BSC

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DISCLAIMER

The calculations contained in this document were developed by Bechtel SAIC Company, LLC (BSC) and are intended solely for the use of BSC in its work for the Yucca Mountain Project.

CONTENTS

TABLES

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ACRONYMS AND ABBREVIATIONS

Acronyms

ATR	Advanced Test Reactor
BSC	Bechtel SAIC Company, LLC
CD	Compact Disc
DOE	Department of Energy
EF	Enrico Fermi
FFTF	Fast Flux Test Facility
FSV	Fort St. Vrain
MCNP	Monte Carlo N-Particle
SNF	Spent Nuclear Fuel
SLWBR	Shippingport Light Water Breeder Reactor
SPWR	Shippingport Pressurized Water Reactor
TRIGA	Training, Research, Isotope, General Atomics
USL	Upper Subcritical Limit

Abbreviations

k_{eff}	effective neutron multiplication factor
Δk_{EROA}	penalty on the USL to account for extension of the range of applicability
ZAID	MCNP nuclear data library identifier

1. PURPOSE

The purpose of this calculation is to establish the relative change in the effective neutron multiplication factor (k_{eff}) due to the use of MCNP unique identifiers (ZAIDs) in *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Attachment 3, *MCNP inputs.zip*) that are different to the ZAIDs used in the *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Table 5-3). This calculation determines the penalty (Δk_{EROA}), if any, on the applicability of the validation documented in *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Section 6.3) to the selected preclosure configurations described in Section 1.1, which have, in some instances, used different ZAIDs.

The MCNP ZAIDs refer to a specific nuclear data library of an element or isotope. The ZAID labels are based on the atomic number (Z), mass number (A), and data library specifier of the element or isotope of interest. Differences between the ZAIDs modeled in *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Attachment 3, *MCNP inputs.zip*) and those modeled in the *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Table 5-3) exist because of isotopic representation as opposed to elemental representation. Additional differences exist due to the use of different nuclear data libraries.

1.1 SCOPE

The scope of this calculation is limited to eleven Department of Energy (DOE) Spent Nuclear Fuel (SNF) MCNP models documented in *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Attachment 3, *MCNP inputs.zip*). The eleven MCNP models are modified to update the MCNP ZAIDs consistent with the ZAIDs used in the *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Table 5-3). The models selected encompass each of the DOE SNF canisters examined in *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Section 1.1.1). The eleven models selected generally represent configurations that are most limiting, in terms of producing the greatest subcritical k_{eff}. The eleven models are summarized in Table 1-1. All eleven models include a 30 cm thick stainless steel reflector, which is anticipated to amplify any relative change in k_{eff} on account of the typical isotopic representation of iron in the DOE SNF canister MCNP models (*Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF,* Reference 2.2.1, Attachment 3, *MCNP inputs.zip*), compared with its elemental treatment in the *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Table 5-3).

Table 1-1: DOE SNF Canister MCNP Models Examined

MCNP Model from *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Attachment 3, *MCNP inputs.zip*)	**Description of MCNP Model**
fermi_single_can_acc_dry_reflectors_92_in	A hypothetical damaged canister configuration consisting of a rearrangement of the Enrico Fermi SNF, the surrounding -01 and -04 fuel canisters, and the canister basket structure, to create a highly packed configuration of SNF. The k_{eff}, including calculational uncertainty, for this configuration is 0.65657 (Reference 2.2.1, Figure 7-19).
fftf_single_can_acc_dry_reflectors_92_in	A hypothetical damaged canister configuration consisting of a rearrangement of the FFTF SNF and the canister basket structure, to create a highly packed configuration of SNF. The k_{eff}, including calculational uncertainty, for this configuration is 0.78185 (Reference 2.2.1, Figure 7-21).
slwbr_single_can_acc_dry_reflectors_92_in	A hypothetical damaged canister configuration consisting of a rearrangement of the SLWBR SNF and the canister basket structure, to create a highly packed configuration of SNF. The k_{eff}, including calculational uncertainty, for this configuration is 0.40957 (Reference 2.2.1, Figure 7-24).
triga_single_can_acc_dry_reflectors_92_in	A hypothetical damaged canister configuration consisting of a rearrangement of the TRIGA SNF and the canister basket structure, to create a highly packed configuration of SNF. The k_{eff}, including calculational uncertainty, for this configuration is 0.79706 (Reference 2.2.1, Figure 7-29).
hypo_atr_dry_0_92_in	A hypothetical damaged canister configuration consisting of complete separation of ATR SNF from its cladding and the surrounding canister basket structure. The SNF is conservatively represented at full density (i.e. a 100 % non-physical packing fraction), with a cylindrical geometry at the base of the canister. The SNF debris is surrounded with close-fitting 30 cm thick stainless steel reflection. The k_{eff}, including calculational uncertainty, for this configuration is 0.77415 (Reference 2.2.1, Figure 7-30).
hypo_fermi_dry_ref_92_in	A hypothetical damaged canister configuration consisting of complete separation of Enrico Fermi SNF from its cladding, the surrounding -01 and -04 fuel canisters, and the canister basket structure. The SNF is conservatively represented at full density (i.e. a 100 % non-physical packing fraction), with a cylindrical geometry at the base of the canister. A fraction of the basket filler material (40 % of the total filler mass) is homogeneously mixed with the SNF debris. The SNF/basket filler debris is surrounded with close-fitting 30 cm thick stainless steel reflection. The k_{eff}, including calculational uncertainty, for this configuration is 0.8075 (Reference 2.2.1, Figure 7-35).

