            26000.55c   0.05977
            28000.50c   0.008239
m6          5010.50c  1.9592E-03       $ Boral 0.0067 gm/cm2
            5011.50c  8.1175E-03
            6000.50c  2.5176E-03
            13027.50c 5.4933E-02
m7          13027.50c    1.           $ Al Clad
mt4        lwtr.01t
prdmp    j   -120   j   2
fm4      1000   1   -6
f4:n   1
sd4      1000
e4    1.000E-11   1.000E-10   5.000E-10   7.500E-10   1.000E-09   1.200E-09
      1.500E-09   2.000E-09   2.500E-09   3.000E-09
      4.700E-09   5.000E-09   7.500E-09   1.000E-08   2.530E-08
      3.000E-08   4.000E-08   5.000E-08   6.000E-08   7.000E-08
      8.000E-08   9.000E-08   1.000E-07   1.250E-07   1.500E-07
      1.750E-07   2.000E-07   2.250E-07   2.500E-07   2.750E-07
      3.000E-07   3.250E-07   3.500E-07   3.750E-07   4.000E-07
      4.500E-07   5.000E-07   5.500E-07   6.000E-07   6.250E-07
      6.500E-07   7.000E-07   7.500E-07   8.000E-07   8.500E-07
      9.000E-07   9.250E-07   9.500E-07   9.750E-07   1.000E-06
      1.010E-06   1.020E-06   1.030E-06   1.040E-06   1.050E-06
      1.060E-06   1.070E-06   1.080E-06   1.090E-06   1.100E-06
      1.110E-06   1.120E-06   1.130E-06   1.140E-06   1.150E-06
      1.175E-06   1.200E-06   1.225E-06   1.250E-06   1.300E-06
      1.350E-06   1.400E-06   1.450E-06   1.500E-06   1.590E-06
      1.680E-06   1.770E-06   1.860E-06   1.940E-06   2.000E-06
      2.120E-06   2.210E-06   2.300E-06   2.380E-06   2.470E-06
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2.570E-06	2.670E-06	2.770E-06	2.870E-06	2.970E-06
3.000E-06	3.050E-06	3.150E-06	3.500E-06	3.730E-06
4.000E-06	4.750E-06	5.000E-06	5.400E-06	6.000E-06
6.250E-06	6.500E-06	6.750E-06	7.000E-06	7.150E-06
8.100E-06	9.100E-06	1.000E-05	1.150E-05	1.190E-05
1.290E-05	1.375E-05	1.440E-05	1.510E-05	1.600E-05
1.700E-05	1.850E-05	1.900E-05	2.000E-05	2.100E-05
2.250E-05	2.500E-05	2.750E-05	3.000E-05	3.125E-05
3.175E-05	3.325E-05	3.375E-05	3.460E-05	3.550E-05
3.700E-05	3.800E-05	3.910E-05	3.960E-05	4.100E-05
4.240E-05	4.400E-05	4.520E-05	4.700E-05	4.830E-05
4.920E-05	5.060E-05	5.200E-05	5.340E-05	5.900E-05
6.100E-05	6.500E-05	6.750E-05	7.200E-05	7.600E-05
8.000E-05	8.200E-05	9.000E-05	1.000E-04	1.080E-04
1.150E-04	1.190E-04	1.220E-04	1.860E-04	1.925E-04
2.075E-04	2.100E-04	2.400E-04	2.850E-04	3.050E-04
5.500E-04	6.700E-04	6.830E-04	9.500E-04	1.150E-03
1.500E-03	1.550E-03	1.800E-03	2.200E-03	2.290E-03
2.580E-03	3.000E-03	3.740E-03	3.900E-03	6.000E-03
8.030E-03	9.500E-03	1.300E-02	1.700E-02	2.500E-02
3.000E-02	4.500E-02	5.000E-02	5.200E-02	6.000E-02
7.300E-02	7.500E-02	8.200E-02	8.500E-02	1.000E-01
1.283E-01	1.500E-01	2.000E-01	2.700E-01	3.300E-01
4.000E-01	4.200E-01	4.400E-01	4.700E-01	4.995E-01
5.500E-01	5.730E-01	6.000E-01	6.700E-01	6.790E-01
7.500E-01	8.200E-01	8.611E-01	8.750E-01	9.000E-01
9.200E-01	1.010E+00	1.100E+00	1.200E+00	1.250E+00
1.317E+00	1.356E+00	1.400E+00	1.500E+00	1.850E+00
2.354E+00	2.479E+00	3.000E+00	4.304E+00	4.800E+00
6.434E+00	8.187E+00	1.000E+01	1.284E+01	1.384E+01
1.455E+01	1.568E+01	1.733E+01	2.000E+01	

```
HI-STAR containing MPC68F, 07x07 in DFC with 13 missing rods
c     3.00 % uniform enrichment, unreflected cask, 0.0067 g/cmsq B-10 in Boral
c
c
1     1 -10.522      -1  u=2        $ fuel
2     4 -1.0      1  -2  u=2        $ gap
3     3 -6.55     2  -3  u=2        $ Zr Clad
4     4 -1.0          3  u=2        $ water in fuel region
5     4 -1.0   -4:5      u=3        $ water in guide tubes
6     3 -6.55   4 -5     u=3        $ guide tubes
7     4 -1.0   -6   +7   -8   +9   u=1  lat=1
      fill= -4:4    -4:4   0:0
      1  1 1 1 1 1 1 1  1
      1  2 2 2 2 2 2 2  1
      1  2 1 2 1 2 1 2  1
      1  2 2 1 2 1 2 2  1
      1  2 1 2 1 2 1 2  1
      1  2 2 1 2 1 2 2  1
      1  2 1 2 1 2 1 2  1
      1  2 2 2 2 2 2 2  1
      1  1 1 1 1 1 1 1  1
c
C  BOX TYPE R
c
8     0  -10   11  -12   13          u=4 fill=1
9     3  -6.55    60   -61    62   -63  #8      u=4      $ Zr flow channel
100   5  -7.84   74 -75 76 -77 (-70:71:-72:73)  u=4      $ DFC
10    4  -1.      64   -65    66   -67  #8 #9 #100 u=4   $ water
11    5  -7.84    20   -23    67   -14          u=4      $ 0.075" STEEL
12    4  -1.      20   -23    14   -15          u=4      $ WATER POCKET
13    7  -2.7     20   -23    15   -16          u=4      $ Al CLAD
14    6  -2.66    20   -23    16   -17          u=4      $ BORAL Absorber
15    7  -2.7     20   -23    17   -18          u=4      $ Al Clad
16    4  -1.      20   -23    18  -118          u=4      $ Water
17    5  -7.84    118:-129:65:-66               u=4      $ Steel
18    4  -1.      64   -21    67   -118         u=4      $ Water
19    4  -1.      24   -65    67   -118         u=4      $ water
20    5  -7.84    21   -20    67   -118         u=4      $ Steel
21    5  -7.84    23   -24    67   -118         u=4      $ Steel
22    4  -1.     129   -64    33   -118         u=4      $ Water
c
23    5  -7.84    25   -64    30   -31          u=4      $ Steel
24    4  -1.      26   -25    30   -31          u=4      $ Water
25    7  -2.7     27   -26    30   -31          u=4      $ Al clad
26    6  -2.66    28   -27    30   -31          u=4      $ Boral
27    7  -2.7     29   -28    30   -31          u=4      $ Al clad
28    4  -1.     129   -29    30   -31          u=4      $ water
29    5  -7.84   129   -64    32   -30          u=4      $ Steel ends
30    5  -7.84   129   -64    31   -33          u=4      $ Steel ends
31    4  -1.     129   -64    66   -32          u=4      $ Water
c
c    Type A box - Boral only on left side
c
32    0  -10   11  -12   13          u=6 fill=1
33    3  -6.55    60   -61    62   -63  #8      u=6      $ Zr flow channel
101   5  -7.84   74 -75 76 -77 (-70:71:-72:73)  u=6      $ DFC
34    4  -1.      64   -65    66   -118 #8 #9 #101 u=6   $ water
35    5  -7.84    118:-129:65:-66               u=6      $ Steel
36    4  -1.     129   -64    67   -118         u=6      $ Water
c
```

```
37     5  -7.84     25    -64     30    -31          u=6      $ Steel
38     4  -1.       26    -25     30    -31          u=6      $ Water
39     7  -2.7      27    -26     30    -31          u=6      $ Al clad
40     6  -2.66     28    -27     30    -31          u=6      $ Boral
41     7  -2.7      29    -28     30    -31          u=6      $ Al clad
42     4  -1.      129    -29     30    -31          u=6      $ water
43     4  -1.      129    -64     33    -67          u=6      $ Water
44     5  -7.84    129    -64     32    -30          u=6      $ Steel ends
45     5  -7.84    129    -64     31    -33          u=6      $ Steel ends
46     4  -1.      129    -64     66    -32          u=6      $ Water
c
c    Type B box -  Boral on Top only
c
47     0  -10   11  -12   13          u=7 fill=1
48     3  -6.55     60    -61     62    -63  #8      u=7      $ Zr flow channel
102    5  -7.84    74 -75 76 -77 (-70:71:-72:73)  u=7      $ DFC
49     4  -1.       64    -65     66    -67  #8 #9 #102 u=7  $ water
50     5  -7.84     20    -23     67    -14          u=7      $ 0.075" STEEL
51     4  -1.       20    -23     14    -15          u=7      $ WATER POCKET
52     7  -2.7      20    -23     15    -16          u=7      $ Al CLAD
53     6  -2.66     20    -23     16    -17          u=7      $ BORAL Absorber
54     7  -2.7      20    -23     17    -18          u=7      $ water
55     4  -1.       20    -23     18   -118          u=7      $ Water
56     5  -7.84     118:-129:65:-66                   u=7      $ Steel
57     4  -1.       64    -21     67    -118         u=7      $ Water
58     4  -1.       24    -65     67    -118         u=7      $ water
59     5  -7.84     21    -20     67    -118         u=7      $ Steel
60     5  -7.84     23    -24     67    -118         u=7      $ Steel
61     4  -1.      129    -64     66    -118         u=7      $ Water
c
c    Type E box  - No Boral Panels
c
62     0  -10   11  -12   13          u=8 fill=1
63     3  -6.55     60    -61     62    -63  #8      u=8      $ Zr flow channel
103    5  -7.84    74 -75 76 -77 (-70:71:-72:73)  u=8      $ DFC
64     4  -1.      129    -65     66   -118  #8 #9 #103 u=8  $ water
