8 CRITICALITY EVALUATION

8.1 Conduct of Review

The staff's review of the criticality evaluation included Chapter 3, "Principal Design Criteria;" Chapter 4, "Installation Design;" Chapter 4, Appendix A (Appendix 4A), "Criticality Models;" and Chapter 5, "Operation Systems," of the Idaho Spent Fuel Facility Safety Analysis Report (SAR). In addition, the staff reviewed the criticality analyses provided in Appendix A to the SAR, "Safety Evaluation of DOE-ID Provided Transfer Cask." The purpose of the criticality review is to ensure that the stored materials remain subcritical under normal, off-normal, and accident conditions during all operations, transfers, and storage at the proposed ISF Facility. This review considered how the information in the SAR addresses the following regulatory requirements:

- 10 CFR §72.40(a)(13) requires that there is reasonable assurance that: (i) The activities authorized by the license can be conducted without endangering the health and safety of the public, and (ii) these activities will be conducted in compliance with the applicable regulations of this chapter.

- 10 CFR §72.124(a) requires that spent fuel handling, packaging, transfer, and storage systems must be designed to be maintained subcritical and to ensure that, before a nuclear criticality accident is possible, at least two unlikely, independent, and concurrent or sequential changes must occur in the conditions essential to nuclear criticality safety. The design of handling, packaging, transfer, and storage systems must include margins of safety for the nuclear criticality parameters that are commensurate with the uncertainties in the data and methods used in calculations and demonstrate safety for the handling, packaging, transfer and storage conditions and in the nature of the immediate environment under accident conditions.

- 10 CFR §72.124(b) requires that when practicable, the design of an ISFSI must be based on favorable geometry, permanently fixed neutron absorbing materials (poisons), or both. Where solid neutron absorbing materials are used, the design must provide for positive means of verifying their continued efficacy. For dry spent fuel storage systems, the continued efficacy may be confirmed by a demonstration or analysis before use, showing that significant degradation of the neutron absorbing materials cannot occur over the life of the facility.

- 10 CFR §72.124(c) requires that a criticality monitoring system shall be maintained in each area where special nuclear material is handled, used, or stored which will energize clearly audible alarm signals if accidental criticality occurs. Monitoring of dry storage areas where special nuclear material is packaged in its stored configuration under a license issued under this subpart is not required.

8.1.1 Criticality Design Criteria and Features

The applicant described the criticality design criteria and features in Section 3.3.4 of the SAR. The criticality design criteria include double contingency, a safety margin for the multiplication factor, favorable geometry, and criticality alarms. The ISF Facility has been designed to ensure that all facility processes (cask receipt, fuel transfer and fuel storage) are performed in a dry environment. In addition, the applicant has evaluated possible scenarios of fuel aggregation, for normal operations, off-normal operation and accident conditions, to ensure that in the event of a flooding situation, criticality safety margins exist.

In SAR Section 5.1.3.1, Criticality Prevention, the applicant discusses the design features, procedures and special techniques used to prevent a criticality in the ISF Facility. The following design features and procedures are applicable to all locations within the ISF Facility:

no mixing of fuel types,
limitations on the number of fuel elements, and
geometry control of the transfer and storage baskets.

The facility design ensures that, in the event of a flooding situation, maximum multiplication factor, $k_{eff,}$ does not exceed 0.95, including all biases and uncertainties, at the 95 percent confidence level.

Fuel handling operations are performed within the Fuel Packaging Area (FPA), a sub-area of the Transfer Area. The applicant describes, in Section 3.3.5.3, the criticality alarms that will be located in the FPA. Additionally, Technical Specification 3.3.2 requires criticality monitoring during Loading Operations when spent fuel is in the FPA.

8.1.2 Stored Material Specifications

Sections 3.3.1 and 3.3.4 of the SAR contain descriptions of the TRIGA fuel, Peach Bottom fuel and Shippingport reflector modules to be stored in the ISF Facility.