MCNP Model from *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Attachment 3, *MCNP inputs.zip*)	**Description of MCNP Model**
hypo_fftf_dry_ref_92_in	A hypothetical damaged canister configuration consisting of complete separation of FFTF SNF from its cladding and the surrounding canister basket structure. The SNF is conservatively represented at full density (i.e. a 100 % non-physical packing fraction), with a cylindrical geometry at the base of the canister. A fraction of the basket filler material (15 % of the total filler mass) is homogeneously mixed with the SNF debris. The SNF/basket filler debris is surrounded with close-fitting 30 cm thick stainless steel reflection. The k_{eff}, including calculational uncertainty, for this configuration is 0.72476 (Reference 2.2.1, Figure 7-40).
hypo_fsv_dry_0.01_0_92_in	A hypothetical damaged canister configuration consisting of complete separation of Fort St. Vrain SNF from its graphite fuel element block. The SNF is conservatively represented at full density (i.e. a 100 % non-physical packing fraction), with a cylindrical geometry at the base of the canister. The SNF debris is surrounded with close-fitting 30 cm thick stainless steel reflection. The k_{eff}, including calculational uncertainty, for this configuration is 0.82326 (Reference 2.2.1, Figure 7-41).
hypo_slwbr_dry_0_92_in	A hypothetical damaged canister configuration consisting of complete separation of SLWBR SNF from its cladding and the surrounding canister basket structure. The SNF is conservatively represented at full density (i.e. a 100 % non-physical packing fraction), with a cylindrical geometry at the base of the canister. The SNF debris is surrounded with close-fitting 30 cm thick stainless steel reflection. The k_{eff}, including calculational uncertainty, for this configuration is 0.62686 (Reference 2.2.1, Figure 7-43).
hypo_spwr_dry_0_92_in	A hypothetical damaged canister configuration consisting of complete separation of SPWR SNF from its cladding and the surrounding canister basket structure. The SNF is conservatively represented at full density (i.e. a 100 % non-physical packing fraction), with a cylindrical geometry at the base of the canister. The SNF debris is surrounded with close-fitting 30 cm thick stainless steel reflection. The k_{eff}, including calculational uncertainty, for this configuration is 0.60501 (Reference 2.2.1, Figure 7-44).
hypo_triga_dry_ref_92_in	A hypothetical damaged canister configuration consisting of complete separation of TRIGA SNF from its cladding, and the canister basket structure. The SNF is conservatively represented at full density (i.e. a 100 % non-physical packing fraction), with a cylindrical geometry at the base of the canister. A fraction of the basket structure material (5 % of the total basket structure mass) is homogeneously mixed with the SNF debris. The SNF/basket structure debris is surrounded with close-fitting 30 cm thick stainless steel reflection. The k_{eff}, including calculational uncertainty, for this configuration is 0.74576 (Reference 2.2.1, Figure 7-48).