65     5  -7.84     118:-129:65:-66                   u=8      $ Steel
c
c    Type F box  - No Boral Panels or fuel
c
66     4  -1.      129    -65     66   -118          u=9      $ water
67     5  -7.84     118:-129:65:-66                   u=9      $ Steel
c
68     4  -1.0     -34   35   -36   37   u=5  lat=1  fill=-7:6  -7:6  0:0
                5 5 5 5 5 5 5 5 5 5 5 5 5 5
                5 9 9 9 9 9 9 9 9 9 9 9 9 5
                5 9 9 9 9 9 7 4 9 9 9 9 9 5
                5 9 9 9 7 4 4 4 4 4 9 9 9 5
                5 9 9 7 4 4 4 4 4 4 4 9 9 5
                5 9 9 7 4 4 4 4 4 4 4 9 9 5
                5 9 7 4 4 4 4 4 4 4 4 4 9 5
                5 9 8 4 4 4 4 4 4 4 4 6 9 5
                5 9 9 7 4 4 4 4 4 4 4 9 9 5
                5 9 9 8 4 4 4 4 4 4 6 9 9 5
                5 9 9 9 8 4 4 4 6 6 9 9 9 5
                5 9 9 9 9 9 8 6 9 9 9 9 9 5
                5 9 9 9 9 9 9 9 9 9 9 9 9 5
                5 5 5 5 5 5 5 5 5 5 5 5 5 5
69     0           -41                 50   -49  fill=5 (8.1661  8.1661  0)
70     4  -1.0     -41        43   -50              $ Water below Fuel
```

```
71    4  -1.0    -41       49  -44            $ Water above Fuel
72    5  -7.84   -42       68  -43            $ Steel below Fuel
73    5  -7.84   -42       44  -69            $ Steel above Fuel
74    5  -7.84    41  -42  43  -44            $ Radial Steel
75    0            42 :-68:  69               $ outside world

1     cz         0.5220     $ Fuel OD
2     cz         0.5334     $ Clad ID
3     cz         0.6172     $ Clad OD
4     cz         0.5398     $ Thimble ID
5     cz         0.6261     $ Thimble OD
6     px         0.8014     $ Pin Pitch
7     px        -0.8014
8     py         0.8014
9     py        -0.8014
10    px         5.7684     $ Channel ID
11    px        -5.7684
12    py         5.7684
13    py        -5.7684
14    py         7.8016
15    py         7.8155
16    py         7.8410
17    py         8.0467
18    py         8.0721
118   py         8.0861
20    px        -6.0325
21    px        -6.2230
23    px         6.0325
24    px         6.2230
25    px        -7.8016
26    px        -7.8155
27    px        -7.8410
28    px        -8.0467
29    px        -8.0721
129   px        -8.0861
30    py        -6.0325
31    py         6.0325
32    py        -6.2230
33    py         6.2230
34    px         7.6111
35    px        -8.7211
36    py         8.7211
37    py        -7.6111
41    cz         85.57
42    cz         108.43
43    pz         11.46
44    pz         252.15
49    pz         230.66      $ Top of Active Fuel
50    pz         30.         $ Start of Active Fuel
60    px        -5.9207     $ Channel OD
61    px         5.9207
62    py        -5.9207
63    py         5.9207
64    px        -7.6111     $ Cell Box ID
65    px         7.6111
66    py        -7.6111
67    py         7.6111
68    pz        -10.13
69    pz         291.52
70    px        -6.2611       $ DFC ID
```

```
71    px          6.2611
72    py         -6.2611
73    py          6.2611
74    px         -6.5659        $ DFC OD
75    px          6.5659
76    py         -6.5659
77    py          6.5659

imp:n     1 77r 0
kcode   10000  0.94   20  120
c
sdef  par=1  erg=d1 axs=0 0 1 x=d4 y=fx d5 z=d3
c
sp1 -2 1.2895
c
si3  h 30. 230.66
sp3  0 1
c
c
si4  s                15 16
                 13 14 15 16 17 18
             12 13 14 15 16 17 18 19
             12 13 14 15 16 17 18 19
         11 12 13 14 15 16 17 18 19 20
         11 12 13 14 15 16 17 18 19 20
             12 13 14 15 16 17 18 19
             12 13 14 15 16 17 18 19
                 13 14 15 16 17 18
                       15 16
sp4  1 67r
c
ds5  s                30 30
                 29 29 29 29 29 29
             28 28 28 28 28 28 28 28
             27 27 27 27 27 27 27 27
         26 26 26 26 26 26 26 26 26 26
         25 25 25 25 25 25 25 25 25 25
             24 24 24 24 24 24 24 24
             23 23 23 23 23 23 23 23
                 22 22 22 22 22 22
                       21 21
c
si11  -80.6831 -67.6783
si12  -64.1985 -51.1937
si13  -47.7139 -34.7091
si14  -31.2293 -18.2245
si15  -14.7447 -1.7399
si16   1.7399   14.7447
si17   18.2245  31.2293
si18   34.7091  47.7139
si19   51.1937  64.1985
si20   67.6783  80.6831
c
si21  -80.6831 -67.6783
si22  -64.1985 -51.1937
si23  -47.7139 -34.7091
si24  -31.2293 -18.2245
si25  -14.7447 -1.7399
si26   1.7399   14.7447
si27   18.2245  31.2293
```

```
si28   34.7091  47.7139
si29   51.1937  64.1985
si30   67.6783  80.6831
sp11  0 1
sp12  0 1
sp13  0 1
sp14  0 1
sp15  0 1
sp16  0 1
sp17  0 1
sp18  0 1
sp19  0 1
sp20  0 1
sp21  0 1
sp22  0 1
sp23  0 1
sp24  0 1
sp25  0 1
sp26  0 1
sp27  0 1
sp28  0 1
sp29  0 1
sp30  0 1
c
m1            92235.50c   -0.02644      $ 3.00% E Fuel
              92238.50c   -0.85504
              8016.50c    -0.11852
m3            40000.56c   1.            $ Zr Clad
m4            1001.50c    0.6667        $ Water
              8016.50c    0.3333
m5            24000.50c   0.01761       $ Steel
              25055.50c   0.001761
              26000.55c   0.05977
              28000.50c   0.008239
m6            5010.50c  1.9592E-03       $ Boral 0.0067 gm/cm2
              5011.50c  8.1175E-03
              6000.50c  2.5176E-03
              13027.50c 5.4933E-02
m7            13027.50c    1.            $ Al Clad
mt4          lwtr.01t
prdmp     j   -120   j   2
fm4       1000   1   -6
f4:n   1
sd4       1000
e4     1.000E-11   1.000E-10   5.000E-10   7.500E-10   1.000E-09   1.200E-09
       1.500E-09   2.000E-09   2.500E-09   3.000E-09
       4.700E-09   5.000E-09   7.500E-09   1.000E-08   2.530E-08
       3.000E-08   4.000E-08   5.000E-08   6.000E-08   7.000E-08
       8.000E-08   9.000E-08   1.000E-07   1.250E-07   1.500E-07
       1.750E-07   2.000E-07   2.250E-07   2.500E-07   2.750E-07
       3.000E-07   3.250E-07   3.500E-07   3.750E-07   4.000E-07
       4.500E-07   5.000E-07   5.500E-07   6.000E-07   6.250E-07
       6.500E-07   7.000E-07   7.500E-07   8.000E-07   8.500E-07
       9.000E-07   9.250E-07   9.500E-07   9.750E-07   1.000E-06
       1.010E-06   1.020E-06   1.030E-06   1.040E-06   1.050E-06
       1.060E-06   1.070E-06   1.080E-06   1.090E-06   1.100E-06
       1.110E-06   1.120E-06   1.130E-06   1.140E-06   1.150E-06
       1.175E-06   1.200E-06   1.225E-06   1.250E-06   1.300E-06
       1.350E-06   1.400E-06   1.450E-06   1.500E-06   1.590E-06
       1.680E-06   1.770E-06   1.860E-06   1.940E-06   2.000E-06
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2.120E-06	2.210E-06	2.300E-06	2.380E-06	2.470E-06
2.570E-06	2.670E-06	2.770E-06	2.870E-06	2.970E-06
3.000E-06	3.050E-06	3.150E-06	3.500E-06	3.730E-06
4.000E-06	4.750E-06	5.000E-06	5.400E-06	6.000E-06
6.250E-06	6.500E-06	6.750E-06	7.000E-06	7.150E-06
8.100E-06	9.100E-06	1.000E-05	1.150E-05	1.190E-05
1.290E-05	1.375E-05	1.440E-05	1.510E-05	1.600E-05
1.700E-05	1.850E-05	1.900E-05	2.000E-05	2.100E-05
2.250E-05	2.500E-05	2.750E-05	3.000E-05	3.125E-05
3.175E-05	3.325E-05	3.375E-05	3.460E-05	3.550E-05
3.700E-05	3.800E-05	3.910E-05	3.960E-05	4.100E-05
4.240E-05	4.400E-05	4.520E-05	4.700E-05	4.830E-05
4.920E-05	5.060E-05	5.200E-05	5.340E-05	5.900E-05
6.100E-05	6.500E-05	6.750E-05	7.200E-05	7.600E-05
8.000E-05	8.200E-05	9.000E-05	1.000E-04	1.080E-04
1.150E-04	1.190E-04	1.220E-04	1.860E-04	1.925E-04
2.075E-04	2.100E-04	2.400E-04	2.850E-04	3.050E-04
5.500E-04	6.700E-04	6.830E-04	9.500E-04	1.150E-03
1.500E-03	1.550E-03	1.800E-03	2.200E-03	2.290E-03
2.580E-03	3.000E-03	3.740E-03	3.900E-03	6.000E-03
8.030E-03	9.500E-03	1.300E-02	1.700E-02	2.500E-02
3.000E-02	4.500E-02	5.000E-02	5.200E-02	6.000E-02
7.300E-02	7.500E-02	8.200E-02	8.500E-02	1.000E-01
1.283E-01	1.500E-01	2.000E-01	2.700E-01	3.300E-01
4.000E-01	4.200E-01	4.400E-01	4.700E-01	4.995E-01
5.500E-01	5.730E-01	6.000E-01	6.700E-01	6.790E-01
7.500E-01	8.200E-01	8.611E-01	8.750E-01	9.000E-01
9.200E-01	1.010E+00	1.100E+00	1.200E+00	1.250E+00
1.317E+00	1.356E+00	1.400E+00	1.500E+00	1.850E+00
2.354E+00	2.479E+00	3.000E+00	4.304E+00	4.800E+00
6.434E+00	8.187E+00	1.000E+01	1.284E+01	1.384E+01
1.455E+01	1.568E+01	1.733E+01	2.000E+01	

