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Title RANGE OF PARAMETERS FOR PWR SNF IN A 21 PWR WP

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PURPOSE AND SUMMARY OF RESULTS:

This calculation file uses the MCNP neutron transport code to determine the range of parameters (ROP) for Pressurized Water Reactor Spent Nuclear Fuel (PWR SNF) contained within a 21 PWR waste package (WP). Four base geometry patterns were considered in this work and included the following: intact fuel assemblies with intact WP internal components, intact fuel assemblies with degraded WP internal components, degraded fuel assemblies with intact WP internal components, and degraded fuel assemblies with degraded WP internal components. For the degraded fuel assemblies, the pitch of the fuel rods was varied such that the largest range of neutronics parameters could be obtained (i.e., average energy of neutrons causing fission (AENCF)). The calculations involved in this work span an initial U^{235} weight percent range of 2 to 5 wt%. The burnup values corresponding to k_{eff} values of 0.92 and 0.99 are found for each enrichment and geometry configuration. Results of this work will be used to support efforts of the Yucca Mountain Project (YMP) in predicting the range of various parameters for which the MCNP code must be benchmarked.

Tables 5-1 - 5-8 of this calculation report the results of the enrichment/burnup iteration calculations, including k_{eff}, AENCF, and fuel rod pitch to pellet diameter ratio. Considering only the configurations which yielded a k_{eff} of 0.99 or 0.92, the AENCF range over all cases was 0.17482 to 0.50332.

A brief discussion on the range of applicability is also given in this file, including initial U^{235} enrichment, AENCF values, fuel rod pitch to diameter ratios, and cladding and burnable absorber materials. Data is plotted for both the range of applicability and the range of parameters presented in this file.

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV
MCNP 4.B.2	

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

Record of Revision

Revision No.	Description	Release Date
00	Original Issue	September 2003

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1.0 PURPOSE

This calculation file uses the MCNP neutron transport code to determine the range of parameters (ROP) for Pressurized Water Reactor Spent Nuclear Fuel (PWR SNF) contained within a 21 PWR waste package (WP). Four base geometry patterns were considered in this work and included the following: intact fuel assemblies with intact WP internal components, intact fuel assemblies with degraded WP internal components, degraded fuel assemblies with intact WP internal components, and degraded fuel assemblies with degraded WP internal components. For the degraded fuel assemblies, the pitch of the fuel rods was varied such that the largest range of neutronics parameters could be obtained (i.e., average energy of neutrons causing fission (AENCF)). The calculations involved in this work span an initial U^{235} weight percent range of 2 to 5 wt%. The burnup values corresponding to k_{eff} values of 0.92 and 0.99 are found for each enrichment and geometry configuration. Results of this work will be used to support efforts of the Yucca Mountain Project (YMP) in predicting the range of various parameters for which the MCNP code must be benchmarked.

This report is an engineering calculation supporting the burnup credit methodology of YMP 2000 (Reference 1) and was performed under Framatome ANP Administrative Procedure 0402-01, Preparing and Processing FANP Calculations (Reference 2) and Framatome Quality Management Manual (Reference 3).

2.0 KEY ASSUMPTIONS

There are no assumptions made for the current calculation.

3.0 COMPUTER CODES

Calculations in this file are performed using the computer program MCNP4.B.2 (Reference 6) to calculate k_{eff} for a WP. MCNP4.B.2 has been certified according to Procedure 0902-06, Software Certification (Reference 4).

A listing of all relevant output files included in COLD is given in Section 7.0.

4.0 METHOD AND PROCEDURE

A base MCNP input file for the intact fuel assembly with intact WP internal components for the 21 PWR SNF WP was obtained from Reference 7 in 1/8th core geometry. This model was used for the intact fuel assembly with intact WP internal components. For ease of discussion, the following terms are used:

1) degraded assembly: Fuel rods only. Other assembly components are removed, including guide tubes, instrument tube, and spacer grids.
2) degraded WP: WP with degraded internal components. Namely, the basket absorber plates, fuel tubes and side/corner guides are removed.

For the intact assembly/degraded WP, the base MCNP was modified to remove the WP internal components. This was done by changing the materials for the WP fuel tubes, guides and basket plates to moderator. No geometry changes were necessary to account for the degradation of the WP internal components. For this model, three different fuel assembly pitches were used: minimum pitch (assemblies touching), nominal pitch (assemblies in same location as for intact assembly/intact WP), and maximum pitch (assemblies filling WP). For the intact WP, the distance between fuel cells 3 and 4 is 0.5 cm greater than the distance between fuel cells 4 and 5 due to the presence of the absorber plate between fuel cells 3 and 4. This 0.5 cm difference was kept for both the nominal and maximum pitch cases for the intact assembly/degraded WP configuration.

Figure 4-1 shows the geometry for the intact assembly/intact WP and for the intact assembly/degraded WP model for nominal pitch. Note that the geometry for these two configurations are the same. Differences due to the degradation of the WP are modeled with material specifications.

The degraded assembly/intact WP model is shown in Figure 4-2. As can be seen in this figure, the fuel rods were placed into a fixed hexagonal pitch in all directions. Due to the symmetry of this configuration, the base model was expanded to ½ WP geometry. To maintain the correct number of fuel rods within the degraded assembly, two inner spaces were filled with moderator. The inner spaces were chosen so that the system AENCF would be minimized and the range of available AENCF would be maximized. This configuration was modeled with maximum fuel rod pitch as well as with a fuel rod pitch of 1.31 cm. The 1.31 cm pitch is the pitch which corresponds to a k_{eff} of 0.92 for 5 wt% U^{235} at a burnup of 0.001 GWd/MTU. This is the minimum pitch that could be achieved over all enrichments while still providing the desired k_{eff} value.

For the degraded assembly/degraded WP, the base MCNP model was modified to remove the WP internal components as well as the assembly structures. All 4368 fuel rods were then placed into a hexagonal pitch. To account for proper symmetry, the core model was expanded to ¼ geometry (1092 fuel rods in ¼ WP). For the degraded assembly/degraded WP, three fuel rod pitches were considered: (1) maximum pitch (fuel rods filling up inside of WP), (2) pitch corresponding to a k_{eff} of 0.99 for 5 wt% U^{235} (burnup = 0.01 GWd/MTU), and (3) pitch corresponding to a k_{eff} of 0.92 for 5 wt% U^{235} (burnup = 0.01 GWd/MTU). These last two pitches represent the minimum pitches that could be achieved over all enrichments while still providing the desired k_{eff} values. The degraded assembly/degraded WP model with maximum pitch is shown in Figure 4-3.

For each geometry configuration, the fuel material (material # 6013) was modified to correspond to the desired enrichment and burnup. Several iterations of fuel material were completed to find the burnup value that resulted in a k_{eff} value of 0.99 or 0.92 for each enrichment. The desired values of k_{eff} were based on the critical limit derived in Reference 8. To ensure that all potentially critical configurations are captured, the critical limit was enveloped with the band of 0.92 and 0.99. All material specifications were taken from Reference 7.

Burnup values were varied in 0.5 GWd/MTU increments. For each MCNP run, the k_{eff} value was compared to the desired value of 0.92 or 0.99. The final burnup/enrichment pairs were chosen by having a k_{eff} value within two standard deviations (s.d.) of the desired k_{eff}. If the calculated k_{eff} value was outside of the 2 s.d. rule-of-thumb, then the burnup would be increased or decreased by 0.5 GWd/MTU. If the burnup was changed and the calculated k_{eff} value was outside of 2 s.d. on the opposite side of the desired k_{eff}, then the value that was just outside the desired band (lower than 0.92 or greater than 0.99) was used.