8.1.2.1 TRIGA Fuel

The TRIGA fuel elements to be stored at the ISF Facility are made of a homogeneous mixture of uranium-zirconium hydride (UZrH) alloy, containing 8 to 9 weight percent uranium. The maximum enrichment of the fuel is 20 weight percent ^{235}U. Graphite reflectors are located at each end of the active fuel and the fuel elements are clad in either stainless steel or aluminum. The active fuel length is either 14 inches or 15 inches, depending on the fuel design. The ISF Facility will store 1285 stainless steel clad elements and 315 aluminum clad elements.

8.1.2.2 Peach Bottom Fuel

The Peach Bottom fuel elements contain solid annulus-shaped graphite compacts. Embedded into the graphite compacts are microspheres of uranium carbide enriched to a maximum of 93.15 weight percent ^{235}U. The compacts are loaded onto a central graphite spine that runs the length of the active fuel region. Additionally, graphite reflectors are placed above and below the active fuel. The fuel element is held together by a pyrolytic carbon sleeve that acts as an outer

cladding. The active fuel length of the Peach Bottom fuel elements is approximately 89 inches. The ISF Facility will store 1601.5 Peach Bottom fuel elements.

8.1.2.3 Shippingport Reflector Modules

The Shippingport reflector modules contain fuel rods, which are similar to commercial UO_2 fuel rods, with the exception that the Shippingport rods contain thorium, in the form of solid ThO_2 pellets, instead of UO_2 pellets. The Shippingport fuel contained no fissile material at manufacture, and very small quantities of ^{233}U were produced during reactor operations. Some of the Shippingport reflector modules were disassembled prior to shipment to the ISF Facility. The ISF Facility will store 11 intact reflector modules, four clamped reflector modules and 127 loose reflector rods.

8.1.3 Analytical Means

SAR Sections 4.2.3.3.7, Criticality Evaluation, 4.7.3.4, Criticality Evaluation for Spent Fuel Handling Operations and Appendix 4A contain the criticality models used to ensure that an inadvertent criticality cannot occur in the ISF Facility for normal, off-normal and accident conditions. The applicant evaluated the criticality potential of each fuel element type as the fuel is moved through the ISF Facility. Known basket configurations for each fuel element type were evaluated, to show subcriticality for normal conditions during fuel handling. The applicant evaluated postulated off-normal and bounding configurations (for accident conditions) to ensure that, in the event of a flooding scenario and/or a fuel handling error, an inadvertent criticality will not occur.

8.1.3.1 Model Configuration

A. DOE Transfer Cask Receipt

Spent fuel enters the ISF Facility in the Cask Receipt Area within a transfer cask designed by the Department of Energy (DOE). The transfer casks will be two existing Peach Bottom Casks provided by the DOE. The transfer casks will be used to transport Peach Bottom high-temperature gas-cooled reactor (HTGR) fuel from Core 1 and Core 2, Shippingport breeder reactor (LWBR) reflector modules and loose rods, and TRIGA fuel rods from their current storage locations at the INEEL to the ISF Facility.

<u>Peach Bottom Fuel</u>

The transfer cask will ship a maximum of 18 Peach Bottom fuel elements from Core 1 or 12 fuel elements from Core 2. The criticality evaluations for the Peach Bottom HTGR fuel are located in Chapter 4 and Appendix A. For normal conditions, the applicant evaluated a dry, close-packed array in the configuration provided by the package during transfer. The applicant bounded off-normal and accident conditions, by evaluating close-packed and crushed fuel elements to bound any drops which may result in loss of geometry of the transfer cask and basket. The applicant evaluated the close-packed fuel elements as optimally moderated, while the crushed fuel elements were modeled as a homogenous graphite-moderated sphere. Additionally, the applicant provided, in Appendix A, a DOE evaluation for accident conditions of

19 Peach Bottom fuel elements optimally spaced and flooded. Note that the evaluation included more fuel elements than the basket accommodates.

Shippingport Reflector Modules and Loose Rods

The normal, off-normal and accident conditions criticality evaluations for Shippingport reflector modules and loose rods are bounded by the evaluation of infinite arrays of pellets and rods. In Appendix A, the applicant determined the k_{eff} of an infinite array of pellets in a dry, close-packed array (optimum spacing). Additionally, the applicant bounds the evaluation of off-normal and accident conditions by evaluating an infinite array of optimumly moderated loose rods.