```
=NITAWL
' k4rf5f45, HI-STAR containing MPC24, 15x15 assembly a17 @ 4.1% E
0$$ 84 E
1$$ 0 13  0  4R0  1  E T
2$$ 92235    92238
    40000    1001     8016     5010     5011     6012
    13027    24000    25055    26000    28000
3** 92238 294.6    2   .4752    .1928    0.      0.02251     1
   16.0   7.8209   1   235.04  0.5154   1      1.0            T
END
=KENO5A
k4rf5f45, HI-STAR containing MPC24, 15x15 assembly a17 @ 4.1% E
READ PARAM TME=10000 GEN=300 NPG=10000 NSK=50 LIB=4 TBA=5
END PARAM
READ MIXT SCT=2  EPS=1.0
MIX=1   92235  9.7463E-04
        92238  0.02251
        8016   0.04694
MIX=2   40000  0.04323
MIX=3   1001   0.06688
        8016   0.03344
MIX=4   24000  0.01761
        25055  0.001761
        26000  0.05977
        28000  0.008239
MIX=5   5010   8.7066E-03
        5011   3.5116E-02
        6012   1.0948E-02
        13027  3.6936E-02
MIX=6   1001   0.06688
        8016   0.03344
MIX=7   13027  0.06026
END MIXT
'
' cell-id       8.98
' cell-pitch    10.906
' wall-thkns    5/16
' angle-thkns   5/16
' boral-gap     0.0035
' boral-pocket  0.082
' boral-thkns   0.075
' boral-clad    0.01
' boral-core    0.055
' sheathing     0.0235
' boral-wide    7.500
' boral-narrow  6.250
'
' gap size      1.09
'
READ GEOM
UNIT            1
COM="FUEL ROD"
CYLINDER         1  1  0.4752                                    381.0   0.
CYLINDER         3  1  0.4851                                    381.0   0.
CYLINDER         2  1  0.5436                                    381.0   0.
CUBOID           3  1  0.7214   -0.7214    0.7214    -0.7214     381.0   0.
UNIT            2
COM="GUIDE  TUBE CELL"
```