For this work, the burnup range was limited to near fresh fuel (~0.001 GWd/MTU) to 75 GWd/MTU.

The AENCF for each case was taken from the MCNP output by dividing the loss to fission energy by the weight.

Tally cards were used in the MCNP models to track the fluence and fission rates in the fuel pins. Volumes were input on the SD cards and are based on the surfaces found in the MCNP model. The volume of each fuel rod = $\pi*0.47879^2*360.172 = 259.39$ cm^3. For a full fuel assembly, the volume was 259.39 cm^3/fuel rod * 208 fuel rods = 53952.71 cm^3. For 1/8-assembly and ½-assembly symmetries, the fuel volumes were 6744.09 cm^3 and 26976.36 cm^3, respectively.

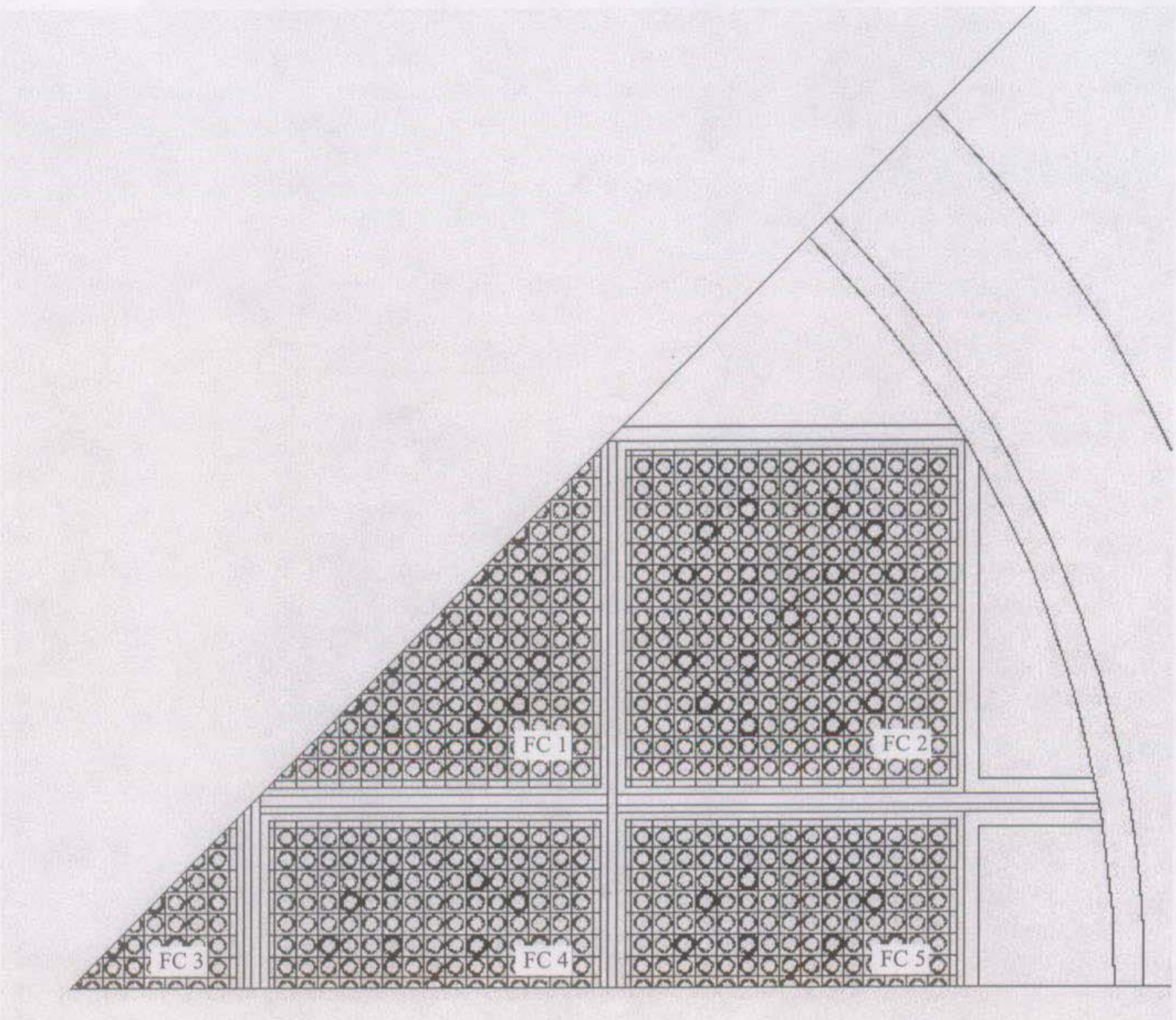

Figure 4-1. Geometry for the Intact Assemblies/Intact WP and for the Intact Assemblies/Degraded WP with Nominal Assembly Pitch (FC = fuel cell).

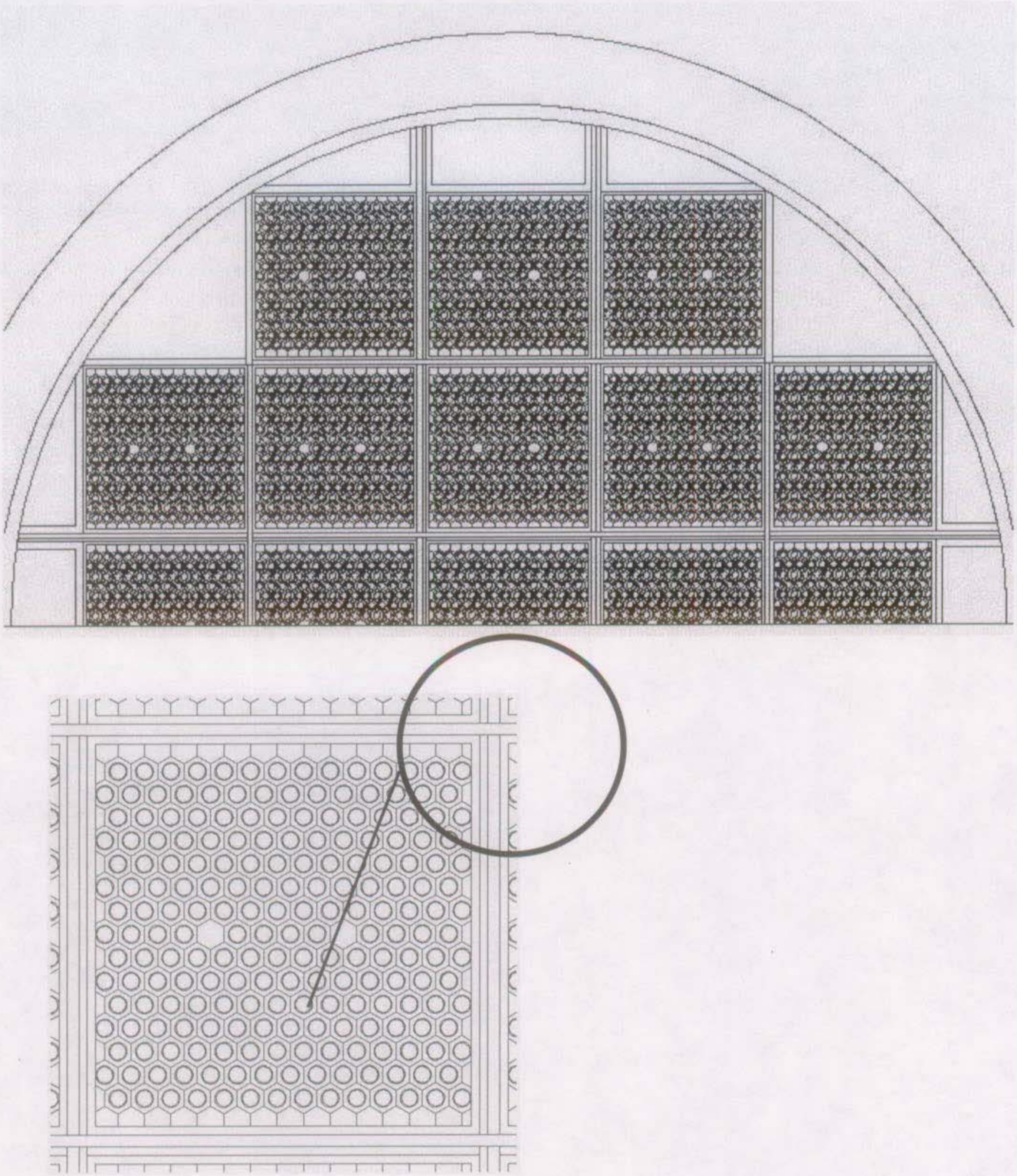

Figure 4-2. Degraded Assemblies/Intact WP with Maximum Fuel Rod Pitch.