TRIGA Fuel

Up to five TRIGA fuel elements are placed inside a standard TRIGA fuel can and six TRIGA fuel cans are placed inside of a TRIGA bucket, as shown in Figures A-31, A-31a and A-38. Three TRIGA buckets are stacked vertically inside of the DOE canister for a maximum of 90 TRIGA fuel elements per transfer. The descriptions of the criticality evaluation for the DOE transfer cask containing TRIGA fuel elements are located in Section 4.7.3.4, Appendix 4A and in Appendix A, provided by the DOE. For normal conditions, the applicant referenced the criticality evaluation in Appendix A. In Appendix A, the DOE modeled a geometry similar to that provided by the fuel cans and buckets. The model of the transfer cask takes credit for the spacing provided by the 5-position TRIGA fuel can, but not the stainless steel material of the fuel can or tubes in which the fuel is located. The DOE conservatively modeled the fuel elements in the fuel can with a smaller spacing than the fuel cans provide. Additionally, the fuel cans were conservatively modeled in an annulus with the fuel cans touching. Although the spacing provided by the fuel bucket is modeled, the aluminum of the fuel bucket was neglected.

The applicant bounded off-normal and accident conditions, by evaluating a close-packed array of fuel elements with reflection on three sides to bound any drops resulting in loss of geometry of the transfer cask and basket. Reference A-13 to Appendix A provides an evaluation of moderated TRIGA rods inside the DOE-ID transfer cask. The DOE evaluated various configurations of the TRIGA rods to determine optimum reactivity. The materials and spacing provided by the DOE-ID basket were neglected. The applicant determined the optimum rod pitch within a layer of rods. The results of the criticality evaluation in Reference A-13 to Appendix A show that for TRIGA rods in the transfer cask (including cans and buckets), the k_{eff} will remain below 0.9, therefore the criticality evaluation of 45 close-packed elements in a corner is bounding.

B. Fuel Packaging Area

With the exception of the TRIGA fuel, individual assemblies are removed directly from the existing DOE canisters and repackaged into the ISF canisters. The transfer cask inner fuel containers are removed and placed into temporary storage within the FPA for eventual return to DOE and re-use. For the TRIGA fuel, the entire fuel bucket containing up to 30 assemblies is removed from the transfer cask and placed into an unloading position in the FPA. From this position, individual TRIGA elements are removed from the bucket and placed into the ISF canister basket. After filling the TRIGA ISF basket, a lid is placed on the basket and the fuel is locked into place, for transfer to the ISF canister. Once loaded, the ISF canisters are vacuum-dried, backfilled with helium and welded closed. Fuel repackaging is planned in three separate

campaigns, one for each fuel type, so that no more than one type of fuel element is present within the FPA at a time. In addition, Technical Specification 3.3.1 limits the presence of fuel types to one fuel type at a time within the FPA.

Within the FPA, a worktable is provided for recovery and repackaging of damaged fuel elements, and recovery of stuck or broken fuel elements in a fuel can. Worktable operations may involve movement of fuel fragments, single fuel elements or multiple fuel elements. The fuel handling operations involve a number of different geometries, including close-packed fuel elements (i.e., baskets of fuel elements or individual fuel elements) and arrays of fuel baskets in close proximity to one another. The applicant has performed criticality evaluations for anticipated configurations to either show that for explicit configurations or for bounding configurations, the fuel will remain subcritical for all normal, off-normal and accident conditions. Section 4.7.3.4.2, Fuel Packaging Area Operations, contains the criticality evaluation for fuel handling in the FPA.

The FPA, as described in SAR Section 8.2.5.3, Flood, is designed to prevent water from entering the area. Additionally, the FPA and workbench elevation levels (4938.5 feet) are above the probable maximum flood level (4920.71 feet) and there are no water systems located in the area.