```
CYLINDER        3  1  0.6350                                        381.0   0.
CYLINDER        2  1  0.6706                                        381.0   0.
CUBOID          3  1  0.7214   -0.7214    0.7214    -0.7214        381.0   0.
UNIT           4
COM="LONG HORIZONTAL BORAL PANEL - NORTH"
CUBOID          5  1  9.525  -9.525   0.06985    -0.06985      381.0   0.
CUBOID          7  1  9.525  -9.525   0.09525    -0.09525      381.0   0.
CUBOID          3  1  9.525  -9.525   0.10414    -0.10414      381.0   0.
CUBOID          4  1  9.58469  -9.58469   0.16383      -0.10414      381.0   0.
UNIT           5
COM="LONG VERTICAL BORAL PANEL - EAST"
CUBOID          5  1  0.06985    -0.06985    9.525  -9.525    381.0   0.
CUBOID          7  1  0.09525    -0.09525    9.525  -9.525    381.0   0.
CUBOID          3  1  0.10414    -0.10414    9.525  -9.525    381.0   0.
CUBOID          4  1  0.16383      -0.10414    9.58469  -9.58469    381.0   0.
UNIT           6
COM="LONG HORIZONTAL BORAL PANEL - SOUTH"
CUBOID          5  1  9.525  -9.525    0.06985   -0.06985      381.0   0.
CUBOID          7  1  9.525  -9.525    0.09525   -0.09525      381.0   0.
CUBOID          3  1  9.525  -9.525    0.10414   -0.10414      381.0   0.
CUBOID          4  1  9.58469  -9.58469    0.10414   -0.16383       381.0   0.
UNIT           7
COM="LONG VERTICAL BORAL PANEL - WEST"
CUBOID          5  1  0.06985    -0.06985    9.525  -9.525    381.0   0.
CUBOID          7  1  0.09525    -0.09525    9.525  -9.525    381.0   0.
CUBOID          3  1  0.10414    -0.10414    9.525  -9.525    381.0   0.
CUBOID          4  1  0.10414    -0.16383      9.58469  -9.58469    381.0   0.
UNIT           8  ARRAY 1  -10.8204    -10.8204       0.
COM="CENTRAL FUEL ASSEMBLIES - 4 BORAL PANELS"
CUBOID          3  1  11.4046  -11.4046   11.4046  -11.4046     381.0   0.
CUBOID          4  1  12.1984  -12.1984   12.1984  -12.1984     381.0   0.
CUBOID          3  1  12.4673  -12.4673   12.4673  -12.4673     381.0   0.
HOLE            4    0.          12.3026     0.
HOLE            5   12.3026       0.         0.
HOLE            6  0.           -12.3026    0.
HOLE            7  -12.3026      0.         0.
' HOLE           17   -11.9802    11.9805    0.
' HOLE           17   -11.9802   -13.59      0.
' HOLE           18   -13.59     -11.90      0.
UNIT          21  ARRAY 1  -10.8204    -10.8204       0.
COM="CENTRAL FUEL ASSEMBLIES - 4 BORAL PANELS, W/O EAST WALL"
CUBOID          3  1  11.4046  -11.4046   11.4046  -11.4046     381.0   0.
CUBOID          4  1  11.4046  -12.1984   12.1984  -12.1984     381.0   0.
CUBOID          3  1  11.4046  -12.4673   12.4673  -12.4673     381.0   0.
HOLE            4    0.          12.3026     0.
HOLE            6  0.           -12.3026    0.
HOLE            7  -12.3026      0.         0.
UNIT          22  ARRAY 1  -10.8204    -10.8204       0.
COM="CENTRAL FUEL ASSEMBLIES - 4 BORAL PANELS, W/O WEST WALL"
CUBOID          3  1  11.4046  -11.4046   11.4046  -11.4046     381.0   0.
CUBOID          4  1  12.1984  -11.4046   12.1984  -12.1984     381.0   0.
CUBOID          3  1  12.4673  -11.4046   12.4673  -12.4673     381.0   0.
HOLE            4    0.          12.3026     0.
HOLE            5   12.3026       0.         0.
HOLE            6  0.           -12.3026    0.
UNIT          23
COM="CELL WALL BETWEEN UNITS 21 AND 22"
CUBOID          4  1  0.396775  -0.396775   23.9998  -23.9998     381.0   0.
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UNIT          9
COM="SHORT HORIZONTAL BORAL PANEL - NORTH"
CUBOID        5  1  7.9375  -7.9375   0.06985    -0.06985     381.0   0.
CUBOID        7  1  7.9375  -7.9375   0.09525    -0.09525     381.0   0.
CUBOID        3  1  7.9375  -7.9375   0.10414    -0.10414     381.0   0.
CUBOID        4  1  7.99719  -7.99719   0.16383      -0.10414      381.0   0.
UNIT         10
COM="SHORT VERTICAL BORAL PANEL - EAST"
CUBOID        5  1  0.06985    -0.06985    7.9375  -7.9375    381.0   0.
CUBOID        7  1  0.09525    -0.09525    7.9375  -7.9375    381.0   0.
CUBOID        3  1  0.10414    -0.10414    7.9375  -7.9375    381.0   0.
CUBOID        4  1  0.16383      -0.10414    7.99719  -7.99719    381.0   0.
UNIT         11
COM="SHORT HORIZONTAL BORAL PANEL - SOUTH"
CUBOID        5  1  7.9375  -7.9375    0.06985   -0.06985     381.0   0.
CUBOID        7  1  7.9375  -7.9375    0.09525   -0.09525     381.0   0.
CUBOID        3  1  7.9375  -7.9375    0.10414   -0.10414     381.0   0.
CUBOID        4  1  7.99719  -7.99719    0.10414   -0.16383       381.0   0.
UNIT         12
COM="SHORT VERTICAL BORAL PANEL - WEST"
CUBOID        5  1  0.06985    -0.06985    7.9375  -7.9375    381.0   0.
CUBOID        7  1  0.09525    -0.09525    7.9375  -7.9375    381.0   0.
CUBOID        3  1  0.10414    -0.10414    7.9375  -7.9375    381.0   0.
CUBOID        4  1  0.10414    -0.16383      7.99719  -7.99719    381.0   0.
UNIT         13  ARRAY 1  -10.8204    -10.8204       0.
COM="Array B short Boral N & E "
CUBOID        3  1  11.4046  -11.4046   11.4046  -11.4046     381.0   0.
CUBOID        4  1  12.1984  -12.1984   12.1984  -12.1984     381.0   0.
CUBOID        3  1  12.4673  -12.4673   12.4673  -12.4673     381.0   0.
HOLE          9    0.         12.3026     0.
HOLE         10   12.3026       0.        0.
HOLE          6  0.          -12.3026    0.
HOLE          7  -12.3026      0.        0.
' HOLE         17   -11.9802    11.9805    0.
' HOLE         17   -11.9802   -13.59      0.
' HOLE         18   -13.59     -11.90      0.
UNIT         14  ARRAY 1  -10.8204    -10.8204       0.
COM="Array C short Boral E & S "
CUBOID        3  1  11.4046  -11.4046   11.4046  -11.4046     381.0   0.
CUBOID        4  1  12.1984  -12.1984   12.1984  -12.1984     381.0   0.
CUBOID        3  1  12.4673  -12.4673   12.4673  -12.4673     381.0   0.
HOLE          4    0.         12.3026     0.
HOLE         10   12.3026       0.        0.
HOLE         11  0.          -12.3026    0.
HOLE          7  -12.3026      0.        0.
' HOLE         17   -11.9802    11.9805    0.
' HOLE         17   -11.9802   -13.59      0.
' HOLE         18   -13.59     -11.90      0.
UNIT         15  ARRAY 1  -10.8204    -10.8204       0.
COM="Array D short Boral S & W "
CUBOID        3  1  11.4046  -11.4046   11.4046  -11.4046     381.0   0.
CUBOID        4  1  12.1984  -12.1984   12.1984  -12.1984     381.0   0.
CUBOID        3  1  12.4673  -12.4673   12.4673  -12.4673     381.0   0.
HOLE          4    0.         12.3026     0.