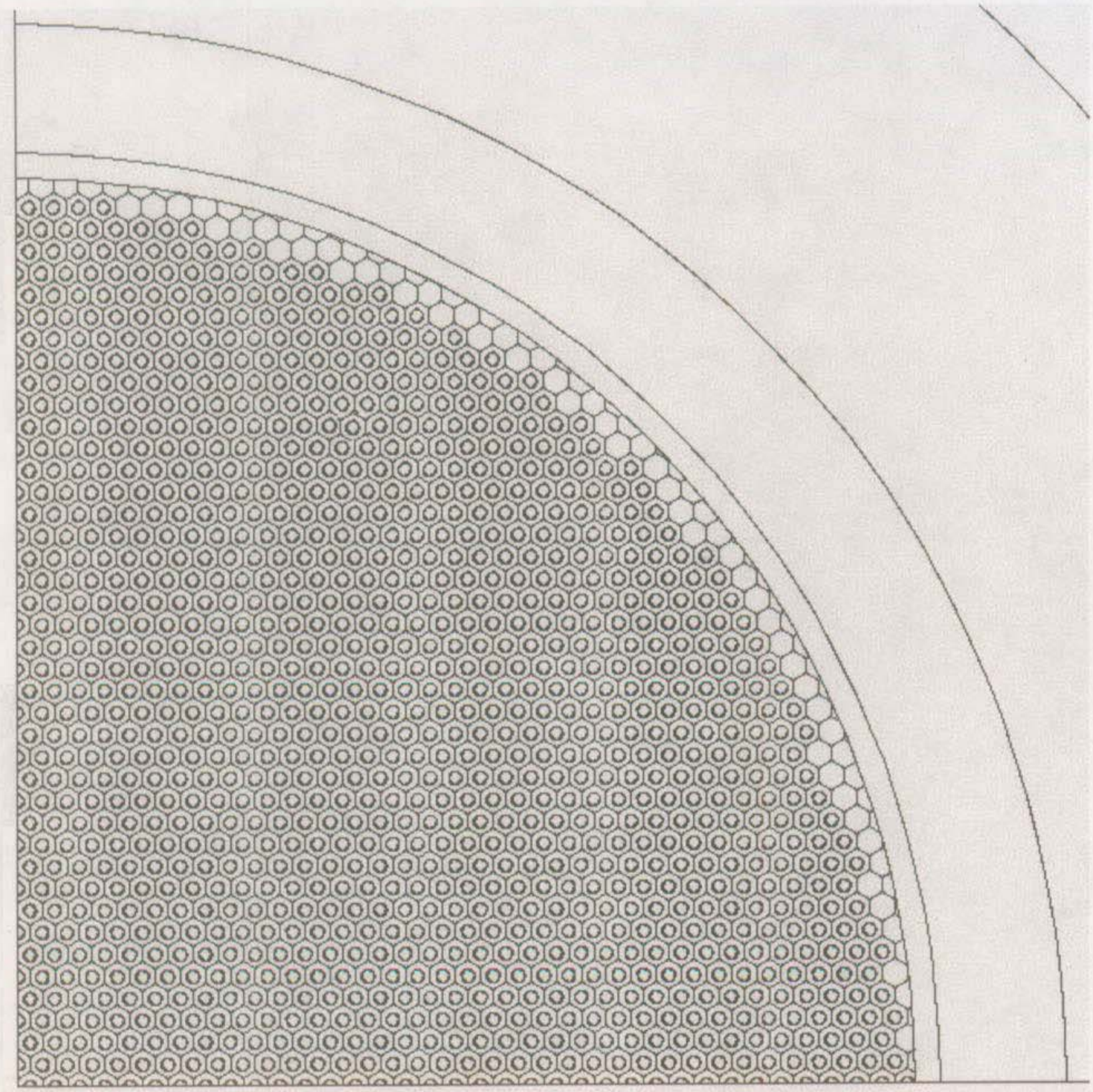

Figure 4-3. Degraded Assemblies/Degraded WP with Maximum Fuel Rod Pitch.

5.0 RESULTS AND DISCUSSION

5-1 Results of ROP

For each configuration discussed in Section 4.0, the enrichment/burnup pairs corresponding to k_{eff} of 0.92 and 0.99 were found.

For each MCNP run, at least 2 million active neutron histories were used. This ensured that the k_{eff} value converged and that the 10 statistical checks for tallies were passed. In some cases, one or two tally bins had large relative errors. However, since the values for these bins were small and should not significantly effect the overall result, the tally results are considered acceptable. Note that the tallies are given for possible future application and are not necessary as part of this work. Since the k_{eff} and AENCF values are taken from the typical MCNP output, no values from the tallies are reported.

Tables 5-1 through 5-6 report the results of the enrichment/burnup iteration calculations, including k_{eff} and AENCF. The fuel rod pitch to pellet diameter ratio (P/D) is also reported in the table titles for each configuration. The P/D values range between 1.18 and 2.08.

For two cases (intact assembly/intact WP (nominal pitch) and degraded assembly/intact WP (maximum pich), the reactivity of the 2 wt% U^{235} fuel was such that a k_{eff} of 0.99 could not be achieved even at very low burnup values. For these two cases, the highest k_{eff} value that was calculated is reported in the tables.

For the degraded assembly/degraded WP, maximum pitch configuration, the reactivity of the 5 wt% fuel was such that the lowest k_{eff} value that could be found at the upper end of the burnup range (75 GWd/MTU) was 1.00440. This value is above the upper range of the desired k_{eff} of 0.99. In addition, the lowest calculated k_{eff} value for several configurations was greater than the lower range of the desired k_{eff} of 0.92. These cases included the following configurations at 75 GWd/MTU: degraded assembly/intact WP, maximum pitch, 3 wt% (0.92985) and 4 wt% (0.96115), and intact assembly/degraded WP, minimum pitch, 5 wt% (0.93315) and nominal pitch, 5 wt% (0.93414 at 74 GWd/MTU).

Results for enrichment / burnup pairs for each configuration yielding a k_{eff} of 0.92 and 0.99 are plotted in Figures 5-1 through 5-6. All plots use the same burnup range for ease of comparison.

