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## 6.0 CRITICALITY EVALUATION

This chapter documents the criticality evaluation of the Universal Transport Cask package with PWR and BWR payloads. The results demonstrate that the cask package design meets the criticality requirements of IAEA Safety Series No. 6 [2] and of 10 CFR 71 sections 71.55 and 71.59 [1]. For the cask containing either PWR or BWR payload, the value of the transport index for nuclear criticality control is determined to be zero and thus meets the requirements of 10 CFR 71.59. Therefore, an infinite number of packages remain subcritical during normal conditions of transport and hypothetical accident conditions. The transport index based on radiation is determined in Chapter 5.0.

### 6.1 Discussion and Results

The Universal Transport Cask is designed to safely transport 24 intact PWR fuel assemblies with an initial enrichment of 4.2 wt % <sup>235</sup>U or 56 intact BWR fuel assemblies 4.0 wt % <sup>235</sup>U. Primarily on the basis of their lengths and cross sections, the fuel assemblies are sorted into classes. Three classes of PWR fuel assemblies and two classes of BWR fuel assemblies are evaluated for transport. Five Transportable Storage Canister assemblies of different lengths and configuration are designed to transport the three classes of PWR fuel assemblies and the two classes of BWR fuel assemblies. The canister assembly includes a fuel basket within which fuel is loaded.

Criticality control in the PWR basket is achieved by using a flux trap principle. Individual fuel assemblies are surrounded by a neutron absorber and four BORAL sheets and are separated by a gap that is filled with water during hypothetical accident conditions when the canister is flooded. Fast neutrons escaping one fuel assembly are moderated in the gap between the assemblies and absorbed by the neutron poison surrounding the assemblies. The flux trap spacing is maintained by the baskets stainless steel support disks which separate individual fuel assembly tubes. Alternating stainless steel disks and aluminum heat transfer disks are placed axially at intervals determined by thermal and structural constraints. The PWR basket design includes 30, 32, or 34 support disks and 29, 31, or 33 heat transfer disks, respectively, depending upon the three classes of PWR fuel the basket is designed to contain. The minimum loading of the BORAL sheets in the PWR fuel tubes is 0.025 g <sup>10</sup>B/cm<sup>2</sup>. Steel cladding holds the BORAL sheets in place.

Individual fuel assemblies in the BWR basket are separated from adjacent fuel assemblies by a water gap and a single poison sheet. Although it does not form a flux trap during accident

conditions this type of arrangement also absorbs thermal neutrons in the poison sheet. Given the smaller amount of fissile material in BWR assemblies compared with PWR assemblies, the single poison sheet arrangement of the BWR basket provides criticality control at a cask neutron multiplication factor ( $k_s$ ) below 0.95. The assembly spacing is maintained by carbon steel disks separating individual fuel assembly tubes placed axially at intervals determined by thermal and structural constraints. Each BWR basket design includes 40 or 41 support disks, depending upon the class of BWR fuel the basket is designed to contain. The BWR basket design also includes 17 aluminum heat transfer disks. Of the total 56 fuel tubes in each BWR basket, 42 tubes contain BORAL sheets on two sides of the tubes; 11 tubes contain BORAL sheets on one side; and the remaining 3 tubes contain no BORAL. 95 BORAL sheets are sufficient to provide one sheet between any two adjacent fuel tubes. The minimum loading of the BORAL sheets in the BWR tubes is  $0.011 \text{ g }^{10}\text{B}/\text{cm}^2$ .

The SCALE 4.3 Criticality Safety Analysis Sequence (CSAS) [3, 4] is used to perform the Universal Transport Cask criticality analysis. This sequence includes KENO-Va [5] (Petrie) Monte Carlo analysis to determine  $k_{\text{eff}}$  under normal and accident conditions. The 27-group ENDF/B-IV neutron cross-section library [6] is used in all calculations, including those used to evaluate the sensitivity of the package to a range of moderator densities and center-to-center spacings. The most reactive PWR and BWR fuel assemblies, in their respective basket configuration, are used in the criticality calculations for the cask. The most reactive PWR assemblies are Westinghouse 17x17 OFA and the most reactive BWR fuel assemblies are Exxon/ANF (Ex/ANF) 9x9 with 79 fuel rods (see Section 6.4.1.2 for detailed discussion). These assemblies bound, respectively, all PWR (Classes 1-3) and BWR (Classes 4-5) fuel assemblies to be transported (see Table 6.2-1), as demonstrated in Section 6.4.1.2.

The MONK8a (AEA Technology) [20] Monte Carlo Program for Nuclear Criticality Safety Analysis is used to evaluate the change in reactivity as a result of the Universal Transport Cask top end drop accident scenario. Evaluation of this scenario is reported in Section 6.4.5.

The results of the criticality analyses are presented in Section 6.4. The values are summarized in Table 6.1-1.

Table 6.1-1 Summary of Criticality Analysis Results

Condition	PWR (Most Reactive Assembly Westinghouse 17×17 OFA)		BWR (Most Reactive Assembly Exxon/ANF 9×9)	
	$k_{\text{eff}} \pm \sigma$	$k_s$	$k_{\text{eff}} \pm \sigma$	$k_s$
Normal conditions:				
Wet-Inside and Outside-Fuel Intact (Single Cask)*	0.9247±0.0009	0.9387	0.9055 ± 0.0008	0.9196
Dry Inside and Optimum Moderation Outside Fuel Intact (Cask Array)	0.3988 ± 0.0007	0.4128	0.4005 ± 0.0008	0.4146
Hypothetical Accident Conditions (100% Fuel Failure):				
Wet Inside and Outside - 100% Fuel Failure (Cask Array)	0.9333 ± 0.0009	0.9475	0.9357 ± 0.0008	0.9497

\* Cask is loaded dry and transported dry. This set added to satisfy 10CFR71.55.

Conservatisms contained in these analyses are as follows.

1. Fuel assembly with maximum uranium loading (95% theoretical density).
2. 75% of the nominal  $^{10}\text{B}$  loading in the BORAL.
3. Infinite array of casks in the x-y plane.
4. Infinite fuel length with no inclusion of end leakage effects.
5. No structural material present in the assembly.
6. No dissolved boron in the cask cavity or surrounding loading or storage area.
7. No credit taken for fuel burnup or for the buildup of fission product neutron poisons.
8. Water inside fuel rod cladding, i.e., 100% fuel failure and water intrusion under accident conditions.
9. No control components in PWR assemblies; no burnable poison in PWR or BWR assemblies.

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## 6.2            Package Fuel Loading

The Universal Transport Cask is designed to transport one of five Transportable Storage Canisters of different lengths. Each canister is specifically designed to accommodate one of three classes of PWR fuel assemblies or one of two classes of BWR fuel assemblies. The classification of the fuel assemblies is based primarily on fuel assembly length and cross section. The classes of major fuel assemblies to be transported in the cask and their characteristics are shown in Tables 6.2-1 (PWR) and 6.2-2 (BWR). Limiting fuel axial dimensions for each class are provided in Table 6.2-3.