Source: *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF,* Reference 2.2.1, Figures 7-19, 7-21, 7-24, 7-29, 7-30, 7-35, 7-40, 7-41, 7-43, 7-44, 7-48 and Attachment 3, *MCNP inputs.zip*

2. REFERENCES

This section details the references used in this calculation. The Document Input Reference system (DIRS) number is provided (within parenthesis) for each applicable reference.

2.1 PROCEDURES/DIRECTIVES

2.1.1 BSC 2007. *Calculations and Analyses*. EG-PRO-3DP-G04B-00037, Rev.10. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071018.0001.

2.1.2 BSC 2007. *Preclosure Safety Analysis Process*. LS-PRO-0201, Rev. 05. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071010.0021.

2.1.3 BSC 2007. Rev. 07, *Software Management*. IT-PRO-0011, Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20070905.0001.

2.1.4 BSC 2007. *Quality Management Directive*, QA-DIR-10, Rev. 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20080103.0002.

2.1.5 BSC 2007. *Qualification of Software*. IT-PRO-0012, Rev. 04. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20070319.0014.

2.2 DESIGN INPUTS

2.2.1 BSC (Bechtel SAIC Company) 2008. *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF*. 000-00C-MGR0-03900-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080107.0028; ENG.20080211.0013. (DIRS 182100).

2.2.2 MCNP V. 4B2LV.2002. WINDOWS 2000.STN: 10437-4B2LV-00 (DIRS 163407).

2.2.3 CRWMS M&O 1998. *Software Qualification Report for MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code*. CSCI: 30033 V4B2LV. DI: 30033-2003, Rev. 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980622.0637 (DIRS 102836).

2.2.4 Briesmeister, J.F., ed. 1997. *MCNP-A General Monte Carlo N-Particle Transport Code*. LA-12625-M, Version 4B. Los Alamos, New Mexico: Los Alamos National Laboratory. ACC: MOL.19980624.0328 (DIRS 103897).

2.2.5 BSC (Bechtel SAIC Company) 2003. *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF*. CAL-DSD-NU-000003 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20030724.0002; DOC.20050728.0006. (DIRS 164419).

2.2.6 Duderstadt, J.J. and Hamilton L.J. 1976. *Nuclear Reactor Analysis*. New York, New York: John Wiley & Sons. TIC: 245454. ISBN 0-471-22363-8. (DIRS 106070).

2.3 DESIGN CONSTRAINTS

None.

2.4 DESIGN OUTPUTS

2.4.1 Preclosure Criticality Safety Analysis.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

None.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

None.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation is prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 2.1.1) and LS-PRO-0201, *Preclosure Safety Analysis Process* (Reference 2.1.2). Therefore, the approved record version has a quality assurance designation of 'QA:QA'. This calculation is subject to the *Quality Management Directive* (QMD) (Reference 2.1.4).

4.2 USE OF SOFTWARE

4.2.1 MCNP

The base-lined Monte Carlo N-Particle (MCNP) code (References 2.2.2 and 2.2.3) is used to calculate k_{eff} of the eleven DOE SNF Canister MCNP models examined in this calculation. The MCNP software specification is as follows:

- Software Title: MCNP
- Version/Revision Number: Version 4B2LV
- Status/Operating System: Qualified/Microsoft Windows 2000 Service Pack 4
- Software Tracking Number: 10437-4B2LV-00
- Computer Type: Dell OPTIPLEX GX260 Workstations

The input and output files for the MCNP calculations are contained on a Compact Disc (CD) attachment to this calculation report (Attachment 2), as detailed in Attachment 1. The MCNP software has been validated as being appropriate for use in modeling a range of radiation transport problems as documented in *Software Qualification Report for MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code* (Reference 2.2.3). The range of validated problems includes cases where MCNP is used to determine k_{eff} of systems containing fissile material. The use of MCNP in determining k_{eff} values is further documented in *A General Monte Carlo N-Particle Transport Code* (Reference 2.2.4). The MCNP software was obtained from

Software Configuration Management in accordance with the appropriate procedure *Software Management* (Reference 2.1.3).