Table 5-1. Results for Intact Fuel Assemblies/Intact WP Internals, nominal fuel assembly pitch (P/D = 1.51)

Enrichment (wt% U^{235})	Burnup (GWd/MTU)	K_{eff}	Standard Deviation	AENCF (MeV)
2	1.0	0.93545	0.00046	0.19680
2	4.5	0.91908	0.00049	0.20992
3	8.0	0.98927	0.00046	0.19839
3	19.0	0.91809	0.00044	0.22312
4	18.0	0.98999	0.00052	0.20404
4	30.0	0.91994	0.00049	0.22583
5	27.0	0.98954	0.00053	0.20765
5	40.5	0.91993	0.00049	0.22912

Table 5-2. Results for Intact Fuel Assemblies/Degraded WP Internals, maximum fuel assembly pitch (P/D = 1.51)

Enrichment (wt% U^{235})	Burnup (GWd/MTU)	K_{eff}	Standard Deviation	AENCF (MeV)
2	18.5	0.98942	0.00036	0.19713
2	32.0	0.91875	0.00041	0.22036
3	32.5	0.99018	0.00041	0.19999
3	47.0	0.92019	0.00039	0.22264
4	45.0	0.98984	0.00045	0.20148
4	60.5	0.91992	0.00039	0.22275
5	56.0	0.99070	0.00043	0.20244
5	72.5	0.92053	0.00045	0.22371

Table 5-3. Results for Intact Fuel Assemblies/Degraded WP Internals, minimum fuel assembly pitch (P/D = 1.51)

Enrichment (wt% U^{235})	Burnup (GWd/MTU)	K_{eff}	Standard Deviation	AENCF (MeV)
2	26.5	0.99091	0.00042	0.24935
2	43.0	0.92067	0.00044	0.27678
3	39.0	0.99243	0.00037	0.25010
3	56.0	0.92080	0.00043	0.27763
4	51.0	0.99000	0.00045	0.25282
4	68.0	0.92012	0.00042	0.27860
5	61.0	0.99047	0.00042	0.25266
5	75.0	0.93315	0.00044	0.27328

Table 5-4. Results for Intact Fuel Assemblies/Degraded WP Internals, nominal fuel assembly pitch (P/D = 1.51)

Enrichment (wt% U^{235})	Burnup (GWd/MTU)	K_{eff}	Standard Deviation	AENCF (MeV)
2	22.5	0.99056	0.00034	0.20546
2	37.5	0.92059	0.00039	0.22914
3 [a]	37.0	0.98917	0.00041	0.20813
3	52.5	0.91971	0.00041	0.22997
4	49.0	0.99144	0.00044	0.20980
4	66.0	0.92043	0.00038	0.23047
5	60.5	0.99143	0.00042	0.20949
5	74.0	0.93414	0.00042	0.22636

[a] The k_{eff} value + 2 standard deviations for this case was 0.98999. Since the value is only 0.00001 from the desired k_{eff} value of 0.99, it is considered acceptable for this work.

Table 5-5. Results for Degraded Fuel Assemblies/Intact WP Internals, maximum fuel rod pitch (P/D = 1.66)

Enrichment (wt% U^{235})	Burnup (GWd/MTU)	K_{eff}	Standard Deviation	AENCF (MeV)
2	0.001	0.93942	0.00047	0.19394
2	4.0	0.92042	0.00043	0.20996
3	7.0	0.99304	0.00047	0.19700
3	18.5	0.91840	0.00042	0.22472
4	17.0	0.99167	0.00052	0.20432
4	29.5	0.91812	0.00050	0.22751
5	26.0	0.99177	0.00051	0.20778
5	39.5	0.92039	0.00048	0.22997

Table 5-6. Results for Degraded Fuel Assemblies/Degraded WP Internals, maximum fuel rod pitch (P/D = 2.08)

Enrichment (wt% U^{235})	Burnup (GWd/MTU)	K_{eff}	Standard Deviation	AENCF (MeV)
2	36.0	0.99065	0.00036	0.17482
2	67.5	0.92035	0.00034	0.19341
3	52.0	0.99039	0.00037	0.17571
3	75.0	0.92985	0.00039	0.19194
4	66.0	0.99060	0.00041	0.17704
4	75.0	0.96115	0.00039	0.18366
5	75.0	1.00440	0.00043	0.17446

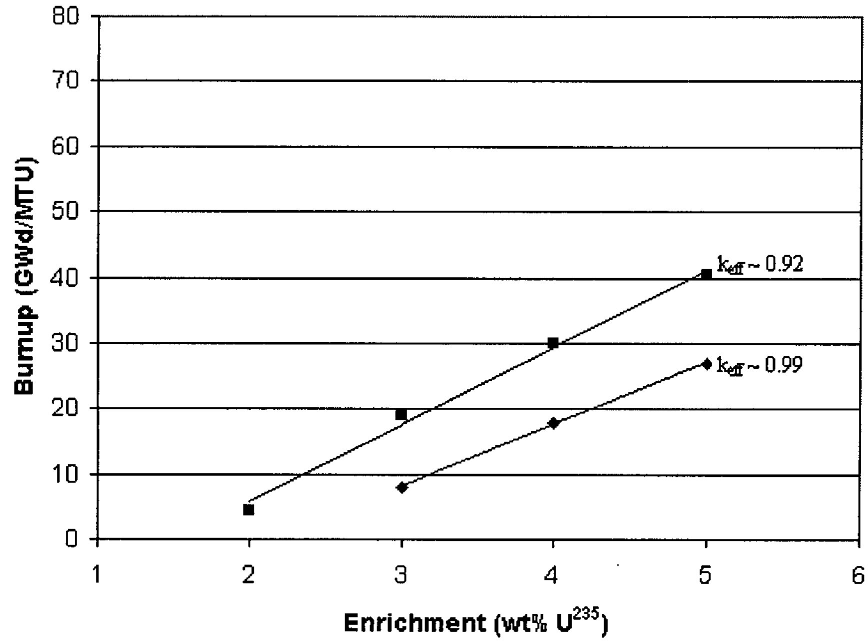

Figure 5-1. Results for Intact Fuel Assemblies/Intact WP Internals, nominal fuel assembly pitch (P/D = 1.51).

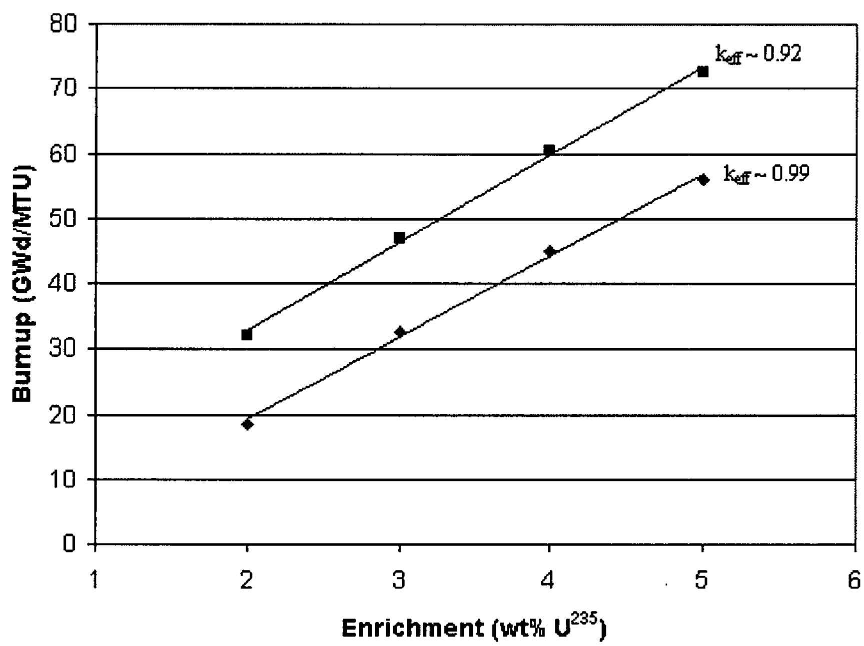

Figure 5-2. Results for Intact Fuel Assemblies/Degraded WP Internals, maximum fuel assembly pitch (P/D = 1.51).