HOLE          5   12.3026       0.        0.
HOLE         11  0.          -12.3026    0.
HOLE         12  -12.3026      0.        0.
' HOLE         17   -11.9802    11.9805    0.
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' HOLE          17   -11.9802   -13.59      0.
' HOLE          18   -13.59     -11.90      0.
UNIT          16  ARRAY 1  -10.8204    -10.8204       0.
COM="Array E short Boral N & W "
CUBOID          3  1  11.4046  -11.4046   11.4046  -11.4046     381.0   0.
CUBOID          4  1  12.1984  -12.1984   12.1984  -12.1984     381.0   0.
CUBOID          3  1  12.4673  -12.4673   12.4673  -12.4673     381.0   0.
HOLE            9    0.         12.3026     0.
HOLE            5   12.3026       0.        0.
HOLE            6  0.           -12.3026    0.
HOLE           12  -12.3026      0.         0.
' HOLE          17   -11.9802    11.9805    0.
' HOLE          17   -11.9802   -13.59      0.
' HOLE          18   -13.59     -11.90      0.
UNIT          17
CUBOID          4  1  0.7938   -0.        1.60      -0.         381.0   0.
UNIT          18
CUBOID          4  1  1.60     -0.        0.7938    -0.         381.0   0.
UNIT          30
CUBOID          4  1  1.37332  -1.37332   3.4925  -3.4925     381.0   0.
UNIT          31
CUBOID          4  1  1.05959  -1.05959   1.37332  -1.37332     381.0   0.
UNIT          41
CUBOID          3  1  14.6768  -14.6768   1.65227  -1.65227     381.0   0.
CUBOID          4  1  14.6768  -14.6768   2.44602  -2.44602     381.0   0.
UNIT          42
CUBOID          3  1  1.65227  -1.65227   14.6768  -14.6768     381.0   0.
CUBOID          4  1  2.44602  -2.44602   14.6768  -14.6768     381.0   0.
GLOBAL
UNIT          19
COM="ASSEMBLY ARRAY + X DIRECTION"
CYLINDER        3  1  86.57                                   396.24  -10.16
HOLE            8   13.8506    13.8506    0.
HOLE            8   13.8506   -13.8506    0.
HOLE           21   17.949    41.5519    0.
HOLE           21   17.949   -41.5519    0.
HOLE           13   13.8506    69.2531    0.
HOLE           14   13.8506   -69.2531    0.
HOLE           22   41.5519    17.949    0.
HOLE           22   41.5519   -17.949    0.
HOLE           13   45.6502    45.6502    0.
HOLE           14   45.6502   -45.6502    0.
HOLE           13   69.2531    13.8506    0.
HOLE           14   69.2531   -13.8506    0.
HOLE            8  -13.8506    13.8506    0.
HOLE            8  -13.8506   -13.8506    0.
HOLE           22  -17.949    41.5519    0.
HOLE           22  -17.949   -41.5519    0.
HOLE           16  -13.8506    69.2531    0.
HOLE           15  -13.8506   -69.2531    0.
HOLE           21  -41.5519    17.949    0.
HOLE           21  -41.5519   -17.949    0.
HOLE           16  -45.6502    45.6502    0.
HOLE           15  -45.6502   -45.6502    0.
HOLE           16  -69.2531    13.8506    0.
HOLE           15  -69.2531   -13.8506    0.
HOLE           23   29.7505    29.7505    0.
HOLE           23  -29.7505    29.7505    0.
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HOLE            23   29.7505   -29.7505    0.
HOLE            23  -29.7505   -29.7505    0.
HOLE             5   30.2516    41.5519    0.
HOLE             5   30.2516   -41.5519    0.
HOLE             7  -30.2516    41.5519    0.
HOLE             7  -30.2516   -41.5519    0.
HOLE             7   29.2494    17.949    0.
HOLE             7   29.2494   -17.949    0.
HOLE             5  -29.2494    17.949    0.
HOLE             5  -29.2494   -17.949    0.
HOLE            30       0.        0.    0.
HOLE            31   2.43291       0.    0.
HOLE            31  -2.43291       0.    0.
HOLE            41   41.5519       0.    0.
HOLE            41  -41.5519       0.    0.
HOLE            42       0.    41.5519    0.
HOLE            42       0.   -41.5519    0.
CYLINDER         4  1  108.43                                435.61  -31.75
CUBOID           3  1  139   -139    139   -139    435.61   -31.75
END GEOM
READ ARRAY
ARA=1  NUX=15  NUY=15  NUZ=1
COM="15 X 15 FUEL ASSEMBLY"
FILL
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
      1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
      1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
END ARRAY
END DATA
END
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=NITAWL
' HI-STAR containing MPC68, 08x08 @ 4.2% E
0$$ 84 E
1$$ 0 13  0  4R0  1  E T
2$$ 92235    92238
    40000    1001     8016     5010     5011     6012
    13027    24000    25055    26000    28000
3** 92238 294.6    2   .5207    .1623    0.       0.02248     1
   16.0   7.8330   1   235.04  0.5662    1      1.0           T
END
=KENO5A
HI-STAR containing MPC68, 08x08 @ 4.2% E
'  GE 8X8R FUEL 2 WATER HOLES
READ PARAM TME=10000 GEN=1100 NPG=5000 NSK=100
     LIB=4 TBA=5  LNG=400000   NB8=900
END PARAM
READ MIXT SCT=2  EPS=1.
MIX=1   92235  9.983E-04
        92238  0.02248
        8016   0.04697
MIX=2   40000  0.04323
MIX=3   1001   0.06688
        8016   0.03344
MIX=4   24000  0.01761
        25055  0.001761
        26000  0.05977
        28000  0.008239
MIX=5   5010   8.071E-03
        5011   3.255E-02
        6012   1.015E-02
        13027  3.805E-02
MIX=6   13027  0.06026
END MIXT
READ GEOM
UNIT           1
COM=           "FUEL ROD"
CYLINDER        1  1  0.5207                                    381.0   0.
CYLINDER        3  1  0.5321                                    381.0   0.
CYLINDER        2  1  0.6134                                    381.0   0.
CUBOID          3  1  0.8128   -0.8128    0.8128    -0.8128     381.0   0.
UNIT           2
COM=           "GUIDE  TUBE CELL"
CYLINDER        3  1  0.6744                                    381.0   0.
CYLINDER        2  1  0.7506                                    381.0   0.
CUBOID          3  1  0.8128   -0.8128    0.8128    -0.8128     381.0   0.
UNIT           4
COM=           "HORIZONTAL BORAL PANEL"
CUBOID          5  1  6.0325   -6.0325    0.1027    -0.1027     381.0   0.
CUBOID          6  1  6.0325   -6.0325    0.1283    -0.1283     381.0   0.
CUBOID          3  1  6.0325   -6.0325    0.1422    -0.1422     381.0   0.
CUBOID          4  1  6.4611   -6.4611    0.1422    -0.3327     381.0   0.
UNIT           5
COM=           "VERTICAL BORAL PANEL"
CUBOID          5  1  0.1027   -0.1027     6.0325   -6.0325    381.0   0.
CUBOID          6  1  0.1283   -0.1283     6.0325   -6.0325    381.0   0.
CUBOID          3  1  0.1422   -0.1422     6.0325   -6.0325    381.0   0.
CUBOID          4  1  0.3327   -0.1422     6.4611   -6.4611    381.0   0.
UNIT           8  ARRAY 1  -6.5024     -6.5024        0.