Table 6.2-1 PWR Fuel Assembly Characteristics (Zirc-4 Clad)

Fuel Class	Vendor	Array	Version	Max MTU	No of Fuel Rods	Pitch (in)	Rod Dia. (in)	Clad Thick (in)	Pellet Dia (in)	Active Length (in)
1	CE	14 x 14	Std.	0.4037	176	0.5800	0.440	0.0280	0.3765	137.0
1	CE	14 x 14	Ft Cal.	0.3772	176	0.5800	0.440	0.0280	0.3765	128.0
1	CE	15 x 15	Palis.	0.4317	216	0.5500	0.418	0.0260	0.3580	132.0
1	CE	16 x 16	Lucie 2	0.4025	236	0.5060	0.382	0.0250	0.3250	136.7
1	Ex/ANF	14 x 14	WE	0.3689	179	0.5560	0.424	0.0300	0.3505	142.0
1	Ex/ANF	14 x 14	CE	0.3814	176	0.5800	0.440	0.0310	0.3700	134.0
1	Ex/ANF	14 x 14	Praire Isl.	0.3741	179	0.5560	0.417	0.0300	0.3505	144.0
1	Ex/ANF	15 x 15	WE	0.4410	204	0.5630	0.424	0.0300	0.3565	144.0
1	Ex/ANF	15 x 15	Palis	0.4310	216	0.5500	0.417	0.0300	0.3580	131.8
1	Ex/ANF	17 x 17	WE	0.4123	264	0.4960	0.360	0.0250	0.3030	144.0
1	WE	14 x 14	Std/ZCA	0.4144	179	0.5560	0.422	0.0225	0.3674	145.2
1	WE	14 x 14	OFA	0.3612	179	0.5560	0.400	0.0243	0.3444	144.0
1	WE	14 x 14	Std/ZCB	0.4144	179	0.5560	0.422	0.0225	0.3674	145.2
1	WE	14 x 14	CE Model	0.4115	176	0.5800	0.440	0.0260	0.3805	136.7
1	WE	15 x 15	Std	0.4646	204	0.5630	0.422	0.0242	0.3659	144.0
1	WE	15 x 15	Std/ZC	0.4646	204	0.5630	0.422	0.0242	0.3659	144.0
1	WE	15 x 15	OFA	0.4646	204	0.5630	0.422	0.0242	0.3659	144.0
1	WE	17 x 17	Std	0.4671	264	0.4960	0.374	0.0225	0.3225	144.0
1	WE	17 x 17	OFA	0.4282	264	0.4960	0.360	0.0225	0.3088	144.0
1	WE	17 x 17	Vant 5	0.4282	264	0.4960	0.360	0.0225	0.3088	144.0
2	B&W	15 x 15	Mark B	0.4807	208	0.5680	0.430	0.0265	0.3686	144.0
2	B&W	15 x 15	Mark BZ	0.4807	208	0.5680	0.430	0.0265	0.3686	144.0
2	B&W	17 x 17	Mark C	0.4658	264	0.5020	0.379	0.0240	0.3232	143.0
3	CE	16 x 16	Sono 2&3	0.4417	236	0.5060	0.382	0.0250	0.3250	150.0
3	CE	16 x 16	ANO2	0.4417	236	0.5060	0.382	0.0250	0.3250	150.0
3	CE	16 x 16	SYS80	0.4417	236	0.5060	0.382	0.0250	0.3250	150.0

Table 6.2-2 BWR Fuel Assembly Characteristics (Zirc-2 Clad)

Fuel Class	Vendor	Array	Version	Max MTU	No of Fuel Rods	Pitch (in)	Rod Dia (in)	Clad Thick (in)	Pellet Dia (in)	Active Length (in)
4 <sup>(5)</sup>	Ex/ANF	7 X 7	GE	0.1960	48	0.738	0.570	0.036	0.490	144
4	Ex/ANF	8 X 8	JP-3	0.1764	63	0.641	0.484	0.036	0.4045	145.2
4	Ex/ANF	9 X 9	JP-3	0.1722	79	0.572	0.424	0.03	0.3565	145.2
4	GE	7 X 7	GE-2a	0.1985	49	0.738	0.570	0.036	0.488	144
4	GE	7 X 7	GE-2b	0.1977	49	0.738	0.563	0.032	0.487	144
4	GE	7 X 7	GE-3	0.1896	49	0.738	0.563	0.037	0.477	144
4	GE	8 X 8	GE-4	0.1855	63	0.640	0.493	0.034	0.416	144
4	GE	8 X 8	GE-5	0.1788	62	0.640	0.483	0.032	0.410	145.2
4	GE	8 X 8	GE-6 (prep)	0.1788	62	0.640	0.483	0.032	0.410	145.2
4	GE	8 X 8	GE-7 (barr)	0.1788	62	0.640	0.483	0.032	0.410	145.2
4	GE	8 X 8	GE-8	0.1730	60	0.640	0.484	0.032	0.410	145.2 <sup>(1)</sup>
4	GE	8 X 8	GE-10	0.1730	60	0.640	0.484	0.032	0.410	145.2 <sup>(1,2)</sup>
5 <sup>(6)</sup>	Ex/ANF	8 X 8	JP-4,5	0.1793	62	0.641	0.484	0.036	0.4045	150
5	Ex/ANF	9 X 9	JP-4,5	0.1779	79	0.572	0.424	0.03	0.3565	150
5	Ex/ANF	9 X 9	JP-4,5	0.1666	74	0.572	0.424	0.03	0.3565	150
5	GE	7 X 7	GE-2	0.1977	49	0.738	0.563	0.032	0.487	144
5	GE	7 X 7	GE-3a	0.1896	49	0.738	0.563	0.037	0.477	144
5	GE	7 X 7	GE-3b	0.1923	49	0.738	0.563	0.037	0.477	146
5	GE	8 X 8	GE-4a	0.1855	63	0.640	0.493	0.034	0.416	144
5	GE	8 X 8	GE-4b	0.1880	63	0.640	0.493	0.034	0.416	146
5	GE	8 X 8	GE-5	0.1847	62	0.640	0.483	0.032	0.410	150 <sup>(1)</sup>
5	GE	8 X 8	GE-6 (prep)	0.1847	62	0.640	0.483	0.032	0.410	150 <sup>(1)</sup>
5	GE	8 X 8	GE-7 (barr)	0.1847	62	0.640	0.483	0.032	0.410	150 <sup>(1)</sup>
5	GE	8 X 8	GE-10	0.1787	60	0.640	0.484	0.032	0.410	150 <sup>(1,2)</sup>
5	GE	9 X 9	GE-11	0.1854	74	0.566	0.441	0.028	0.376	150 <sup>(1,3,4)</sup>
5	GE	9 X 9	GE-11	0.1979	79	0.566	0.441	0.028	0.376	150 <sup>(1,3,4)</sup>

- Notes
1. 6-in, natural uranium blankets on top and bottom.
  2. 1 large water hole - 3.2 cm ID, 0.1 cm thickness.
  3. 2 large water holes occupying 7 fuel rod locations - 2.5 cm ID, 0.07 cm thickness.
  4. Shortened active fuel length in some rods.
  5. Class of fuel for BWR/2-3.
  6. Class of fuel for BWR/4-6.