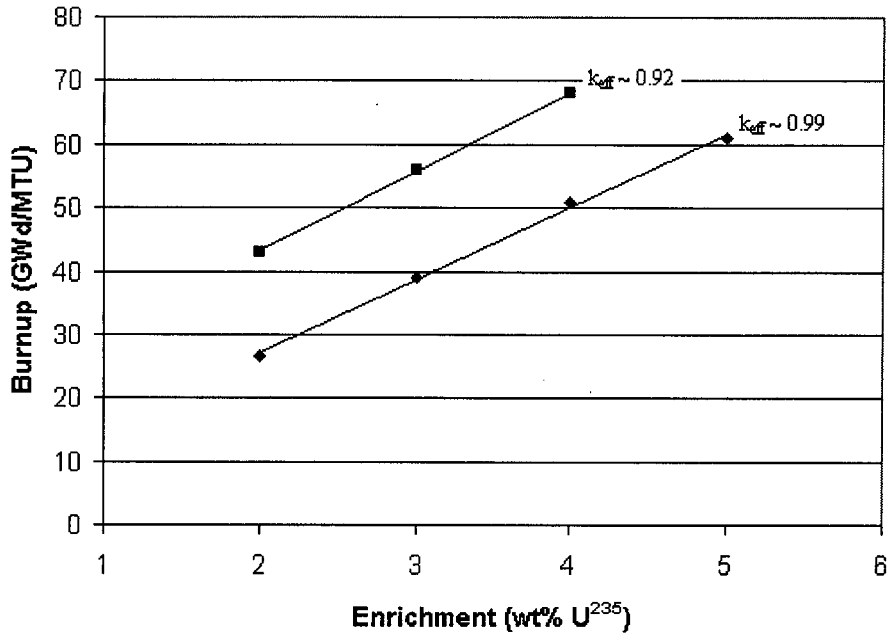

Figure 5-3. Results for Intact Fuel Assemblies/Degraded WP Internals, minimum fuel assembly pitch (P/D = 1.51).

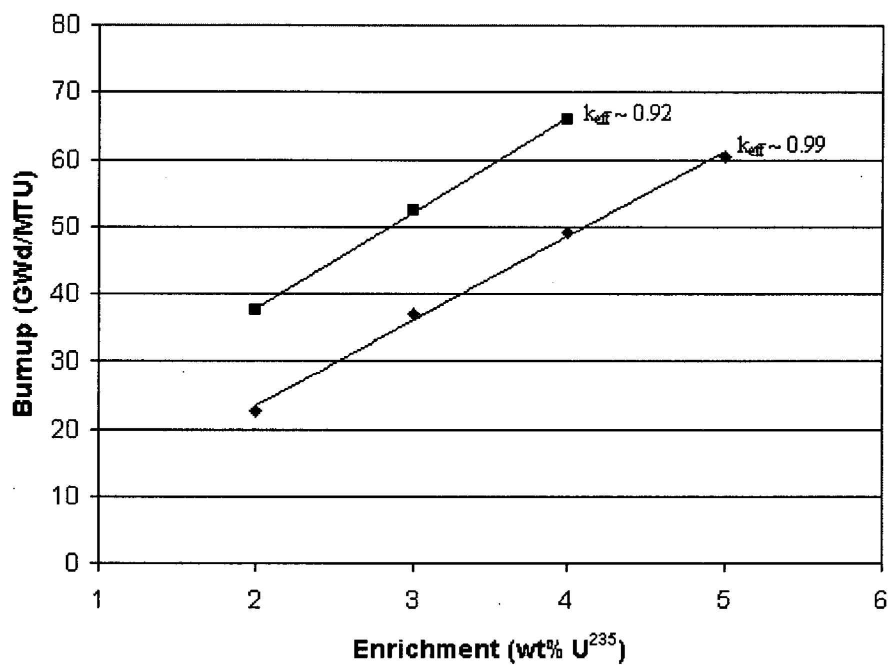

Figure 5-4. Results for Intact Fuel Assemblies/Degraded WP Internals, nominal fuel assembly pitch (P/D = 1.51).

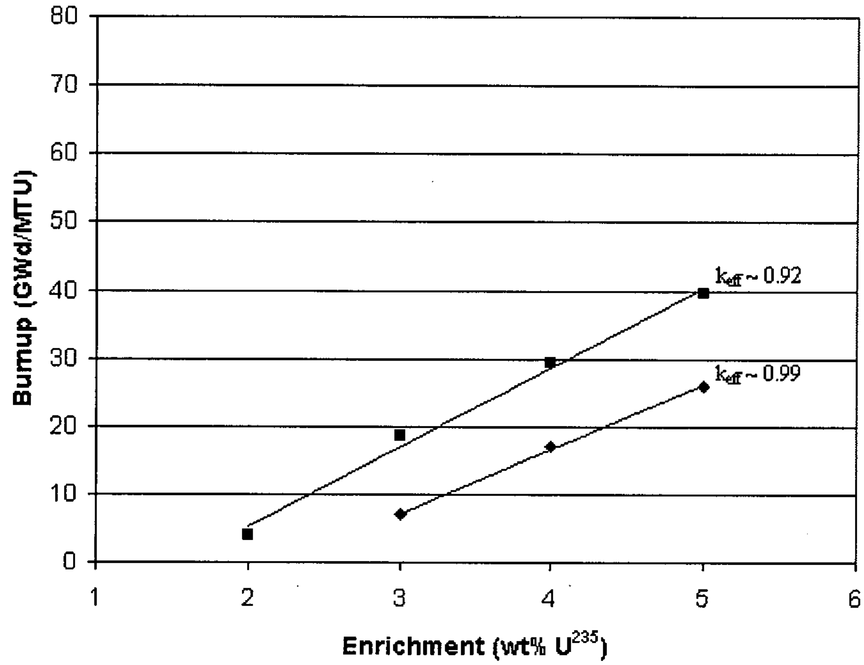

Figure 5-5. Results for Degraded Fuel Assemblies/Intact WP Internals, maximum fuel rod pitch (P/D = 1.66).

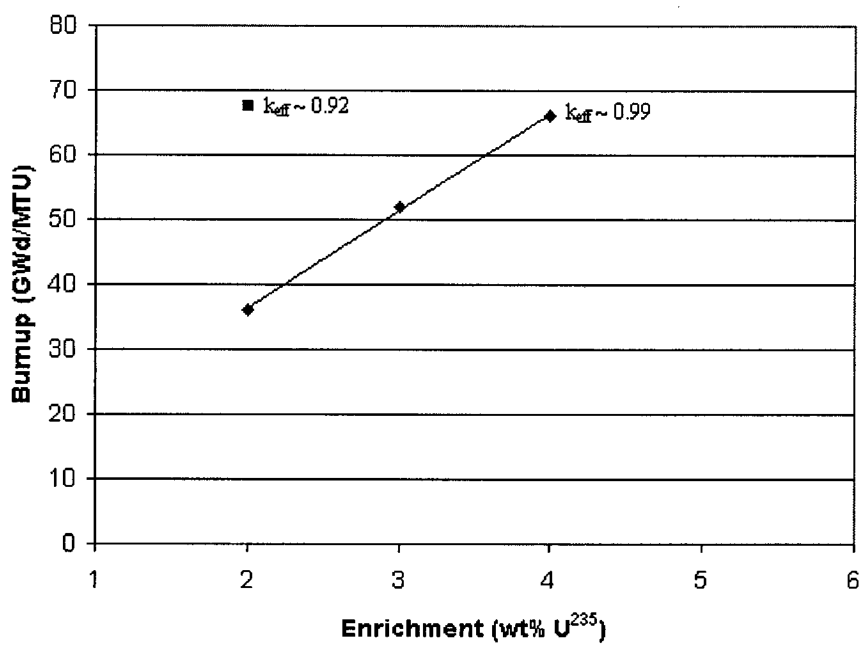

Figure 5-6. Results for Degraded Fuel Assemblies/Degraded WP Internals, maximum fuel rod pitch (P/D = 2.08).