COM=           "FUEL ASSEMBLIES - 2 BORAL PANELS"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
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CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
HOLE            4    0.         7.9438     0.
HOLE            5  -7.9438       0.         0.
CUBOID          4  1  7.6111   -8.7211    8.7211   -7.6111          381.0   0.
UNIT            9  ARRAY 1  -6.5024      -6.5024        0.
COM=            "FUEL ASSEMBLIES - Type A"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
HOLE            5  -7.9438       0.         0.
CUBOID          4  1  8.2461   -8.7211    8.7211   -7.6111          381.0   0.
UNIT           10  ARRAY 1  -6.5024      -6.5024        0.
COM=            "FUEL ASSEMBLIES - Type B"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
HOLE            5  -7.9438       0.         0.
CUBOID          4  1  7.6111   -8.7211    8.7211   -7.6111          381.0   0.
UNIT           11  ARRAY 1  -6.5024      -6.5024        0.
COM=            "FUEL ASSEMBLIES - Type C"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
HOLE            4    0.         7.9438     0.
HOLE            5  -7.9438       0.         0.
CUBOID          4  1  8.2461   -8.7211    8.7211   -7.6111          381.0   0.
UNIT           12  ARRAY 1  -6.5024      -6.5024        0.
COM=            "FUEL ASSEMBLIES - Type D"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
HOLE            4    0.         7.9438     0.
HOLE            5  -7.9438       0.         0.
CUBOID          4  1  8.2461   -8.7211    8.7211   -8.2461          381.0   0.
UNIT           13  ARRAY 1  -6.5024      -6.5024        0.
COM=            "FUEL ASSEMBLIES - Type E"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
HOLE            4    0.         7.9438     0.
HOLE            5  -7.9438       0.         0.
CUBOID          4  1  7.6111   -8.7211    8.7211   -8.2461          381.0   0.
UNIT           14  ARRAY 1  -6.5024      -6.5024        0.
COM=            "FUEL ASSEMBLIES - Type F"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
HOLE            4    0.         7.9438     0.
CUBOID          4  1  7.6111   -8.7211    8.7211   -8.2461          381.0   0.
UNIT           15  ARRAY 1  -6.5024      -6.5024        0.
COM=            "FUEL ASSEMBLIES - TYPE G"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
HOLE            4    0.         7.9438     0.
CUBOID          4  1  7.6111   -8.7211    8.7211   -7.6111          381.0   0.
UNIT           16  ARRAY 1  -6.5024      -6.5024        0.
COM=            "FUEL ASSEMBLIES - TYPE H"
CUBOID          3  1  6.7031   -6.7031    6.7031   -6.7031          381.0   0.
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CUBOID          2  1  6.9571   -6.9571    6.9571   -6.9571          381.0   0.
CUBOID          3  1  7.6111   -8.0861    8.0861   -7.6111          381.0   0.
CUBOID          4  1  7.6111   -8.7211    8.7211   -7.6111          381.0   0.
UNIT           17  ARRAY 2     -48.9966  -48.9966          0
UNIT           18  ARRAY 3     -16.3322  -7.6111           0.
UNIT           19  ARRAY 4     -48.9966  -7.6111           0.
UNIT           20  ARRAY 5     -8.7211   -16.3322          0.
UNIT           21  ARRAY 6     -8.7211   -50.1068          0.
UNIT           22  ARRAY 7     -8.7211   -16.3322          0.
UNIT           23  ARRAY 8     -8.7211   -16.3322          0.
UNIT           24  ARRAY 9     -8.7211   -16.3322          0.
UNIT           25  ARRAY 10    -8.7211   -16.3322          0.
UNIT           26  ARRAY 11    -16.3322  -8.7213           0.
UNIT           27  ARRAY 12    -16.3322  -7.6111           0.
UNIT           28  ARRAY 13    -16.3322  -8.7213           0.
UNIT           29  ARRAY 14    -16.3322  -8.7213           0.
GLOBAL
UNIT           30
CYLINDER        3  1   85.57                                        402.5   -18.54.
HOLE           17      0.0        0.0        0.
HOLE           18      0.0       73.4949     0.
HOLE           19      0.0       57.1627     0.
HOLE           20     -73.4949    0.0        0.
HOLE           21     -56.6077    0.0        0.
HOLE           22      57.7177   32.6644     0.
HOLE           23      57.7177    0.0        0.
HOLE           24      74.052     0.0        0.
HOLE           25      57.7177  -32.6644     0.
HOLE           26      32.6644  -57.7177     0.
HOLE           27       0.0     -57.7177     0.
HOLE           28     -32.6644  -57.7177     0.
HOLE           29       0.0     -74.052      0.
CYLINDER        4   1   108.43                                   441.85  -40.13
CUBOID          3   1   109.     -109.      109.     -109.    442     -40.2
END GEOM
READ ARRAY
ARA=1  NUX=8   NUY=8   NUZ=1
COM=   "8 X 8 FUEL ASSEMBLY"
FILL
 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1
 1 1 1 2 1 1 1 1
 1 1 1 1 2 1 1 1
 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1
END FILL
ARA=2  NUX=6   NUY=6   NUZ=1
COM=   "6 X 6 CENTRAL ARRAY OF FUEL ASSEMBLIES"
FILL
  8 8 8 8 8 8
  8 8 8 8 8 8
  8 8 8 8 8 8
  8 8 8 8 8 8
  8 8 8 8 8 8
  8 8 8 8 8 8
END FILL
ARA=3  NUX=2   NUY=1   NUZ=1
COM=   "2 X 1  ARRAY OF FUEL ASSEMBLIES - TOP ROW"
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FILL
 16  9
END FILL
ARA=4  NUX=6   NUY=1   NUZ=1
COM=   "6 X 1  ARRAY OF FUEL ASSEMBLIES - 2ND ROW"
FILL
  16  10  8  8  10  9
END FILL
ARA=5  NUX=1   NUY=2   NUZ=1
COM=   "2 X 1  ARRAY OF FUEL ASSEMBLIES - OUTER LEFT"
FILL
  14
  16
END FILL
ARA=6  NUX=1   NUY=6   NUZ=1
COM=   "1 X 6  ARRAY OF FUEL ASSEMBLIES - 2ND ROW LEFT"
FILL
  14  15  8  8  15  16
END FILL
ARA=7  NUX=1   NUY=2   NUZ=1
COM=   "1 X 2  ARRAY OF FUEL ASSEMBLIES - UPPER RIGHT"
FILL
  11
   9
END FILL
ARA=8  NUX=1   NUY=2   NUZ=1
COM=   "1 X 2  ARRAY OF FUEL ASSEMBLIES - MIDDLE RIGHT"
FILL
   8
   8
END FILL
ARA=9  NUX=1   NUY=2   NUZ=1
COM=   "1 X 2  ARRAY OF FUEL ASSEMBLIES - MIDDLE RIGHT"
FILL
   11
    9
END FILL
ARA=10  NUX=1   NUY=2   NUZ=1
COM=   "1 X 2  ARRAY OF FUEL ASSEMBLIES - LOWER RIGHT"
FILL
  11
  11
END FILL
ARA=11  NUX=2   NUY=1   NUZ=1
COM=   "2 X 1  ARRAY OF FUEL ASSEMBLIES - 2ND BOTTOM ROW"
FILL
  13  13
END FILL
ARA=12  NUX=2   NUY=1   NUZ=1
COM=   "2 X 1  ARRAY OF FUEL ASSEMBLIES - BOTTOM ROW"
FILL
  8  8
END FILL
ARA=13  NUX=2   NUY=1   NUZ=1
COM=   "2 X 1  ARRAY OF FUEL ASSEMBLIES - BOTTOM ROW"
FILL
  14  13
END FILL
ARA=14  NUX=2   NUY=1   NUZ=1
COM=   "2 X 1  ARRAY OF FUEL ASSEMBLIES - BOTTOM ROW"
```

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FILL
  14 13
END FILL
END ARRAY
END DATA
END
```