Table 6.2-3 UMS Transport Cask Top End Impact Bounding Fuel Dimensions

UMS Canister Class	1	2	3	4	5
Vendor	WE	B&W	CE	Ex/ANF	Ex/ANF
Array	15 x 15	15 x 15	16 x 16	9 x 9	9 x 9
Active Length (inch)	144	144	150	145.2	150
Fuel Rod Height (inch)	152.756	153.125	161.168	155.52	160.288
Top End-Cap Height (inch)	0.685	0	0.5	1.675	1.685
Bottom End-Cap Height (inch)	0.685	0	0.891	0.355	0.355
Lower Plenum Region Height (inch)	0	4.5625	0	0	0
Fuel Assembly Height (inch)	160.1	165.625	176.803	171.29	176.058
Lower Nozzle Height (inch)	2.738	2	3.812	6.94	6.94
Upper Nozzle Height (inch)	3.48	8.875	9.723	7.5	7.5
Gap Fuel Rod To Bottom Nozzle (inch)	0	0	0	0	0
Upper Plenum Region Height (inch)	5.01	4.5625	9.527	9.58	9.578
Gap Fuel Rod To Top Nozzle (inch)	1.037	1.625	2.1	0	0
Limiting Distance From Assembly Top to Fuel, Rods To Assembly Top & Fuel Into 50% of Plenum (inch)	6.670	11.156	14.987	13.965	13.974

### 6.3 Criticality Model Specification

#### 6.3.1 Calculational Methodology

The SCALE 4.3 PC CSAS25 [3, 4] sequence and the SCALE 27-group neutron library are used to perform the criticality analysis of the Universal Transport Cask for transporting both PWR and BWR fuel. This sequence includes the SCALE Material Information Processor, [7] BONAMI-S, [8] NITAWL-S, [9] and KENO-Va [5]. The Material Information Processor generates number densities for standard compositions, prepares geometry data for resonance self-shielding, and creates data input files for the cross-section processing codes. The BONAMI-S and NITAWL-S codes are used to prepare a resonance-corrected cross section library in AMPX working format. The KENO-Va code uses Monte Carlo techniques to calculate the model  $k_{\text{eff}}$ . The 27-group ENDF/B-IV group neutron library is used in all KENO-Va cask criticality calculations.

The CSAS criticality analysis sequence is validated through a series of calculations based on critical experiments performed by Babcock and Wilcox (B&W), Pacific Northwest Laboratory (PNL), and Valduc Critical Mass Laboratory (VCML). The 27-group ENDF/B-IV neutron cross-section library is used in the validation, which includes statistical analysis of results. Validation of the CSAS and the method statistics are addressed in Section 6.5.

The criticality analysis of the Universal Transport Cask is performed in several steps.

The MONK8a (AEA Technology) [20] Monte Carlo Program for Nuclear Criticality Safety Analysis is used to evaluate the change in reactivity as a result of the Universal Transport Cask top end drop accident scenario. This code employs the Monte Carlo technique in combination with JEF 2.2-based point energy neutron libraries to determine the effective neutron multiplication factor ( $k_{\text{eff}}$ ). The specific libraries are dec96j2v5 for general neutron cross section information and therm96j2v2 for thermal scatter data in the water moderator. MONK8a, with the JEF 2.2 neutron cross section libraries, is benchmarked by comparison to critical experiments relevant to Light Water Reactor fuel in storage and transport casks as shown in Section 6.5.5:

- The major PWR and BWR fuel assembly designs provided in Tables 6.2-1 and 6.2-2 are screened to identify sets of standard PWR and BWR arrays to be included for criticality analysis.

- The identified sets of arrays are analyzed to determine the most reactive PWR and BWR fuel assemblies for design basis.
- The criticality impact of mechanical perturbations and geometric tolerances is resolved on the basis of a fuel tube-in-basket model (PWR) and a basket in-cask-model (BWR) in which the most reactive assembly is used. See Section 6.4.1.2, the most reactive assembly analysis, for a description of the fuel tube-in-basket (PWR) and basket-in-cask (BWR) models.
- A canister-in-transport cask model is prepared to evaluate the reactivity variation between normal and worst-case configuration of the cask contents under normal and hypothetical accident conditions.
- Values of  $k_{\text{eff}}$  and  $k_s$  (the bias adjusted  $k_{\text{eff}}$ ) are evaluated for a single cask and for an array of casks. The evaluation is based on the worst-case configured cask basket under normal operating and accident conditions.

The results of criticality calculations for PWR and BWR assembly loaded casks are provided in Sections 6.4.3.2 and 6.4.3.3, respectively.

### 6.3.2 Basket Model Assumptions

Assumptions for the basket model are as follows.

- The fuel assembly is modeled at a fuel density of 95% theoretical ( $0.95 \times 10.96 \text{ gm/cm}^2 = 10.412 \text{ g/cm}^2$ ).
- Baseline enrichment for the PWR fuel assembly is 4.2 wt%  $^{235}\text{U}$ . The PWR fuel assembly included in this model is the Westinghouse 17×17 OFA fuel assembly which is determined to be the most reactive assembly in the PWR basket (see Section 6.4.1.2.1). The most reactive BWR fuel assembly included in this model is the Ex/ANF 9×9 fuel assembly with an enrichment of 4.00 wt%  $^{235}\text{U}$  (see Section 6.4.1.2.2). BWR analysis of heterogeneous versus homogeneous pin enrichment shows that assuming a homogeneous “bundle average” enrichment produces conservative  $k_{\text{eff}}$  values in the BWR canister (see section 6.4.1.3.2).