To maximize the range of parameters available in the four basic configurations, different pitch sizes were used, varying from minimum values (rods or assemblies as close as possible) to maximum values (rods or assembly spacing limited by WP inner radius). For the minimum fuel rod pitch cases (degraded assembly/intact WP and degraded assembly/degraded WP), the reactivity of the configurations was not great enough to yield a k_{eff} value of 0.92 using the highest enrichment of 5 wt% at small burnups. Therefore, the pitch was increased until the configuration with the 5 wt% fuel had a k_{eff} value of 0.92. For the degraded assembly/degraded WP, the pitch was further increased to yield a k_{eff} value of 0.99. The results of the pitch iteration calculations are shown in Tables 5-7 and 5-8.

Table 5-7. Results for Degraded Fuel Assemblies/Intact WP Internals, Burnup = 0.001 GWd/MTU

Enrichment (wt% U^{235})	Pitch (cm)	K_{eff}	Standard Deviation	AENCF (MeV)	P/D
5	1.31	0.92096	0.00056	0.24553	1.37

Table 5-8. Results for Degraded Fuel Assemblies/Degraded WP Internals, Burnup = 0.01 GWd/MTU

Enrichment (wt% U^{235})	Pitch (cm)	K_{eff}	Standard Deviation	AENCF (MeV)	P/D
5	1.127	0.91993	0.00068	0.50332	1.18
5	1.161	0.99086	0.00046	0.43829	1.21

Considering only the configurations which yielded a k_{eff} of 0.99 or 0.92, the AENCF range over all cases was 0.17482 (degraded assembly/degraded WP, maximum spacing, 2 wt% fuel, k_{eff} = 0.99065) to 0.50332 (degraded assembly/degraded WP, pitch = 1.127 cm, 5 wt% fuel, k_{eff} = 0.91993). Figure 5-7 shows the AENCF values for all configurations.

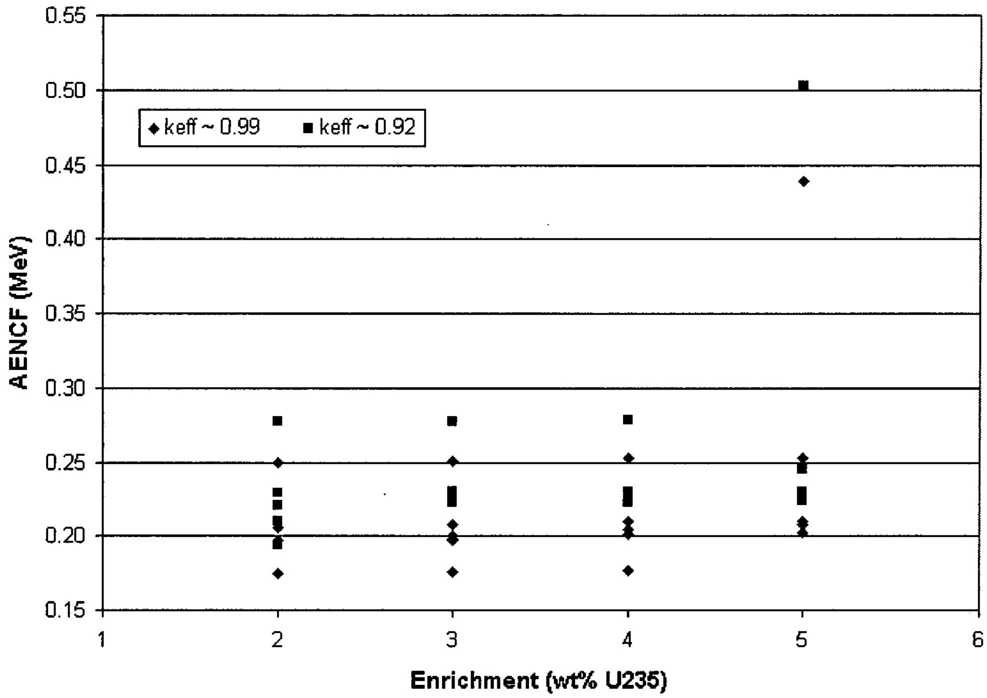

Figure 5-7. AENCF vs. Enrichment for All Configurations.

5-2 Discussion of ROA

Data from laboratory critical experiments (LCE) and from commercial reactor criticals (CRC) are taken from Tables 1 and 2 of Reference 8, including initial U^{235} enrichment, AENCF values, and fuel rod pitch to diameter ratios. These data provide the Range of Applicability (ROA) for the critical limit (CL) developed in Reference 8.

While the ROP calculated in Section 5.1 gives an indication of the conditions likely to be seen in a WP at YMP, the ROA refers to the data for which the CL was established. The ROA was based on LCE and CRC data that is available for benchmarking the MCNP code. Comparison between the ROP and ROA shows what additional data is needed for a complete benchmark effort.

The LCE and CRC data are plotted in Figures 5-8 through 5-10. The ranges for each parameter are listed in Table 5-9. Figure 5-11 plots the data found in Section 5.1 (Figure 5-7) along with the range of AENCF for the LCE and CRC data. For this figure, the lowest and highest AENCF values for LCE or CRC data is applied over all enrichments.

Table 5-9. Range of Neutronics Parameters for LCE and CRC Data

	Enrichment (wt% U^{235})	AENCF (MeV)	P/D
LCE	2.350 – 6.704	0.0796 – 0.3776	1.26 – 3.08
CRC	2.445 – 4.015	0.2344 – 0.2660	1.53

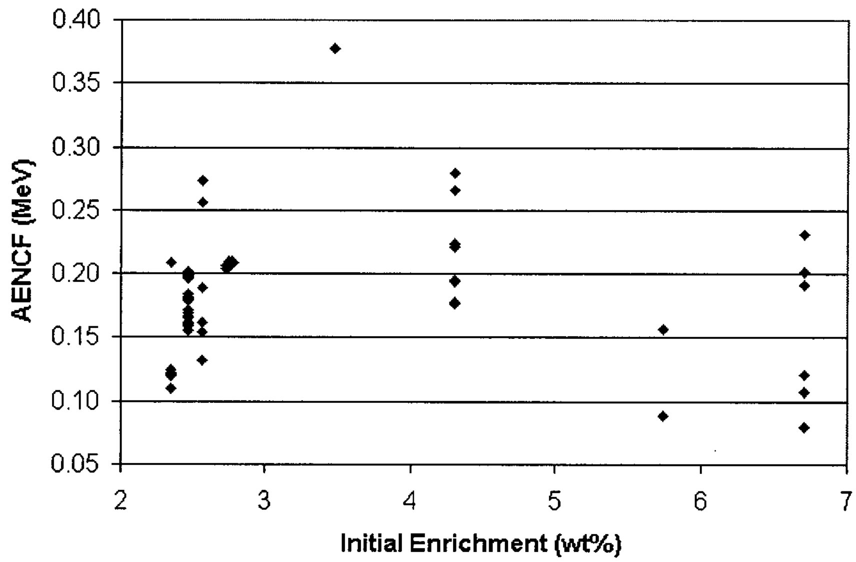

Figure 5-8. Enrichment vs. AENCF for LCE Data.