Appendix 6.E

Supplemental Information about the Evaluation of Operating Parameters used in the Depletion Calculations for Burnup Credit

6.E.1 Purpose

Section 6.4.11.2.1 discusses the core operating parameters used in the burnup credit evaluations. This appendix provides additional information on how the parameters were established.

Appendix 6.F

Fuel Inserts and Burnable Poisons

6.F.1 Purpose

Section 6.4.11.2.2 discusses the reactivity effect of inserts and burnable poisons during the depletion of the fuel and the approach taken in the design basis calculations. This appendix provides additional information.

Appendix 6.G

CASMO Sample Input Files

6.G.1 Assembly Class 17x17A, 4.0% Enrichment

```
*
*  burnup / isotope vector for 17a assembly @ 4.00%
*
DIM 17,1/
TTL,  TFU=1181  TMO=620   BOR=1200  * 17a 4.00%
FUE,1,10.522/4.00
PIN,1,0.3922,0.4001,0.4572
PIN,2,0.56134,0.60198/'COO','CAN'//1
PIN,3,0.56134,0.60198/'COO','CAN'//1
* Pyrex
PIN,2,.213995,.230505,.24130,.42672,.43688,.48387,0.56134,0.60198/
       'AIR','MI5','AIR','MI2','AIR','MI5','COO','CAN' //1 'BPR'
'ROD'
MI2,2.299/14000=40.9006,8000=55.2173,5010=0.698784,5011=3.18335
MI5,8.00/347=100
ROD 'BPR'
LPI
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 3 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 2 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 2 1 1 1 1 1 1 1 1 1 2 1 1 1
1 1 1 1 1 2 1 1 2 1 1 2 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
**
** t-fuel 1181
** element-pitch 21.50
** mode s
** calc-code k
** boron 1200
** rod-pitch 1.2598
```

```
** enrichment 4.00
** powerdensity 61.61
** class 17a
** t-mod 620
** we17bpr we17prx
** cooling 5
** max-burnup 65
** bw15bpr bw15bpr
** rods 17
** enrich-code 40
**
MGA 6*1      NLI
PWR 17 1.2598,21.50,4*0,1
PDE 61.61        * W/GM U
DEP -65
STA
*
TTL    * 17a 4.00% Decay
RES,,0.1,2,5,8,10,12.5,-65
* Burnup in ~2.5 GWD steps
TMO 300 TFU 300 PDE 0 CNU,'FUE',54135,0 BOR 0
THE 0
ROD 'OUT'
* 5 years cooling time
SDC,5/'DY'
STA
END
```

6.G.2 Assembly Class 15x15F, 4.0% Enrichment

```
*
*  burnup / isotope vector for 15f assembly @ 4.00%
*     (15x15 B&W)
*
TTL,  TFU=1169  TMO=604   BOR=1200  * 15f 4.00%
FUE,1,10.522/4.00
PIN,1,0.4752,0.4851,0.5436
PIN,2,0.63246,0.6731/'COO','CAN'//1
PIN,3,0.56007,0.690965/'COO','CAN'//1
*
PIN,2,.4318,.4572,.5461,0.63246,0.6731/   * BPRA's
       'MI2','AIR','CAN','COO','CAN' //1 'BPR' 'ROD'
MI2,3.7/13000=51.33732,8000=45.66268,6000=0.65213,5010=0.42262,501
1=1.92525
ROD 'BPR'
LPI
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 3 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 1 1 2 1 1 1 2 1 1 2 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 2 1 1 1 1 1 1 1 2 1 1 1
1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
**
** t-fuel 1169
** element-pitch 21.81
** mode s
** calc-code k
** boron 1200
** rod-pitch 1.44272
** enrichment 4.00
** powerdensity 47.36
** class 15f
** t-mod 604
** we17bpr we17prx
** cooling 5
** max-burnup 65
```

```
** bw15bpr bw15bpr
** rods 15
** enrich-code 40
**
MGA 6*1      NLI
PWR 15 1.44272,21.81,4*0,1
PDE 47.36        * W/GM U
DEP -65
STA
*
TTL    * 15f 4.00% Decay
RES,,0.1,2,5,8,10,12.5,-65
* Burnup in ~2.5 GWD steps
TMO 300 TFU 300 PDE 0 CNU,'FUE',54135,0 BOR 0
THE 0
ROD 'OUT'
* 5 years cooling time
SDC,5/'DY'
STA
END
```

Appendix 6.H

Isotopic Benchmarks

6.H.1 Purpose

This appendix contains additional information and discussions about the isotopic benchmark calculations for burnup credit. For a principal discussion of these benchmarks and a summary of the results see Subsection 6.4.11.3.1.

6.H.2 Selected Benchmark Experiments

Eight sets of experiments were selected for the isotopic benchmark calculations. Each set is from one single commercial nuclear plant, but contains analyses from several spent fuel assemblies. The main characteristics of the sets of experiments, including the plant names, and burnup and enrichment ranges, are listed below.

Set Number	Plant Name	Number of Samples	Number of Assemblies	Minimum Enrichment (wt% ^{235}U)	Maximum Enrichment (wt% ^{235}U)	Minimum Burnup (GWd/MTU)	Maximum Burnup (GWd/MTU)	Reference
1	Calvert Cliffs Unit 1	9	3	2.45	3.03	18.68	46.46	6.4.21
2	HB Robinson Unit 2	4	1	2.56	2.56	16.02	31.6	6.4.21
3	Mihama 3	9	3	3.203	3.21	6.92	34.32	6.4.21
4	Obrigheim	6	5	3.13	3.13	25.93	29.52	6.4.21
5	Trino-Vercellese	14	3	3.13	3.897	11.53	24.55	6.4.21
6	Turkey Point Unit 3	5	2	2.556	2.556	30.51	31.56	6.4.21
7	Yankee Rowe	8	2	3.4	3.4	15.95	35.97	6.4.21
8	Takahama 3	16	2	2.63	4.11	7.79	47.25	6.4.10
All	-	71	21	2.45	4.11	6.92	47.25	-

Sets 1 through 7 were used for the isotopic benchmark calculations in [6.4.3]. Set 8 is a more recently published evaluation of PWR spent fuel, with a significant number of samples taken from fuel of burnups of 35 GWd/MTU or more.

Figure 6.H.1: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.2: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.3: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.4: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.5: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.6: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.7: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.8: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.9: HOLTEC PROPRIETARY INFORMATION

Figure 6.H.10: HOLTEC PROPRIETARY INFORMATION

Appendix 6.I

Commercial Reactor Critical Benchmark Calculations

6.I.1 Purpose

Subsection 6.4.11.3.3 discusses the Commercial Reactor Criticals (CRCs) benchmark calculations. This appendix provides additional information about these calculations.

6.I.4 Summary of Calculations

A summary of the results is listed in Table 6.I.1, which shows the calculated reactivity and standard deviation of the criticality calculation, together with the corresponding core average burnup, for every state point analyzed. These results are also depicted in Figure 6.4.13.

Table 6.I.1

RESULTS OF THE CRITICALITY EVALUATIONS FOR THE COMMERCIAL REACTOR CRITICAL EXPERIMENTS

State Point	Average Core Burnup	k-calc	Standard Deviation	State Point	Average Core Burnup	k-calc	Standard Deviation
Davis Besse Unit 1							
sp40	2.9	1.0085	0.0006	sp43	11.6	1.0046	0.0006
sp41	10.1	1.014	0.0007	sp44	13.1	1.0064	0.0007
sp42	10.0	1.0064	0.0007	sp45	16.2	1.0091	0.0007
Crystal River Unit 3							
sp13	12.0	1.0156	0.0007	sp24	16.6	1.0126	0.0007
sp14	15.0	1.0218	0.0007	sp25	24.8	1.0239	0.0007
sp15	24.4	1.0364	0.0007	sp26	24.9	1.025	0.0007
sp16	10.0	1.0119	0.0007	sp27	28.2	1.0234	0.0007
sp17	18.1	1.0168	0.0007	sp28	14.2	1.0095	0.0006
sp18	19.0	1.0202	0.0006	sp29	19.1	1.0157	0.0006
sp19	19.9	1.0207	0.0006	sp30	21.0	1.0129	0.0007
sp20	24.3	1.0293	0.0008	sp31	25.4	1.0257	0.0007
sp21	24.9	1.028	0.0007	sp32	15.2	1.0092	0.0006
sp22	12.3	1.0082	0.0007	sp33	32.9	1.0244	0.0007
sp23	15.3	1.0119	0.0006				
McGuire Unit 1							
sp47	11.7	1.0083	0.0006	sp50	16.1	1.0103	0.0006
sp48	14.3	1.0109	0.0006	sp51	22.5	1.0183	0.0007
sp49	10.8	1.007	0.0006				

Appendix 6.J

Axial Burnup Distributions

6.J.1 Purpose

Subsection 6.4.11.4.1 provides a discussion of the principal approach and the results of the evaluations of the axial burnup distribution in the fuel. This section provides additional information for this subject.