- No fuel assembly structural materials (e.g., spacer grids) are included in the active fuel region (except for the fuel assembly channels in the BWR case). Eliminating the structural materials simplifies model construction significantly. Removing parasitic absorbers and increasing the effective H/U ratio in the normally under-moderated assembly increases reactivity. Evaluation of the reactivity impact for a variety of channel dimensions in the BWR most reactive assembly analysis demonstrates that the impact of the channel material on cask criticality is not statistically significant. Removal of the channel on the most reactive assembly (Ex/ANF 9x9) resulted in  $k_{\text{eff}}$  decrease of 0.001 from 0.872 to 0.871 with a Monte Carlo uncertainty of 0.001.
- Fuel assembly neutron poisons, e.g., gadolinium rods (BWR), are excluded from the analysis, thereby substantially increasing assembly reactivity of the unburned assembly.
- The array for all KENO-Va analyses is axially infinite, i.e., no axial leakage.
- Geometric tolerances and mechanical perturbations (fuel movement in tube, tube movement in the disk opening, and combined fuel and tube movement) are analyzed to arrive at the highest reactivity basket configuration. PWR system geometric tolerances and mechanical perturbations are initially evaluated by using an "infinite array" of tubes in the basket model. An "infinite array" of tubes is produced by modeling mirrored boundary conditions in the x-y plane and a single fuel tube surrounded by the basket structure out to one half the web width. A basket-in-canister model taking into account any positive biases determined from the single-tube-in-basket model is the "worst case," highest reactivity, transport cask configuration. BWR geometric tolerances and mechanical perturbations are directly evaluated by a basket-in-cask model.
- Fuel assembly cladding is intact. For normal operating conditions, no water is present in the gap between fuel pellet and clad. For hypothetical accident conditions, water is present in the pellet-to-clad gap. Because the cask is shown not to fail structurally under normal or accident conditions and the presence of water in the pellet-to-clad gap requires failure of the sealed canister and fuel in addition to failure of the cask, the assumption of water in the pellet-to-clad gap for accident analysis is extremely conservative.
- Full-density moderator is water at standard temperature and pressure (293°K and 0.9982 g/cm<sup>3</sup>).

- Fuel, cladding, and structural materials are at 293°K.
- $^{10}\text{B}$  density is reduced to 75% in accordance with 10 CFR 71 licensing guidance and requirements provided in the "Standard Review Plan for Dry Cask Storage Systems" (NUREG-1536) [11].
- The basket will retain their structure and will not show any significant permanent deformation during normal or accident conditions.
- The basket-in-transport-cask model for the KENO-Va neutron shield dimensions for the account for radial neutron shield expansions space (1/8 in. modeled as void) and an equivalent volume neutron shield and neutron shield shell thickness.
- During the top end drop accident condition, all fuel rods in each assembly are shifted to the top of the assembly, the fuel within these rods are shifted up half the height of the plenum, and each assembly is shifted up until it is in contact with the lid, while the tolerated basket remains in contact with the canister bottom plate.

### 6.3.3 Description of Calculational Models

The Universal Transport Cask PWR KENO-Va model is derived from a cylindrical segment of the cask at the active fuel region. The model is a stack of four slices containing one aluminum disk, two identical water regions, and one steel disk region (stack is aluminum, water, steel, water). The basket is modeled in each slice and contains 24 design basis PWR fuel assemblies at 4.2 wt%  $^{235}\text{U}$  enrichment and fuel density corresponding to a 95% theoretical fuel density. The fuel pin array is explicitly modeled in each of the 24 possible locations. Each basket slice is surrounded by the cask body shielding regions of steel, lead, steel, NS4FR and steel. Each cask slice is surrounded by a cuboid. The four slices are stacked into the KENO global unit.

The KENO-Va model for the cask containing BWR fuel is also derived from a cylindrical segment of the cask at the active fuel region. The model is a stack of four slices, one at the carbon steel disk elevation and thickness, one at the aluminum disk elevation and thickness, and two composed of the water space between disks. The basket is modeled in each slice and contains 56 design basis BWR fuel assemblies at 4.00 wt%  $^{235}\text{U}$  enrichment and fuel density corresponding to a 95% theoretical fuel density. The fuel pin array is explicitly modeled in each

of the 56 possible locations. Each basket slice is surrounded by the cask body shielding regions of steel, lead, steel, NS4FR, and steel. Each cask slice is surrounded by a cuboid. The two slices are stacked into the KENO global unit.

In both the PWR and BWR KENO-Va models, periodic boundary conditions are imposed on the top and bottom of the global KENO-Va unit to simulate an infinite cylinder, and reflecting boundary conditions are imposed on the sides, thereby simulating an infinite number of casks in the x-y plane. The reflecting boundary condition on the exterior cuboids x-y faces forms a square pitch array. As shown in Section 6.4 the transport casks are neutronicly isolated from one another. Therefore no further array configuration (i.e. triangular pitch) requires analysis. Moderator density is varied both in the cask cavity regions voided during normal operations and in the exterior cuboid. Cask center-to-center spacing is varied by the x-y dimensions of the exterior cuboid. The same model is used in analysis of both normal and accident conditions except that the model for accident conditions assumes that the canister interior is wet and the radial neutron shielding (NS4FR) is replaced by external moderator.

The Universal Transport Cask PWR and BWR KENO-Va Basket Cell models are shown in Figure 6.3-1 and Figure 6.3-2, respectively. The PWR and BWR cask KENO-Va models are shown in Figure 6.3-3 and Figure 6.3-4, respectively. Criticality control provisions in the PWR and BWR basket designs are illustrated in Figures 6.3-5 and 6.3-6, respectively.

The MONK8a model geometry is constructed as a finite model that accurately represents the geometry of the canister, the fuel and the basket. The transport cask neutron shield and neutron shield shell are not modeled. Instead, a cylindrical reflector is placed on the surface of the outer shell. The MONK8a criticality code relies on a combinatorial logic geometry package. Therefore, the fuel basket, canister, and cask components are specified by intersecting simple geometry bodies. The appropriate value of each of the geometry bodies is set to recreate the worst case basket/cask condition determined in the KENO-Va analyses, and is then modified to evaluate axial shifting of the contents of the canister.



#### 6.3.4 Package Regional Densities

The densities used in the KENO-Va criticality analyses are as follows.

Material	Density (g/cc)
UO <sub>2</sub>	10.412 (95% theoretical)
Zircaloy	6.56
H <sub>2</sub> O	0.9982
Stainless steel	7.92
Carbon steel	7.82
Lead	11.35
Aluminum	2.70
BORAL (core) PWR	2.60
BORAL (core) BWR	2.68
NS-4-FR	1.63

##### 6.3.4.1 Fuel Region

Fuel rod densities for normal operations conditions are shown below.

Material	Element	Density (atoms/barn-cm)
UO <sub>2</sub> (4.2 wt % <sup>235</sup> U)	<sup>235</sup> U	$9.877 \times 10^{-4}$
	<sup>238</sup> U	$2.224 \times 10^{-2}$
	O	$4.646 \times 10^{-2}$
UO <sub>2</sub> (4.0 wt % <sup>235</sup> U)	<sup>235</sup> U	$9.406 \times 10^{-4}$
	<sup>238</sup> U	$2.229 \times 10^{-2}$
	O	$4.646 \times 10^{-2}$
Zircaloy	Zr	$4.331 \times 10^{-2}$
H <sub>2</sub> O	H	$6.677 \times 10^{-2}$
	O	$3.338 \times 10^{-2}$

6.3.4.2 Cask Material

Cask material densities for normal operations conditions are as follows:

Material	Element	Density (atoms/barn-cm)
Boral core (0.025 g <sup>10</sup> B/cm <sup>2</sup> )	<sup>10</sup> B	$8.880 \times 10^{-3}$ (75% of Nominal)
	<sup>11</sup> B	$4.906 \times 10^{-2}$
	C	$1.522 \times 10^{-3}$
	Al	$2.694 \times 10^{-2}$
Boral core (0.011 g <sup>10</sup> B/cm <sup>2</sup> )	<sup>10</sup> B	$2.212 \times 10^{-3}$ (75% of Nominal)
	<sup>11</sup> B	$1.219 \times 10^{-2}$
	C	$3.786 \times 10^{-3}$
	Al	$5.217 \times 10^{-2}$
Aluminum	Al	$6.031 \times 10^{-2}$
Steel 304	Cr	$1.743 \times 10^{-2}$
	Fe	$5.936 \times 10^{-2}$
	Ni	$7.721 \times 10^{-3}$
	Mn	$1.736 \times 10^{-3}$
Carbon steel	C	$3.925 \times 10^{-3}$
	Fe	$8.350 \times 10^{-2}$
Lead	Pb	$3.297 \times 10^{-2}$
NS4FR	H	$5.854 \times 10^{-2}$
	O	$2.609 \times 10^{-2}$
	C	$2.264 \times 10^{-2}$
	N	$1.394 \times 10^{-3}$
	Al	$7.763 \times 10^{-3}$
	<sup>11</sup> B	$3.422 \times 10^{-4}$
	<sup>10</sup> B	$8.553 \times 10^{-5}$

#### 6.3.4.3 Water Reflector Densities

The material densities for the water reflector outside the cask under normal operations conditions are as follows.

<u>Material</u>	<u>Element</u>	<u>Density (atoms/barn-cm)</u>
H <sub>2</sub> O	H	$6.677 \times 10^{-2}$
	O	$3.338 \times 10^{-2}$