<u>Peach Bottom Fuel</u>

For normal conditions, the applicant evaluated the Peach Bottom fuel in two different configurations. The first configuration was with the baskets stacked vertically in the transfer cask, with each basket containing 18 fuel elements. The second configuration was for an ISF canister loaded with 10 fuel elements. The fuel elements were modeled in a dry, close-packed, hexagonal array with a pitch of 0.1 cm.

For off-normal conditions, the applicant evaluated two different criticality configurations for Peach Bottom fuel. Both configurations were for the DOE transfer cask, since it was more reactive than the ISF canister. The first configuration evaluated is for two DOE transfer cask baskets located side-by-side. Similar to the normal conditions model, fuel elements were modeled in a dry, close-packed, hexagonal array with a pitch of 0.1 cm. The second configuration evaluated included a 19^{th} fuel element that is placed alongside the normal hexagonal fuel element array. This evaluation envelopes dropping an additional fuel element onto or alongside a full DOE transfer canister.

The accident conditions criticality evaluation is for 12 homogeneously crushed Peach Bottom Core 2 fuel elements, which bounds either dropping a fuel element onto a DOE canister or dropping the entire canister when removing it from the transfer cask. The model assumed that the graphite and uranium from the fuel compacts were homogeneously mixed into a sphere and the remaining graphite in the assembly surrounded the sphere to form a reflector. The applicant also varied the number of fuel assemblies from a minimum of 3 to a maximum of 21 fuel elements. Additionally, the applicant evaluated the spheres with a water reflector.

<u>Shippingport Reflector Modules and Loose Rods</u>

The criticality evaluation for the FPA is bounded by the criticality evaluation for the DOE transfer cask, as described in Section 8.1.3.1.A of this SER, above.

TRIGA Fuel

For normal conditions, the applicant evaluated a single, dry ISF basket containing 54 TRIGA fuel elements and an ISF canister containing two baskets, stacked vertically. Each evaluation was performed dry with the TRIGA fuel rods in the spacing provided by the basket. The evaluations included a 1-inch and a 12-inch water reflector.

For off-normal conditions, the applicant evaluated two dry ISF baskets, each containing 54 TRIGA fuel elements, located next to one another. The evaluation covers the off-normal situation where two baskets are brought in close proximity to one another. In this case, the two TRIGA baskets were not surrounded by a reflector.

For accident conditions, the criticality evaluation is bounded by the evaluation of the maximum number of TRIGA fuel elements that can be safely handled in an uncontrolled, unconfined and unmoderated condition in the ISF facility. Since the TRIGA fuel buckets have not been shown to meet the requirements of a single failure-proof lifting device, the TRIGA elements were shown to be subcritical in the event of a dropped bucket. The TRIGA fuel rods were modeled in close-packed square and hexagonal lattices with three sides of the array reflected. The applicant used two different reflectors, 1 inch of water and 36 inches of concrete, to account for reflection from building materials. Additionally, the applicant evaluated the two TRIGA baskets side-by-side, flooded with water and reflected by 12 inches of water.

C. Storage Area

Fuel arriving in the storage area has been repackaged and the canister has been closed. Sections 4.2.3.2.2 through 4.2.3.2.4 of the SAR describe the design of the storage tubes, canisters and baskets, respectively. Section 4.2.3.3.7, Criticality Evaluation, contains the criticality assessment for storage at the ISF facility. The storage vaults are above-ground reinforced concrete structures, as shown in Figure 4.2-4. There are two vaults in the ISF Facility design. Vault 1 contains 102 tubes: 72, 18-inch diameter tubes and 30, 24-inch diameter tubes. Vault 2 contains 144 tubes, all of which are 18 inches in diameter. The applicant did not explicitly model off-normal conditions, since they are bounded by the accident conditions criticality evaluations. All of the criticality models for storage are described in SAR Appendix 4A.