The software qualification report *Software Qualification Report for MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code* (Reference 2.2.3) was performed prior to the effective date of IT-PRO-0012, *Qualification of Software* (Reference 2.1.5), however, MCNP Version 4B2 was qualified software in the centralized baseline as of the effective date of IT-PRO-0012 and is therefore considered acceptable and part of the established software baseline available for level 1 usage (Paragraph 1.2.3 of IT-PRO-0012, *Qualification of Software* Reference 2.1.5).

4.2.2 EXCEL

- Software Title: Excel
- Version/Revision number: Microsoft® Excel 2003 SP-2 (on an OPTIPLEX GX620 Workstation)
- Computer Environment for Microsoft® Excel 2003: Software is installed on a DELL OPTIPLEX GX620 personal computer, running Microsoft Windows XP Professional, Version 2002, Service Pack 2.

Microsoft Excel for Windows is used in calculations and analyses to process the results of the MCNP calculations, using standard mathematical expressions and operations. It is also used to tabulate the MCNP results. The user-defined formulas, inputs, and results are documented in sufficient detail to allow an independent repetition of computations. Thus, Microsoft Excel is used only as a worksheet and not as a software routine. The use of Excel in the calculation constitutes Level 2 software usage, which does not require qualification (*Software Management*, Reference 2.1.3, Attachment 12).

The Microsoft Excel spreadsheet generated for the calculations developed in support of this document are provided in the Microsoft Excel workbook *Results.xls,* included in the CD file of Attachment 2. The Microsoft Excel calculations were verified by hand calculations and visual inspection.

4.3 ANALYSIS PROCESS

The approach used to establish the penalty (Δk_{EROA}), if any, on the applicability of the code bias documented in *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Section 6.3) to the selected preclosure configurations described in Section 1.1, is defined in this section. The penalty examined is limited (Section 1.1) to a consideration of the effect of use of ZAIDs in the preclosure criticality DOE SNF MCNP calculations (described in Section 1.1), that are dissimilar to the ZAIDs used in determination of the code bias (documented in *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF*, Reference 2.2.5, Table 5-3).

4.3.1 METHOD

The following method is used in establishing the penalty (Δk_{EROA}), if any, on the applicability of the code bias documented in *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Section 6.3):

1. A set of MCNP models is selected to encompass each of the DOE SNF canisters examined in *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Section 1.1.1). The MCNP model selection is focused on configurations that are most limiting, in terms of producing the greatest subcritical k_{eff}.

2. The ZAIDs used in the selected MCNP models (1) are compared with the ZAIDs used in the code bias determination documented in *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Table 5-3).

3. The MCNP models selected in (1) are modified to update the MCNP ZAIDs consistent with the specific ZAIDs used in the code bias determination *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Table 5-3).

4. The k_{eff} values computed in each modified MCNP model (3) are compared with the k_{eff} values computed in the unmodified versions of the MCNP models (summarized in Table 7-1). The relative change in the k_{eff} values (between the unmodified and modified versions of the MCNP models) are calculated to determine the impact of ZAID selection on the code bias documented in *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Section 6.3).

It is noted that the MCNP models examined in this analysis are unaltered MCNP models from *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1 Attachment 3, *MCNP inputs.zip*), except that the ZAID listing has been updated as described above. No other modifications are applied to the MCNP models. Explicit details of the geometry and actual material properties of the MCNP models examined are therefore unaltered. Refer to *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Section 6.2.2.1.2 and Attachment 1) for a full description of the MCNP model geometry and material constituents.

5. LIST OF ATTACHMENTS

Attachment #	Title	Number of Pages
1	Compact Disc Listing	1
2	Compact Disc	N/A

6. BODY OF CALCULATION

This section provides a description of the eleven DOE SNF MCNP models examined in this document. The eleven DOE SNF MCNP models are based on the models documented in *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Attachment 3, *MCNP inputs.zip*), but with modification to update the MCNP ZAIDs consistent with the ZAIDs used in the *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Table 5-3). The eleven models represent configurations that are generally the most limiting in respect of producing the greatest subcritical k_{eff}. The eleven base case MCNP models are summarized in Table 1-1. The modifications made to the eleven MCNP models to update the MCNP ZAIDs consistent with the ZAIDs used in the *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Table 5-3) are described in Table 6-1. A summary of the generic ZAID updates is provided in Table 6-2.