Figure 6.3-1 Universal Transport Cask KENO-Va PWR Basket Cell Model

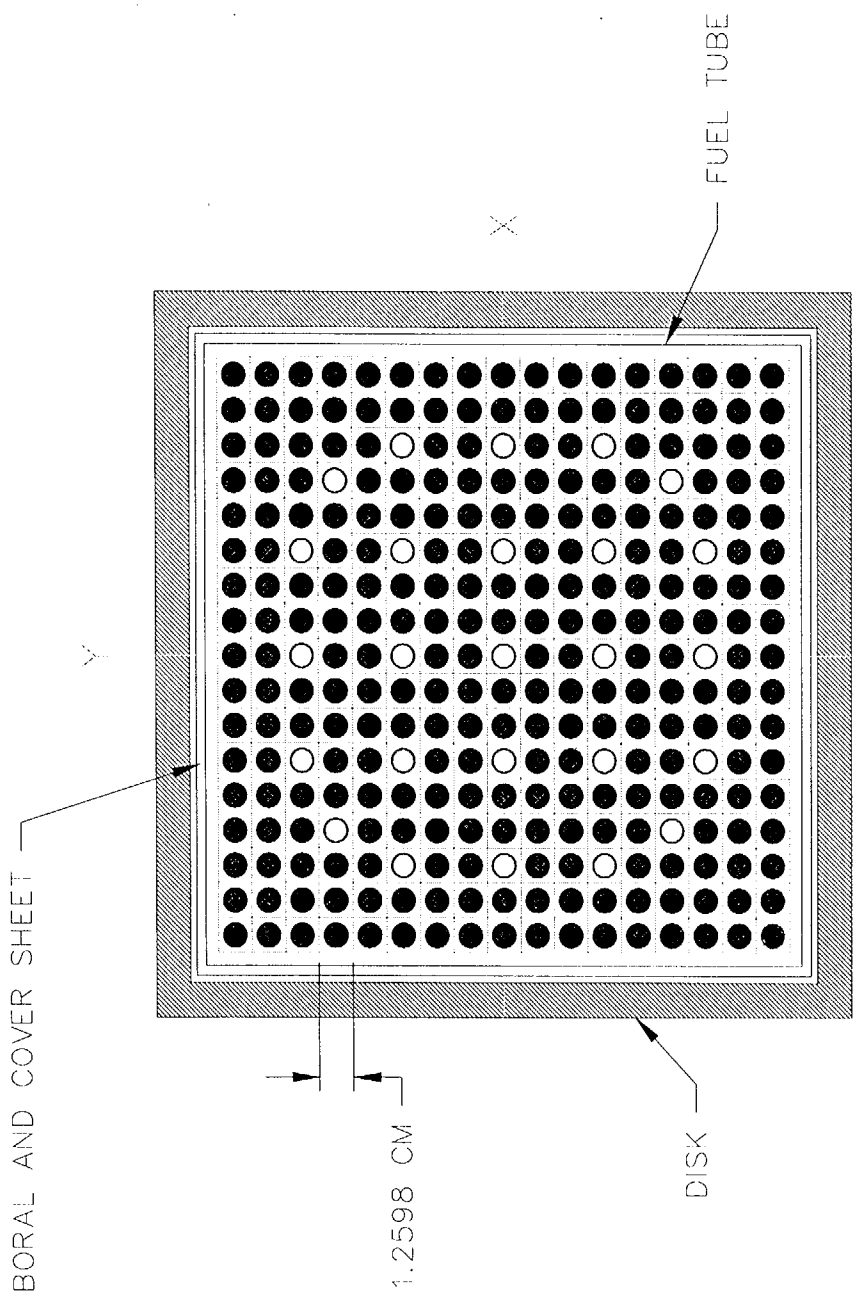


Figure 6.3-2 Universal Transport Cask KENO-Va BWR Basket Cell Model

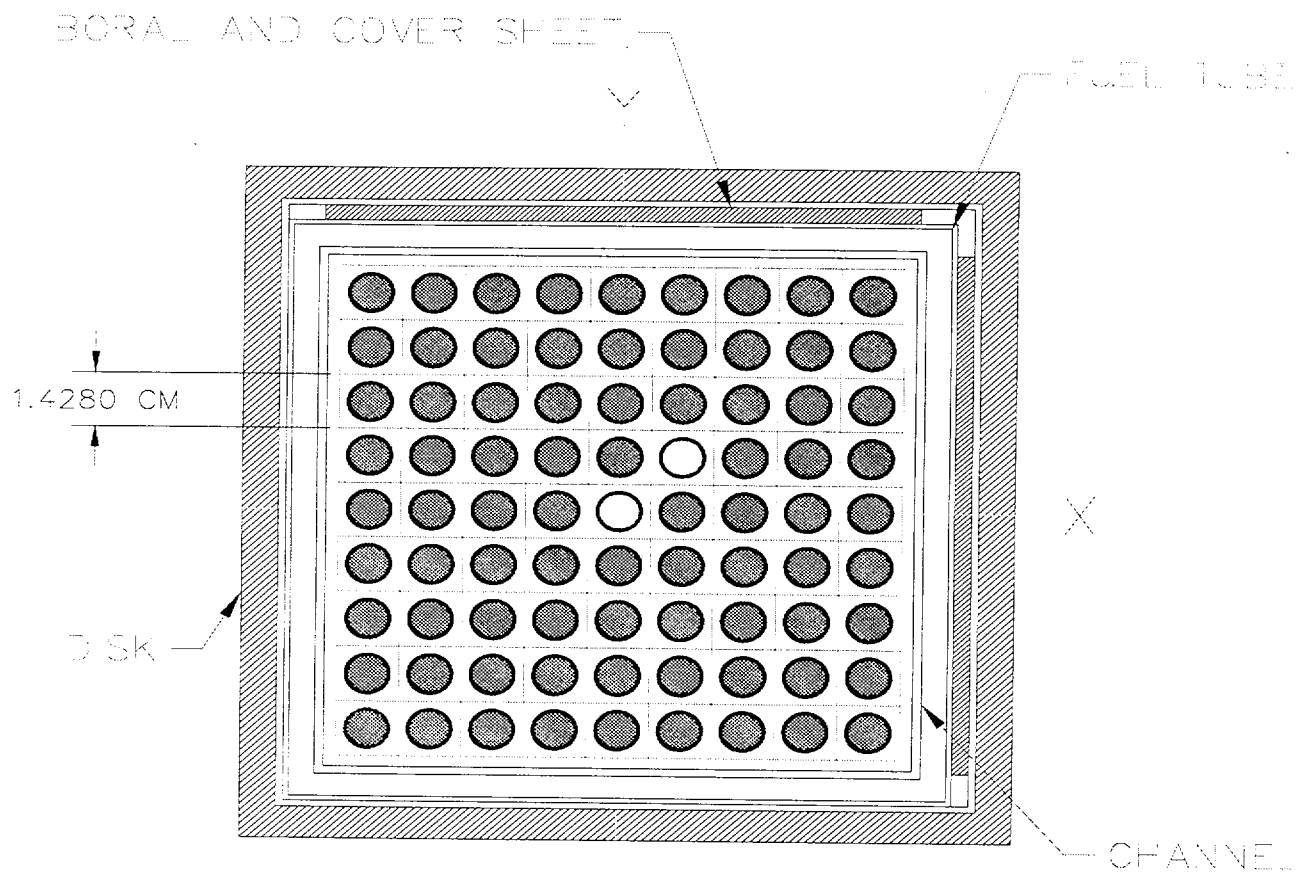


Figure 6.3-3 Universal Transport Cask PWR KENO-Va Cask Model

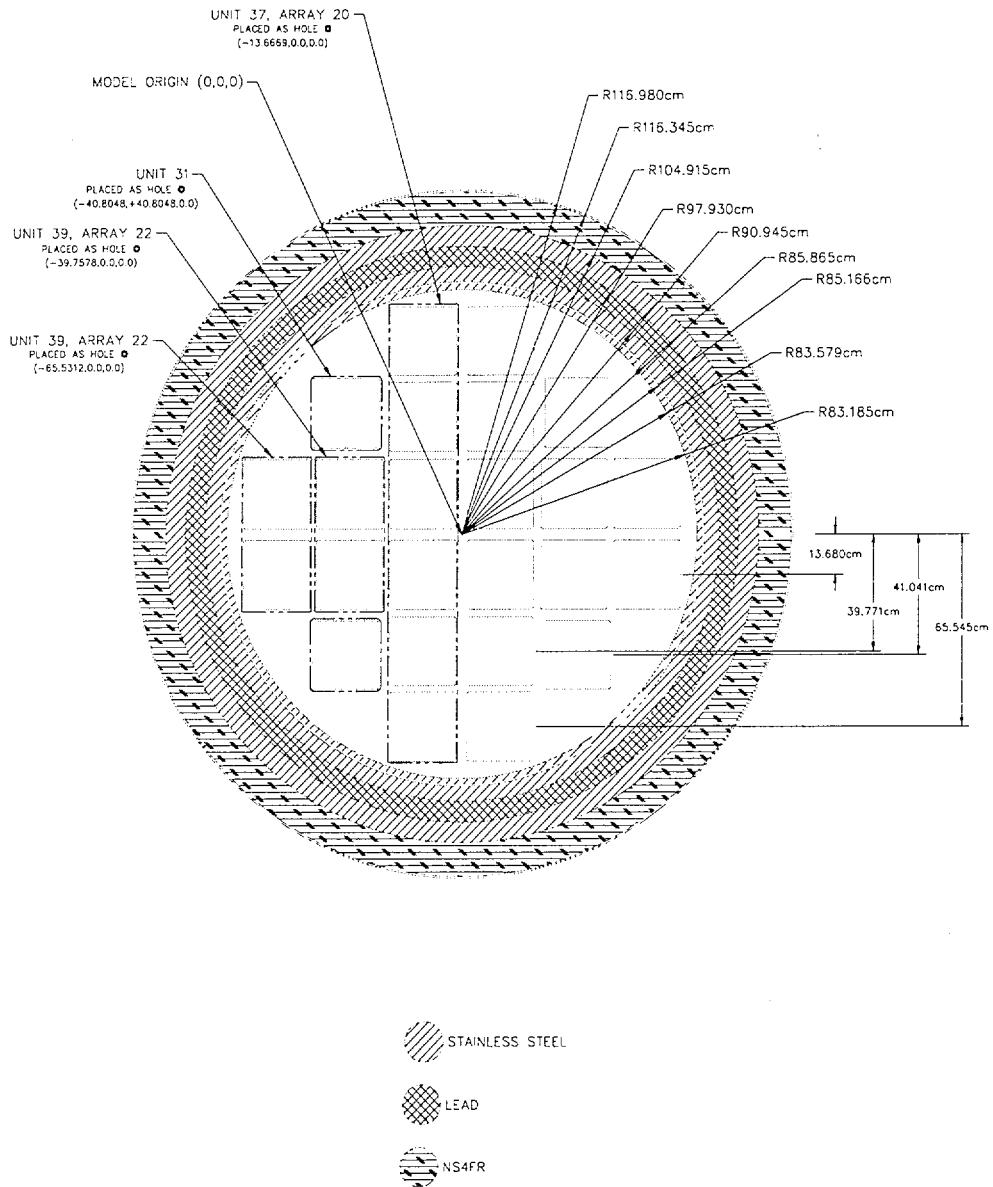


Figure 6.3-4 Universal Transport Cask BWR KENO-Va Cask Model

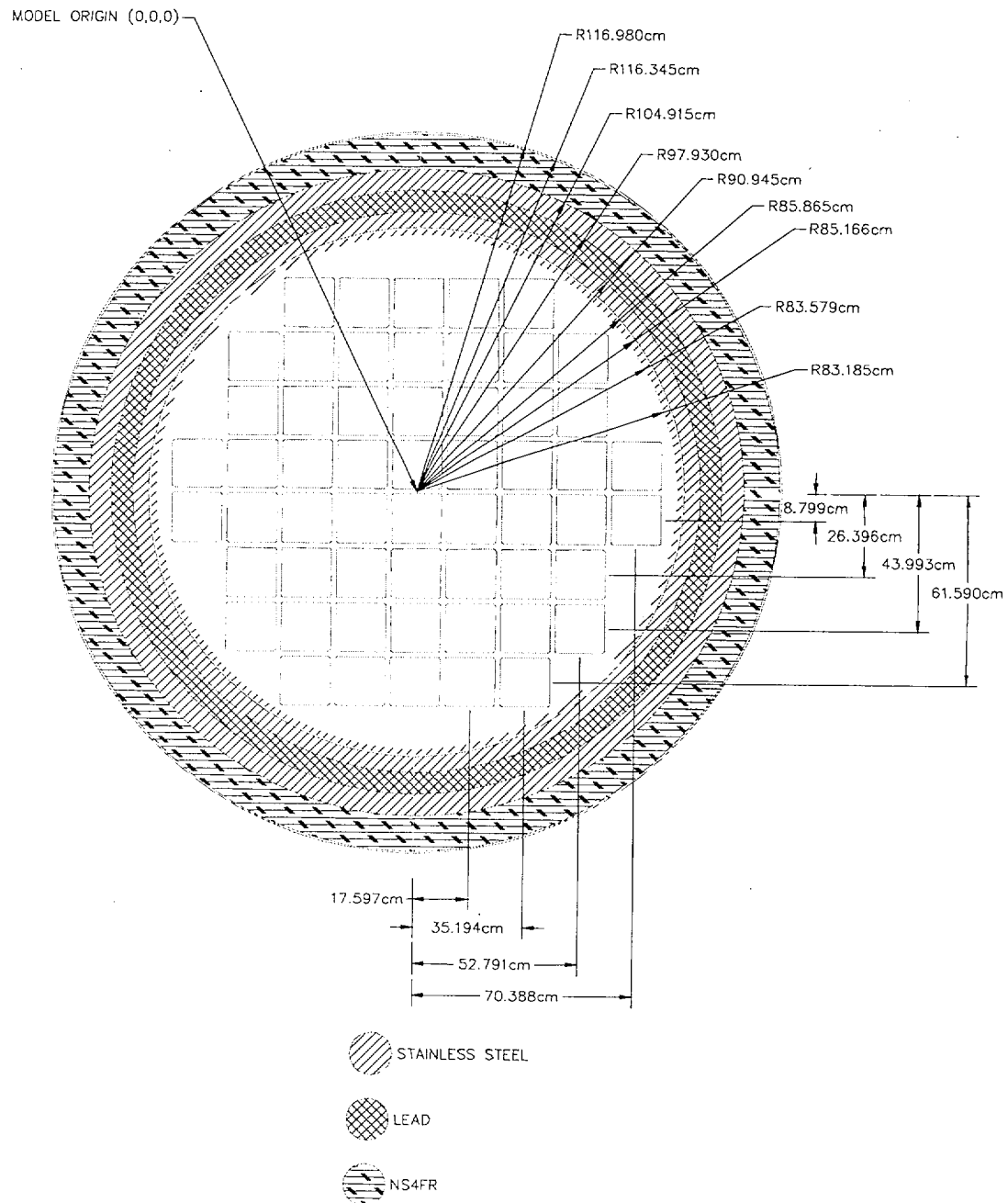


Figure 6.3-5 PWR Basket Criticality Control Design