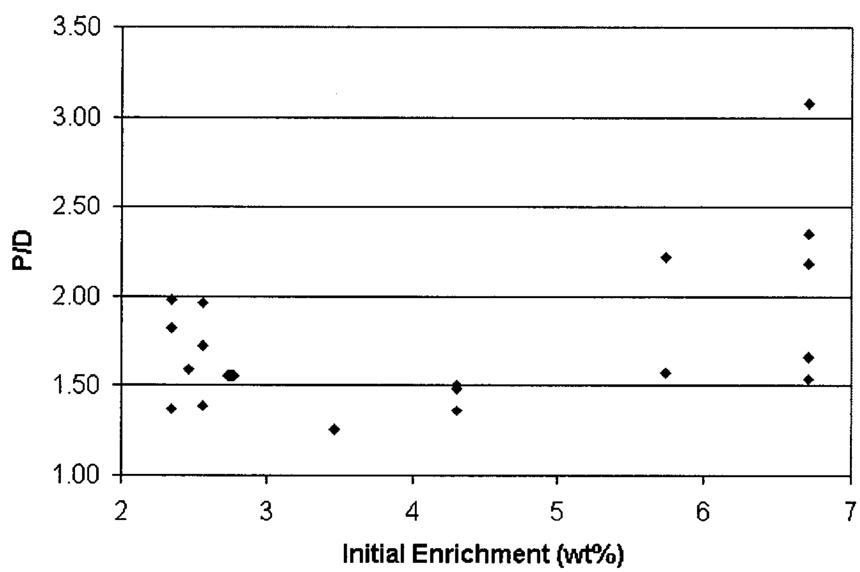

Figure 5-9. Enrichment vs. P/D for LCE Data.

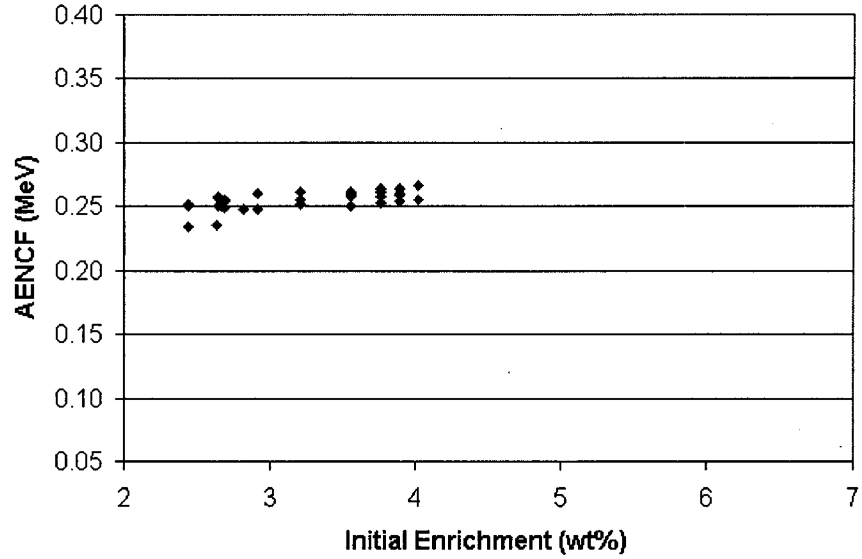

Figure 5-10. Enrichment vs. AENCF for CRC Data.

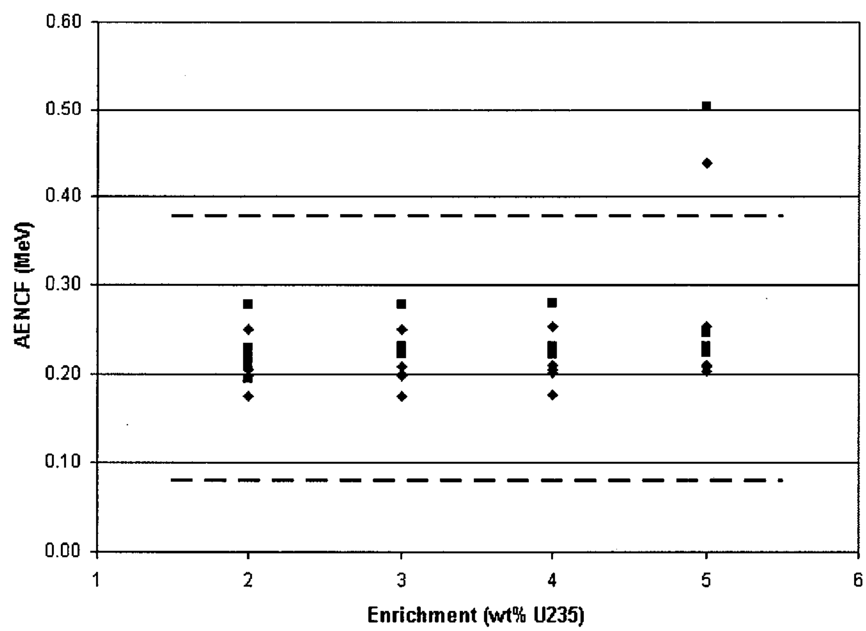

Figure 5-11. AENCF vs. Enrichment for All WP Configurations with AENCF Range for LCE & CRC Data.

In addition to the parameters described above (i.e., enrichment, AENCF, and P/D), cladding material, as well as type of burnable absorbers should be considered when applying the ROA. Cladding materials that have been used in PWR fuel are stainless steel, aluminum, and zircaloy (i.e., Zirc-4 and Zirlo). Burnable absorbers used in PWR applications include discrete burnable absorber rods using boron as B_4C and integral burnable absorbers using gadolinium as UO_2-Gd_2O_3 and erbium as UO_2-Er_2O_3.

Data which includes the use of the above materials is desired to achieve the broadest ROA possible. The LCE and CRC data discussed in this analysis cover all cladding materials and the burnable absorber material boron. For gadolinium, only data using fresh fuel is available. No data using erbium has been obtained for use in creating a CL or ROA. Therefore, to further extend the ROA, additional data using gadolinium in burned fuel and data using erbium as a burnable absorber are needed.

6.0 REFERENCES

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7. Framatome ANP Doc 38-5034166-00, September 2003: BSC (Bechtel SAIC Company) 2003, *Isotopic Generation and Confirmation of the PWR Application Model*, Bechtel Doc. # CAL-DSU-NU-000004 REV 00A. Las Vegas, Nevada; Bechtel SAIC Company.

8. 32-5029773-00, Critical Limit Development for 21 PWR Waste Package.

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13. Comments

Listing of files for CD Attachment contained on page 25 and 26.

THIS DOCUMENT
CONTAINS AN
ELECTRONIC ATTACHMENT

7.0 COMPUTER OUTPUT

Table 7-1 lists the MCNP output files associated with this calculation and located on COLD.

Table 7-1. List of MCNP Output Files on COLD.