Figure 6.J.1: HOLTEC PROPRIETARY INFORMATION

Appendix 6.K

Effect of Tilted Assembly Burnup

6.K.1 Purpose

Subsection 6.4.11.4.2 discusses the effect of a tilt of the burnup in an assembly cross section. This appendix provides additional information on the calculations performed for this condition.

6.K.2 Burnup Difference between Quadrants of the Assembly Cross Section

Reference [6.4.13] contains information about the horizontal burnup gradients in PWR assemblies. These are presented in the form of a percentage difference of the burnup in a quadrant of the assembly cross section to the average burnup within this cross section (see Figure 6.K.1). For most assemblies the percentage difference is less than 5%. However, maximum differences of up to 23.5% for burnups around 10 GWd/MTU, and up to 14% for burnups around 35 GWd/MTU can be found.

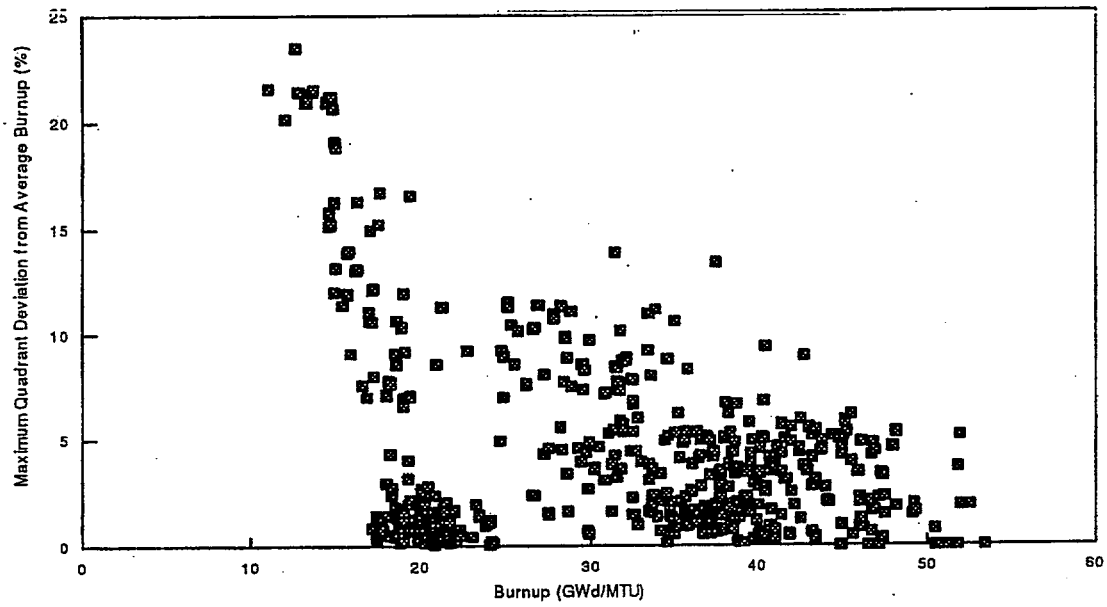

Figure 6.K.1 Maximum Quadrant Deviation from Assembly Average Burnup as a Function of Average Burnup (from [6.4.13])

Figure 6.K.2 HOLTEC PROPRIETARY INFORMATION

Figure 6.K.3 HOLTEC PROPRIETARY INFORMATION

Figure 6.K.4 HOLTEC PROPRIETARY INFORMATION

Appendix 6.L

Studies Regarding the Use of CASMO Isotopic Compositions in MCNP

6.L.1 Purpose

This Appendix shows that results of two studies performed regarding the use of the CASMO isotopic compositions in MCNP. See Subsection 6.4.11.4.3 for a discussion about the need for these studies.

6.L.2 Interpolation of Isotopic Compositions for Intermediate Burnups

CASMO calculations are performed in burnup steps of approximately 2.5 GWd/MTU. Isotopic compositions at intermediate burnups are determined by linear-linear interpolation (except for the reactor critical benchmarks, where it is necessary to perform individual CASMO calculations for each assembly segment). To demonstrate that this is an acceptable approach, one CASMO calculation was re-run with smaller burnup steps of 1.0 GWd/MTU. A set of criticality calculations was then performed, one based on the CASMO run with 2.5 GWd/MTU burnup steps, the other based on the CASMO run with 1.0 GWd/MTU burnup steps. Apart from the source of the isotopic composition of the fuel, both criticality models were identical. The case used for this comparison is the assembly class 17x17A in the MPC-32 at 4.0 % initial enrichment and 37.5 GWd/MTU assembly average burnup with BPRAs inserted. Due to the modeling of the axial burnup distribution in the fuel, this case requires 18 different isotopic compositions, at burnups between 16.4 GWd/MTU and 39.9 GWd/MTU. The results are listed in the following table. The difference is approximately two standard deviations which indicates that the two cases are statistically equivalent. Therefore, burnup steps of 2.5 GWd/MTU are acceptable and are used throughout the burnup credit evaluation.

Case	*Burnup Steps in CASMO runs*	*Calculated k_{eff} (MCNP)*	*Standard Deviation (MCNP)*	*Difference in Calculated k_{eff} to Case 1*
1	*2.5 GWd/MTU*	*0.9284*	*0.0005*	*n/a*
2	*1.0 GWd/MTU*	*0.9293*	*0.0004*	*0.0009*

Appendix 6.M

Best Estimate Isotopic Compositions

6.M.1 Purpose

Subsection 6.4.11.6 discusses the remaining safety margin of the criticality evaluation, and compares it with the reactivity effects of various uncertainties. This appendix provides additional information for these evaluations.

The following table contains a list of the results shown in Figure 6.4.19.

State Point	Average Burnup	k-calc	Standard Deviation	State Point	Average Burnup	k-calc	Standard Deviation
Davis Besse Unit 1							
sp40	2.9	1.0073	0.0007	sp43	11.6	0.9971	0.0006
sp41	10.1	1.0071	0.0006	sp44	13.1	0.9988	0.0006
sp42	10.0	0.9997	0.0007	sp45	16.2	1.0018	0.0006
Crystal River Unit 3							
sp13	12.0	1.0104	0.0006	sp24	16.6	1.004	0.0006
sp14	15.0	1.0147	0.0007	sp25	24.8	1.0115	0.0008
sp15	24.4	1.0199	0.0006	sp26	24.9	1.0119	0.0006
sp16	10.0	1.0088	0.0007	sp27	28.2	1.0092	0.0007
sp17	18.1	1.0066	0.0007	sp28	14.2	1.0042	0.0007
sp18	19.0	1.0114	0.0006	sp29	19.1	1.0064	0.0007
sp19	19.9	1.0086	0.0008	sp30	21.0	1.0039	0.0007
sp20	24.3	1.0166	0.0007	sp31	25.4	1.0122	0.0008
sp21	24.9	1.0138	0.0006	sp32	15.2	1.005	0.0006
sp22	12.3	1.0055	0.0007	sp33	32.9	1.0082	0.0007
sp23	15.3	1.004	0.0005				
McGuire Unit 1							
sp47	11.7	1.0027	0.0007	sp50	16.1	1.0017	0.0006
sp48	14.3	1.0033	0.0007	sp51	22.5	1.0043	0.0007
sp49	10.8	1.0023	0.0007				