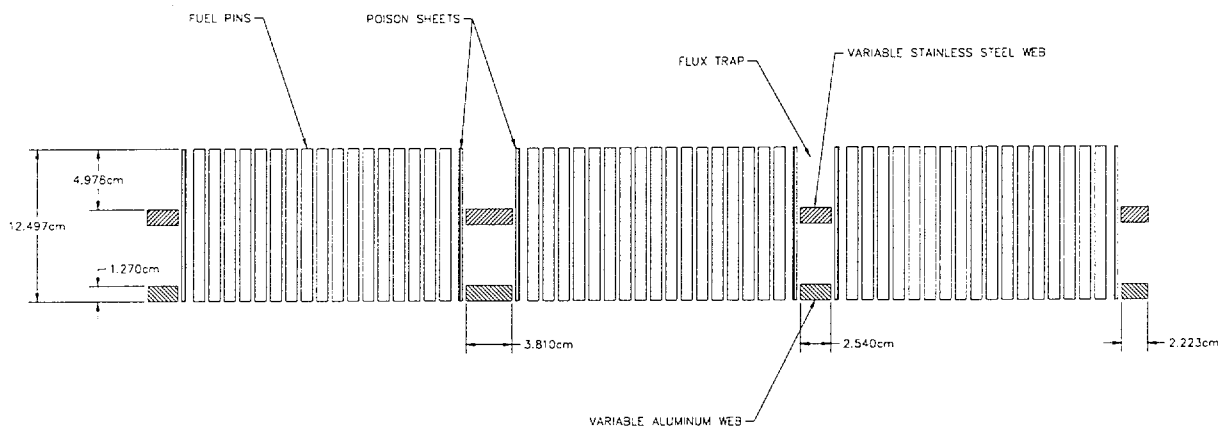
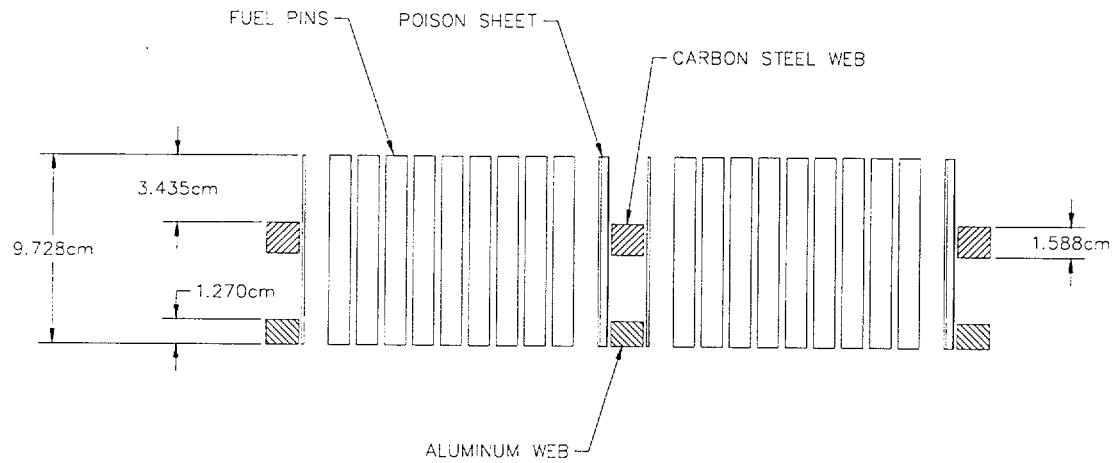




Figure 6.3-6 BWR Basket Criticality Control Design



## 6.4 Criticality Calculation

### 6.4.1 Calculational or Experimental Method

As discussed earlier, criticality analysis of the Universal Transport Cask involves identification of fuel arrays for analysis, determination of most reactive PWR and BWR assemblies, and cask criticality analysis. Detailed discussion follows.