Table 6-1: Description of Explicit DOE SNF Canister MCNP ZAID Modifications

Original MCNP Input File Name (from *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* Reference 2.2.1, Attachment 3, *MCNP inputs.zip*)	**Modified MCNP Input File Name**	**Description of Input Modifications**
fermi_single_can_acc_dry_reflectors_92_in	mod_fermi_single_can_acc_dry_reflectors_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe, Ni and Cu to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe, Ni and Cu. • Replacement of the .60c nuclear data library with the .56c nuclear data library for Zr.
fftf_single_can_acc_dry_reflectors_92_in	mod_fftf_single_can_acc_dry_reflectors_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe and Ni to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe and Ni.
slwbr_single_can_acc_dry_reflectors_92_in	mod_slwbr_single_can_acc_dry_reflectors_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe and Ni to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe and Ni. • Replacement of the .60c nuclear data library with the .56c nuclear data library for Zr.
triga_single_can_acc_dry_reflectors_92_in	mod_triga_single_can_acc_dry_reflectors_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe and Ni to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe and Ni. • Replacement of the .60c nuclear data library with the .56c nuclear data library for Zr.
hypo_atr_dry_0_92_in	mod_hypo_atr_dry_0_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe, Ni and Cu to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe, Ni and Cu.
hypo_fermi_dry_ref_92_in	mod_hypo_fermi_dry_ref_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe and Ni to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe and Ni. • Replacement of the .60c nuclear data library with the .56c nuclear data library for Zr.
hypo_fftf_dry_ref_92_in	mod_hypo_fftf_dry_ref_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe and Ni to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe and Ni.

Original MCNP Input File Name (from *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* Reference 2.2.1, Attachment 3, *MCNP inputs.zip*)	**Modified MCNP Input File Name**	**Description of Input Modifications**
hypo_fsv_dry_0.01_0_92_in	mod_hypo_fsv_dry_0.01_0_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe and Ni to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe and Ni.
hypo_slwbr_dry_0_92_in	mod_hypo_slwbr_dry_0_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe and Ni to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe and Ni. • Replacement of the .60c nuclear data library with the .56c nuclear data library for Zr.
hypo_spwr_dry_0_92_in	mod_hypo_spwr_dry_0_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe and Ni to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe and Ni. • Replacement of the .60c nuclear data library with the .56c nuclear data library for Zr.
hypo_triga_dry_ref_92_in	mod_hypo_triga_dry_ref_92_in	• Collapse of isotopic ZAID treatment for Cr, Fe, Ni and Cu to an elemental representation. • Replacement of the .60c nuclear data library with the .50c nuclear data library for Cr, Fe, Ni and Cu. • Replacement of the .60c nuclear data library with the .56c nuclear data library for Zr.

Source: Original

Table 6-2: Summary of generic DOE SNF Canister MCNP ZAID Modifications

Element	ZAID	
	Elemental Representation	Isotopic Representation
Cr	24000.50c	24050.60c
		24052.60c
		24053.60c
		24054.60c
		24050.60c
Fe	26000.55c	26054.60c
		26056.60c
		26057.60c
		26058.60c
Ni	26000.55c	28058.60c
		28060.60c
		28061.60c
		28062.60c
		28064.60c
Cu	29000.50c	29063.60c
		29065.60c
Zr	40000.56c	40000.60c

Source: Original

7. RESULTS AND CONCLUSIONS

The results of the calculations described in Section 6 are presented in Table 7-1. The results of the eleven modified MCNP models are compared with the results of the eleven unmodified MCNP models documented in *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF* (Reference 2.2.1, Section 7.1).

Based on the results provided in Table 7-1 it is seen that for all MCNP models except one, the ZAID treatment in the unmodified MCNP models results in a k_{eff} value that is greater by a degree of several standard deviations. Thus, the ZAID representation for these models is conservative. In the one instance that results in a relative decrease in k_{eff}, the amount of decrease is found to be approximately one standard deviation; i.e. well within the statistical uncertainty of the calculation.