Name	Date / Time	Description
Intact Fuel Assemblies/Intact WP Internals, nominal fuel assembly pitch		
e20b010.out	Aug 06 2003 17:04:36	Enrichment = 2 wt% U^{235}; Burnup = 1.0 GWd/MTU
e20b045.out	Jul 10 2003 23:02:12	Enrichment = 2 wt% U^{235}; Burnup = 4.5 GWd/MTU
e30b080.out	Jul 10 2003 22:58:25	Enrichment = 3 wt% U^{235}; Burnup = 8.0 GWd/MTU
e30b190.out	Aug 13 2003 15:15:46	Enrichment = 3 wt% U^{235}; Burnup = 19.5 GWd/MTU
e40b180.out	Jul 15 2003 20:27:53	Enrichment = 4 wt% U^{235}; Burnup = 18.0 GWd/MTU
e40b300.out	Jul 11 2003 00:37:04	Enrichment = 4 wt% U^{235}; Burnup = 30.0 GWd/MTU
e50b270.out	Jul 11 2003 00:06:33	Enrichment = 5 wt% U^{235}; Burnup = 27.0 GWd/MTU
e50b405.out	Jul 15 2003 20:03:35	Enrichment = 5 wt% U^{235}; Burnup = 40.5 GWd/MTU
Intact Fuel Assemblies/Degraded WP Internals, maximum fuel assembly pitch		
e20b185b.out	Aug 12 2003 10:35:38	Enrichment = 2 wt% U^{235}; Burnup = 18.5 GWd/MTU
e20b320b.out	Aug 14 2003 14:08:57	Enrichment = 2 wt% U^{235}; Burnup = 32.0 GWd/MTU
e30b325b.out	Aug 06 2003 17:56:19	Enrichment = 3 wt% U^{235}; Burnup = 32.5 GWd/MTU
e30b470b.out	Jul 17 2003 11:23:10	Enrichment = 3 wt% U^{235}; Burnup = 47.0 GWd/MTU
e40b450b.out	Jul 15 2003 21:26:14	Enrichment = 4 wt% U^{235}; Burnup = 45.0 GWd/MTU
e40b605b.out	Aug 06 2003 17:51:13	Enrichment = 4 wt% U^{235}; Burnup = 60.5 GWd/MTU
e50b560b.out	Jul 10 2003 19:34:40	Enrichment = 5 wt% U^{235}; Burnup = 56.0 GWd/MTU
e50b725b.out	Jul 15 2003 17:23:45	Enrichment = 5 wt% U^{235}; Burnup = 72.5 GWd/MTU
Intact Fuel Assemblies/Degraded WP Internals, minimum fuel assembly pitch		
e20b265c.out	Jul 10 2003 18:47:16	Enrichment = 2 wt% U^{235}; Burnup = 26.5 GWd/MTU
e20b430c.out	Jul 10 2003 18:26:19	Enrichment = 2 wt% U^{235}; Burnup = 43.0 GWd/MTU
e30b390c.out	Aug 14 2003 16:28:36	Enrichment = 3 wt% U^{235}; Burnup = 39.0 GWd/MTU
e30b560c.out	Jul 15 2003 14:17:10	Enrichment = 3 wt% U^{235}; Burnup = 56.0 GWd/MTU
e40b510c.out	Jul 15 2003 14:51:38	Enrichment = 4 wt% U^{235}; Burnup = 51.0 GWd/MTU
e40b680c.out	Jul 10 2003 20:43:41	Enrichment = 4 wt% U^{235}; Burnup = 68.0 GWd/MTU
e50b610c.out	Jul 10 2003 20:50:49	Enrichment = 5 wt% U^{235}; Burnup = 61.0 GWd/MTU
e50b750c.out	Jul 10 2003 20:53:41	Enrichment = 5 wt% U^{235}; Burnup = 75.0 GWd/MTU
Intact Fuel Assemblies/Degraded WP Internals, nominal fuel assembley pitch		
e20b225a.out	Aug 14 2003 17:49:12	Enrichment = 2 wt% U^{235}; Burnup = 22.5 GWd/MTU
e20b375a.out	Jul 15 2003 17:10:26	Enrichment = 2 wt% U^{235}; Burnup = 37.5 GWd/MTU
e30b370a.out	Jul 17 2003 11:51:41	Enrichment = 3 wt% U^{235}; Burnup = 37.0 GWd/MTU
e30b525a.out	Jul 10 2003 22:10:07	Enrichment = 3 wt% U^{235}; Burnup = 52.5 GWd/MTU
e40b490a.out	Jul 10 2003 21:21:12	Enrichment = 4 wt% U^{235}; Burnup = 49.0 GWd/MTU
e40b660a.out	Aug 13 2003 14:53:51	Enrichment = 4 wt% U^{235}; Burnup = 66.0 GWd/MTU
e50b605a.out	Jul 17 2003 11:19:35	Enrichment = 5 wt% U^{235}; Burnup = 60.5 GWd/MTU
e50b740a.out	Jul 10 2003 22:47:09	Enrichment = 5 wt% U^{235}; Burnup = 74.0 GWd/MTU

Name	Date / Time	Description
Degraded Fuel Assemblies/Intact WP Internals, maximum fuel rod pitch		
e20b00fm.out	Aug 06 2003 17:24:09	Enrichment = 2 wt% U^{235}; Burnup = 0.001 GWd/MTU
e20b040m.out	Aug 14 2003 13:26:14	Enrichment = 2 wt% U^{235}; Burnup = 4.0 GWd/MTU
e30b070m.out	Aug 14 2003 13:02:47	Enrichment = 3 wt% U^{235}; Burnup = 7.0 GWd/MTU
e30b185m.out	Aug 19 2003 11:21:28	Enrichment = 3 wt% U^{235}; Burnup = 18.5 GWd/MTU
e40b170m.out	Jul 23 2003 10:32:58	Enrichment = 4 wt% U^{235}; Burnup = 17.0 GWd/MTU
e40b295m.out	Jul 23 2003 13:17:13	Enrichment = 4 wt% U^{235}; Burnup = 29.5 GWd/MTU
e50b260m.out	Aug 07 2003 15:11:42	Enrichment = 5 wt% U^{235}; Burnup = 26.0 GWd/MTU
e50b395m.out	Jul 23 2003 12:56:26	Enrichment = 5 wt% U^{235}; Burnup = 39.5 GWd/MTU
Degraded Fuel Assemblies/Intact WP Internals, Burnup = 0.001 GWd/MTU		
e5bf-p131.out	Jul 23 2003 12:20:06	Enrichment = 5 wt% U^{235}; Pitch = 1.31 cm, $k_{eff} \sim 0.92$
Degraded Fuel Assemblies/Degraded WP Internals, maximum fuel rod pitch		
e20b360g.out	Jul 17 2003 16:07:14	Enrichment = 2 wt% U^{235}; Burnup = 36.0 GWd/MTU
e20b675g.out	Aug 13 2003 15:17:53	Enrichment = 2 wt% U^{235}; Burnup = 67.5 GWd/MTU
e30b520g.out	Jul 17 2003 13:10:18	Enrichment = 3 wt% U^{235}; Burnup = 52.0 GWd/MTU
e30b750g.out	Jul 17 2003 13:17:30	Enrichment = 3 wt% U^{235}; Burnup = 75.0 GWd/MTU
e40b660g.out	Jul 17 2003 12:37:48	Enrichment = 4 wt% U^{235}; Burnup = 66.0 GWd/MTU
e40b750g.out	Jul 17 2003 13:46:03	Enrichment = 4 wt% U^{235}; Burnup = 75.0 GWd/MTU
e50b750g.out	Jul 17 2003 13:49:53	Enrichment = 5 wt% U^{235}; Burnup = 75.0 GWd/MTU
Degraded Fuel Assemblies/Degraded WP Internals, Burnup = 0.01 GWd/MTU		
e5bfp127.out	Jul 17 2003 17:33:43	Enrichment = 5 wt% U^{235}; Pitch = 1.127 cm, $k_{eff} \sim 0.92$
e5bfp161.out	Jul 24 2003 15:32:03	Enrichment = 5 wt% U^{235}; Pitch = 1.161 cm, $k_{eff} \sim 0.99$