Peach Bottom Fuel

The applicant evaluated a single ISF canister loaded with 10 fuel elements, two fully loaded, ISF canisters adjacent to one another and an infinite array of ISF canisters in the storage configuration for normal conditions. The two adjacent canisters bounds the scenario where a loaded canister passes over a loaded storage tube. The infinite array of loaded storage tubes bounds any configuration of storage tubes loaded with Peach Bottom fuel. The analyses for single and stacked baskets were performed for unmoderated conditions with the fuel elements in a hexagonal array and a spacing of 0.1 cm between fuel elements. The baskets were reflected by both 1-inch and 12-inches of water.

Scenarios for off-normal and accident conditions are bounded by the evaluation of an infinite array of optimally flooded storage tubes.

Shippingport Reflector Modules and Loose Rods

The criticality evaluation for the storage area is bounded by the criticality evaluation for the DOE transfer cask described in Section 8.1.3.1.A of this SER, above.

TRIGA Fuel

The TRIGA fuel criticality evaluations for normal conditions include a single ISF canister fully loaded (108 fuel elements), two full ISF canisters stacked vertically, and a finite array of ISF canisters in the storage configuration. Although the evaluations for normal conditions do not specifically include water, there is hydrogen present in the UZrH which is included in the criticality model, since it is integral to the fuel elements. The two models for the single and stacked ISF canisters are similar to the Peach Bottom models. The array of canisters in the storage configuration models Vault 2 loaded with all 144 storage tubes filled with two ISF canisters and TRIGA fuel, stacked vertically. The applicant determined the maximum k_{eff} for accident conditions by assuming that the full storage vault contained water at optimum moderation.

Mixed Fuel Types

The applicant also assessed the criticality potential of the storage vault containing mixed fuel types, TRIGA and Peach Bottom. The applicant's model consists of two storage tubes with one tube containing a Peach Bottom basket and the other containing two baskets, vertically stacked, full of TRIGA fuel, as described in Section 3.5 of Appendix 4A. The applicant assumed optimum moderation for this case.

8.1.3.2 Material Properties

The material properties used to evaluate the criticality safety of the ISF Facility are listed in Appendix 4A. The staff agrees that the material properties used in the analyses are appropriate. The applicant did not take credit for any poisons in the fuel assemblies or in the storage canisters. The criticality analyses have been performed with the conservative assumption that water is present inside the confinement boundary, and the applicant has demonstrated that subcriticality will be maintained without the use of poison materials, despite the presence of gadolinium phosphate in two of the three types of fuel that will be stored in the INEEL canisters.

8.1.4 Applicant Criticality Analyses

The criticality evaluation for the facility ensures that the maximum multiplication factor, $k_{eff,}$ does not exceed 0.95, including all biases and uncertainties, at the 95 percent confidence level.

The staff performed confirmatory criticality calculations using the 44groupndf5 cross section set with KENO V.a in the SCALE 4.4a computer code system. The staff performed criticality calculations for a storage vault filled with TRIGA fuel rods. The staff used the cell weighting technique in the CSAS2X module to model the TRIGA fuel and basket. The staff only modeled the rods and the fuel tubes in the basket. Staff modeled the storage tube and then modeled an

array of the tubes. The staff varied the water density in the analysis to find optimum moderation. The staff's maximum k_{eff} agrees well with the applicant's.

8.1.4.1 Computer Programs

To support the fuel assembly specifications, the applicant performed a criticality analysis using the versions 4B2 and 4C of the MCNP code. The applicant addressed the benchmarking for each version of the code.

8.1.4.2 Multiplication Factor

The k_{eff}s calculated by the applicant are provided in Appendix 4A and the results of the DOE criticality evaluation for the DOE-ID transfer cask is in Appendix A. The multiplication factors provided in this section include the Monte Carlo uncertainties, but not the bias.

A. DOE Transfer Cask

The maximum k_{eff} for each fuel type in the DOE Transfer cask is shown in Table 8-1.