The bias and bias uncertainty values for selected critical benchmark experiments applicable to intact and degraded as well as moderated and non-moderated configurations for the DOE SNF types considered in this calculation are summarized in Table 7-2, as adapted from *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Section 6.3). These benchmarks were evaluated with the elemental cross section set presented in

Table 6-2, whereas the configurations summarized in Table 1-1 were evaluated with the isotopic cross section set presented in Table 6-2. The results presented in Table 7-1 demonstrates that the cross section set used to evaluate the DOE SNF configurations (summarized in Attachment 2, *Results.xls*) either results in a statistically similar or higher k_{eff} values than the cross section set used to evaluate the critical benchmark experiments (*Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF,* Reference 2.2.5, Table 5-3). Therefore, the bias and bias uncertainty evaluated in *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF* (Reference 2.2.5, Section 6.3) is applicable to the DOE SNF configurations summarized in Table 1-1 without need for an additional penalty.

Table 7-1: Calculation Results

MCNP Input File Name	**MCNP Output File Name**	k_{eff}	σ	$k_{eff}+2\sigma$	**Delta k_{eff} (%) rel. to modified case**	**Delta k_{eff}/σ rel. to modified case**
Modified MCNP input/outputs Documented in this Calculation						
mod_fermi_single_can_acc_dry_reflectors_92_in	mod_fermi_single_can_acc_dry_reflectors_92_ino	0.65354	0.00082	0.65518	0	0
mod_fftf_single_can_acc_dry_reflectors_92_in	mod_fftf_single_can_acc_dry_reflectors_92_ino	0.77461	0.00096	0.77653	0	0
mod_hypo_atr_dry_0_92_in	mod_hypo_atr_dry_0_92_ino	0.76731	0.00119	0.76969	0	0
mod_hypo_fermi_dry_ref_92_in	mod_hypo_fermi_dry_ref_92_ino	0.80679	0.00083	0.80845	0	0
mod_hypo_fftf_dry_ref_92_in	mod_hypo_fftf_dry_ref_92_ino	0.71771	0.00082	0.71935	0	0
mod_hypo_fsv_dry_0.01_0_92_in	mod_hypo_fsv_dry_0.01_0_92_ino	0.81873	0.00127	0.82127	0	0
mod_hypo_slwbr_dry_0_92_in	mod_hypo_slwbr_dry_0_92_ino	0.62087	0.0009	0.62267	0	0
mod_hypo_spwr_dry_0_92_in	mod_hypo_spwr_dry_0_92_ino	0.59814	0.00099	0.60012	0	0
mod_hypo_triga_dry_ref_92_in	mod_hypo_triga_dry_ref_92_ino	0.74221	0.00083	0.74387	0	0
mod_slwbr_single_can_acc_dry_reflectors_92_in	mod_slwbr_single_can_acc_dry_reflectors_92_ino	0.40021	0.00083	0.40187	0	0
mod_triga_single_can_acc_dry_reflectors_92_in	mod_triga_single_can_acc_dry_reflectors_92_ino	0.79072	0.00129	0.7933	0	0
Original MCNP input/outputs from *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF*, Reference 2.2.1, Attachment 3, *MCNP inputs.zip*						
fermi_single_can_acc_dry_reflectors_92_in	fermi_single_can_acc_dry_reflectors_92_ino	0.65495	0.00081	0.65657	0.141	1.7
fftf_single_can_acc_dry_reflectors_92_in	fftf_single_can_acc_dry_reflectors_92_ino	0.77993	0.00096	0.78185	0.532	5.5
hypo_atr_dry_0_92_in	hypo_atr_dry_0_92_ino	0.77171	0.00122	0.77415	0.440	3.7
hypo_fermi_dry_ref_92_in	hypo_fermi_dry_ref_92_ino	0.80582	0.00084	0.8075	-0.097	-1.2
hypo_fftf_dry_ref_92_in	hypo_fftf_dry_ref_92_ino	0.72282	0.00097	0.72476	0.511	6.2
hypo_fsv_dry_0.01_0_92_in	hypo_fsv_dry_0.01_0_92_ino	0.82082	0.00122	0.82326	0.209	1.6
hypo_slwbr_dry_0_92_in	hypo_slwbr_dry_0_92_ino	0.62498	0.00094	0.62686	0.411	4.6
hypo_spwr_dry_0_92_in	hypo_spwr_dry_0_92_ino	0.60293	0.00104	0.60501	0.479	4.8
hypo_triga_dry_ref_92_in	hypo_triga_dry_ref_92_ino	0.74426	0.00075	0.74576	0.205	2.5
slwbr_single_can_acc_dry_reflectors_92_in	slwbr_single_can_acc_dry_reflectors_92_ino	0.40791	0.00083	0.40957	0.77	9.3
triga_single_can_acc_dry_reflectors_92_in	triga_single_can_acc_dry_reflectors_92_ino	0.79474	0.00116	0.79706	0.402	3.1