Table 8-1 Maximum K_{eff} in the DOE-ID Transfer Cask

Fuel Type	Normal Conditions		Accident Conditions		Upper Subcritical Limit (USL)
	Case Description	K_{eff}	Case Description	K_{eff}	
Peach Bottom	DOE-ID full canister	0.33	19 moderated fuel elements	0.94	0.913
Shippingport	Infinite array of dry pellets	0.19	Infinite array of moderated rods	0.65	0.913
TRIGA	1 full, dry DOE-ID canister	0.38	45 rods in a corner	0.91	0.913

B. Fuel Packaging Area

The maximum k_{eff} for each fuel type in the FPA is shown in Table 8-2. The maximum reactivity of the Shippingport reflector modules and loose rods in the FPA is bounded by the criticality evaluation of infinite pellets and rods described in Section 8.1.4.2.A of this SER, above.

Table 8-2 Maximum k_{eff} in the Fuel Packaging Area							
Fuel Type	Normal Conditions		Off-Normal Conditions		Accident Conditions		USL
	Description	k_{eff}	Description	k_{eff}	Description	k_{eff}	
Peach Bottom	2 adjacent canisters	0.33	2 dry baskets side-by-side	0.39	21 crushed fuel elements in a sphere	0.57	0.913[a] 0.930[b]
TRIGA	1 canister with 2 baskets stacked	0.57	2 dry baskets side-by-side	0.57	45 rods in a corner	0.91	0.913[c] 0.927[d]

a. USL applies to normal and off-normal conditions, based on the code version used in analyses.
b. USL applies to accident conditions, based on the code version used in analyses.
c. USL applies to normal and accident conditions, based on the code version used in analyses.
d. USL applies to off-normal conditions, based on the code version used in analyses.

C. Storage Area

The maximum k_{eff} for each fuel type in the storage area is shown in Table 8-3. The maximum k_{eff} of the Shippingport reflector modules and loose rods in the storage area is bounded by the criticality evaluation of infinite pellets and rods described in Section 8.1.4.2.A of this SER, above. In addition, the results of the criticality evaluation for accident conditions bound off-normal conditions.

Table 8-3 Maximum k_{eff} in the Storage Area					
Fuel Type	Normal Conditions		Accident Conditions		
	Description	k_{eff}	Description	k_{eff}	USL
Peach Bottom	infinite array of dry ISF Canisters	0.46	Infinite, flooded array of canisters	0.5	0.913
TRIGA	Dry fully loaded storage vault	0.71	Moderated fully loaded storage vault	0.82	0.927
Mixed Fuel	Dry Array of TRIGA & Peach Bottom fuel	0.53	Flooded 2 canister Array of TRIGA & Peach Bottom fuel	0.84	0.913

8.1.4.3 Benchmark Comparisons

The applicant performed a benchmarking analysis for both versions 4B2 and 4C of the MCNP computer code.

A. Version 4B2 Benchmarking

The applicant chose 56 intermediate and high enriched uranium critical experiments, which are described in Section 5 of Appendix 4A of the SAR. The experiments are all taken from the International Handbook of Evaluated Criticality Benchmark Experiments (Briggs, 1999). Fifty-two of the critical experiments are high enriched ($80 weight percent ^{235}U) and four are at intermediate enrichments (17 to 20 weight percent ^{235}U).

The applicant determined the Upper Subcritical Limit (USL) using a statistical method from NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology." The applicant performed a trending analysis of the calculated k_{eff}s as a function of enrichment, average fission group, moderator-to-fuel volume ratio and energy of average lethargy causing fission. The applicant's linear regressions show very low R^2 values (<0.12) for both regressions, which indicated a poor correlation. Since trending of the data shows a poor correlation using linear regression, the applicant used the statistical evaluation of bias from Section 2.4.4 of NUREG/CR-6698. The applicant conservatively used the minimum k_{eff} calculated for all of the critical experiments to determining the USL. The applicant determined that the USL for MCNP Version 4B2 is 0.9130.

B. Version 4C Benchmarking

The applicant evaluated MCNP Version 4C for both Peach Bottom fuel and TRIGA fuel, because the benchmarking analysis resulted in different USLs for the two different fuel elements.