Source: Original and *Nuclear Criticality Calculations for Canister-Based Facilities - DOE SNF*, **Reference 2.2.1, Attachment 3 (*MCNP inputs.zip, Dry Damaged Intact Canister Results (Fig 7-16 to Fig 7-29).xls* and *Dry Damaged Degraded Canister Results (Fig 7-30 to 7-48).xls*).**

Table 7-2: Summary of the bias and bias uncertainty for benchmarks applicable to various DOE SNF Configurations

DOE SNF Fuel Type	Subset	Bias and Bias Uncertainty
HEU Oxide (Shippingport PWR)	Intact Moderated	0.046
	Intact Non-Moderated	0.014
	Degraded Moderated	0.019
	Degraded Non-Moderated	0.016
UZrHx (TRIGA)	Intact-Moderated	0.052
	Intact Non-Moderated	0.028
	Degraded Moderated	0.020
	Degraded Non-Moderated	0.016
HEL-Al (ATR)	Intact Moderated	0.013
	Intact Non-Moderated	0.013
	Degraded Moderated	0.034
	Degraded Non Moderated	0.013
U-Mo and U-Zr Alloys (Enrico Fermi)	Intact Moderated	0.025
	Intact Non-Moderated	0.013
	Degraded Moderated	0.034[a]
	Degraded Non-Moderated	0.013
MOX (FFTF)	Intact Moderated	0.021
	Intact Non-Moderated	0.035
	Degraded Moderated	0.023
	Degraded Non-Moderated	0.013
U/Th Carbide (FSV)	Intact Moderated	0.052
	Intact Non-Moderated	0.018
	Degraded Moderated	0.046
	Degraded Non-Moderated	0.028
233U/Th Oxide (Shippingport LWBR)	Intact Moderated	0.025
	Intact Non-Moderated	0.018
	Degraded Moderated	0.025
	Degraded Non-Moderated	0.028

Source: *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF*, Reference 2.2.5, Section 6.3.

NOTES: [a] this value is based on an AENCF of 2 MeV, which is the average energy of a fission neutron (*Nuclear Reactor Analysis*, Reference 2.2.6, page 61).

Attachment 1: Compact Disc Listing

This attachment contains a listing and description of the files contained on the attachment Compact Disc (CD) of this document (Attachment 2). The zip archives were created using WINZIP 9.0. The file attributes on the CD are as follows:

Filename	File Size (bytes)	File Date	File Time	Description
MCNP inputs.zip	72,000	2/15/08	17:43	WinZip file containing all MCNP input files relevant to this document.
MCNP outputs.zip	703,000	2/15/08	17:44	WinZip file containing all MCNP output files relevant to this document.
Results.xls	130,000	2/19/08	18:27	Microsoft Excel workbook containing the MCNP results relevant to this document.

There are eleven total files contained in the zip archive file *MCNP inputs.zip,* and eleven total files contained in the zip archive file *MCNP outputs.zip*. Files suffixed "_in" are input files, whereas files suffixed "_ino" denote output files. Including one Microsoft Excel workbook, the CD contains a total of twenty three files.

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1. QA: QA

This is a placeholder page for records that cannot be scanned.

2. Record Date 02/20/2008	3. Accession Number ATTN to: ENG.20080225.0028
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13. Comments

CDsS: 1 Original & 1 Copy

Validation of complete file transferred. All files copied. Software used: MCNP Version 4B2

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14. RPC Electronic Media Verification

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MD5 Validation

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 Volume in drive D is 080220_1709
 Volume Serial Number is A4B4-46E9

 Directory of D:\

02/15/2008  05:43 PM            72,804 MCNP inputs.zip
02/15/2008  05:44 PM           719,167 MCNP outputs.zip
02/19/2008  06:27 PM           132,608 Results.xls
               3 File(s)        924,579 bytes

     Total Files Listed:
               3 File(s)        924,579 bytes
               0 Dir(s)               0 bytes free
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