TRIGA Fuel

The applicant chose 72 intermediate and high enriched uranium critical experiments, which are described in Table 47 of Appendix 4A. The experiments are all taken from the International Handbook of Evaluated Criticality Benchmark Experiments (Briggs, 1999). Nine of the critical experiments are high enriched ($80 weight percent ^{235}U), eight are at intermediate enrichments (17 and 20 weight percent ^{235}U) and fifty-five are low enriched (<5 weight percent).

The applicant determined the USL using a statistical method from NUREG/CR-6698. The applicant performed a trending analysis of the calculated k_{eff}s as a function of enrichment, average fission group, moderator-to-fuel volume ratio and energy of average lethargy causing fission. The applicants linear regressions show very low coefficient of determination values (R^2<0.26), which indicated a poor correlation. Since trending of the data shows a poor correlation using linear regression, the applicant used the statistical evaluation of bias from Section 2.4 of NUREG/CR-6698. The applicant determined that the upper subcritical limit for MCNP Version 4C is 0.9268.

Peach Bottom Fuel

The applicant chose 58 intermediate and high enriched uranium critical experiments, which are described in Table 49 of Appendix 4A. The experiments are all taken from the International Handbook of Evaluated Criticality Benchmark Experiments (Briggs, 1999). All of the critical experiments are high enriched ($85 weight percent ^{235}U).

The applicant determined the Upper Subcritical Limit using a statistical method from NUREG/CR-6698. The applicant performed a trending analysis of the calculated k_{eff}s as a function of enrichment, average fission group, moderator-to-fuel volume ratio and energy of average lethargy causing fission. With one exception, the applicant's linear regressions show very low coefficient of determination values (R^2<0.23), which indicated a poor correlation. The exception was for enrichment, where the coefficient of determination (R^2) was 0.65. However, each of the k_{eff}s for enrichment was above 1.0, showing that the code overpredicts k_{eff}. Since trending of the data shows a poor correlation using linear regression, the applicant used the statistical evaluation of bias from Section 2.4 of NUREG/CR-6698. The applicant determined that the upper subcritical limit for MCNP Version 4C is 0.9304.

The staff reviewed the applicant's benchmark analysis and agrees that the critical experiments chosen are relevant to the cask design. The staff found the applicant's method for determining the calculation bias acceptable. The staff also verified that only biases that increase k_{eff} have been applied.

8.1.5 Burnup Credit in the Criticality Analysis

The applicant did not take credit for fuel burnup in the criticality analyses.

8.2 Evaluation Findings

The Idaho Spent Fuel Facility and its spent fuel transfer systems are designed to maintain spent fuel subcritical in all configurations. The criticality design is based on favorable geometry. Based on the information provided in the application and the staff's own confirmatory analyses, the staff concludes that the ISF Facility meets the acceptance criteria specified in 10 CFR Part 72. The staff reviewed the applicant's benchmark analysis and agrees that the critical experiments chosen are relevant to the facility design. The staff found the applicant's method for determining the USL acceptable. The staff also verified that only biases that increase k_{eff} have been applied.

The staff also finds, with reasonable assurance, that:

- The design, procedures, and materials to be stored at the proposed ISF Facility provide reasonable assurance that the activities authorized by the license can be conducted without endangering the health and safety of the public in compliance with 10 CFR §72.40(a)(13).

- The design and proposed use of the ISF Facility handling, packaging, transfer, and storage systems for the radioactive materials to be stored provide reasonable assurance that the materials will remain subcritical and, that, before a nuclear criticality accident is possible, at least two unlikely, independent, and concurrent or sequential changes must occur in the conditions essential to nuclear criticality safety. The ISF Facility SAR analyses and confirmatory analyses performed by the NRC staff adequately show that acceptable margins of safety will be maintained in the nuclear criticality parameters commensurate with uncertainties in the data and methods used in calculations. The analyses and information

provided demonstrated that adequate safety will be maintained for the handling, packaging, transfer, and storage of spent fuel during normal, off-normal, and accident conditions, in compliance with 10 CFR §72.124(a),(b) and (c).

8.3 References

J. Blair Briggs, Ed., *International Handbook of Evaluated Criticality Benchmark Experiments*, NEA/NSC/Doc/(95) 03, September 1999.