#### 6.4.1.1 Determination of Fuel Arrays for Criticality Analysis

As shown previously, the maximum values for physical dimensions, cross sections, and weights vary among the fuel assemblies. Therefore, qualitatively determining one enveloping assembly for the Universal Transport Cask criticality analysis is difficult. Thus, a set of standard fuel arrays in the basket configuration is selected and modeled with KENO-Va. The selected standard PWR and BWR assemblies qualitatively bound other assemblies in their sub classes and are as follows.

#### PWR Fuel Assemblies

- |                              |                               |
|------------------------------|-------------------------------|
| • B&W 15x15 Mark B           | • Westinghouse 14x14 (CE)     |
| • B&W 15x15 Mark BZ          | • Westinghouse 15x15 Std      |
| • B&W 17x17 Mark C           | • Westinghouse 15x15 Std/ZC   |
| • CE 14x14 Standard          | • Westinghouse 15x15 OFA      |
| • CE 14x14 Ft. Calhoun       | • Westinghouse 17x17          |
| • CE 14x14 Palisades         | • Westinghouse 17x17 Vant5    |
| • CE 14 x14 Lucie 2          | • Westinghouse 17x17 OFA      |
| • CE 16x16 System 80         | • Ex/ANF 14x14 (CE)           |
| • CE 16x16 San Onofre 2&3    | • Ex/ANF 14x14 (WE)           |
| • CE 16x16 ANO2              | • Ex/ANF 14x14 (Prairie Isl.) |
| • Westinghouse 14x14 Std/ZCA | • Ex/ANF 15x15 (WE)           |
| • Westinghouse 14x14 Std/ZCB | • Ex/ANF 15x15 (Palisades)    |
| • Westinghouse 14x14 OFA     | • Ex/ANF 17x17 (WE)           |

#### BWR Fuel Assemblies

- Ex/ANF 7x7 GE
- Ex/ANF 8x8 JP-3
- Ex/ANF 8x8 JP-4, 5
- ExANF 9x9 JP-3
- ExANF 9x9 JP4, 5
- ExAnf 9x9 JP4, 5
- GE 7x7 GE-2a
- GE 7x7 GE-2b
- GE 7x8 GE-2b
- GE 7x7 GE-2
- GE 7X7 GE-3
- GE 7X7 GE-3a
- GE 7X7 GE-3b
- GE 8x8 GE-4a
- GE 8x8 GE-4b
- GE 8X8 GE-5
- GE 8X8 GE-5
- GE 8X8 GE-6 (prep)
- GE 8x8 GE-6 (prep)
- GE 8x8 GE-7 (barr)
- GE 8x8 GE-7 (barr)
- GE 8x8 GE-8
- Ge 8x8 GE-10
- GE 8x8 GE-10
- GE 9x9 GE-11
- GE 9x9 GE-11

#### 6.4.1.2 Most Reactive Fuel Assembly Determination

To determine the most reactive assembly within each type of fuel, a KENO-Va calculation is performed for the PWR and BWR fuel assemblies identified in Section 6.4.1.1. The calculated  $k_{eff}$  values for the various classes of fuel are given in Table 6.4-1 (located at the end of this section). The model for the PWR and the BWR fuel assembly types is discussed in the following paragraphs. On the basis of this analysis, the Westinghouse 17x17 OFA fuel assembly is determined to be the most reactive PWR fuel assembly. The Ex/ANF 9 x 9 fuel assembly is determined to be the most reactive BWR fuel assembly.

#### 6.4.1.2.1 Most Reactive PWR Assembly Analysis

The most reactive assembly analysis is based on a single assembly model. The assembly is in the PWR basket surrounded by the steel tube, four BORAL sheets, BORAL cover sheets, water to disk gap and steel, aluminum or water disk material. For the most reactive assembly analysis, the assembly is centered in the tube and the tube centered in the disk opening. Web thickness of 1.5, 1.0 and 0.875 in. is present in the PWR basket. Web thickness is assumed to have minimal

impact on the most reactive assembly analysis. Therefore, the analysis is performed for a web thickness of 1.0 inch.

To simplify modeling, three basket slices are made at the active fuel elevation: one at the stainless steel disk elevation and thickness, one at the aluminum disk elevations and thickness, and one at the water gap between disks. By stacking four of the slices (water, steel, water, and aluminum) on top of one another and periodically reflecting the disk stack, an axially infinite fuel-assembly-in-basket model is built. Building an axially infinite model eliminates axial leakage.

With the exception of the axial (z) length, identical KENO-Va units are constructed for fuel pins, guide/instrument tubes, and poison sheets in the water and disk slice. BORAL sheet KENO-Va units are required, one sheet running parallel to the x plane, and one for the y plane for disk and water elevations. Axial dimensions for these units are made equal to either the water gap between disks or the disk heights (stainless steel disk and aluminum disk). In this analysis, all unit cells, except for the global unit, are centered on themselves, which implies symmetric upper and lower z elevation bounds.

After establishing fuel pin, guide tube, instrument tubes and BORAL sheet KENO-Va units, the fuel assembly arrays are constructed. The fuel assembly array, composed of fuel pins and guide/instrument tubes, is surrounded by a water gap, the fuel tube, and a water gap equal in x, y dimensions to the exterior of the BORAL sheet. The BORAL sheets are placed as holes into the water cuboid surrounding the tube. The cuboid containing the BORAL sheets is then surrounded by a thin encapsulating shell and a water cuboid out to the disk opening. Surrounding the disk opening cuboid is either water or disk material out to one half the web thickness (in this case 0.5 in. of material). The fuel tube is centered in the disk opening and the assembly is centered in the tube.

The three complete fuel assembly/basket units are axially stacked in the GLOBAL unit, with mirrored boundary conditions in the x, y plane to model an infinite array of tubes in the disk. An axially infinite model is created by using periodic boundary conditions on the top and bottom of the global KENO-Va unit.

Calculated values of  $k_{eff}$  for the PWR assemblies selected for most reactive assembly analysis are listed in Table 6.4-1 (located at the end of this section). The table includes data for assemblies with water in the fuel-pellet-to-cladding gap and for assemblies with no water in the gap. Also included is a  $\Delta k$  between the dry and wet cases.  $k_{eff}$  values in Table 6.4-1 are for a representative 1.0" flux trap, a  $^{10}\text{B}$  areal density of  $0.02 \text{ g/cm}^2$  and infinite array of tubes in disk and therefore  $k_{eff}$  exceed 0.95 for a number of the assemblies analyzed. However bias and uncertainty adjusted  $k_{eff}$  values for all assemblies are below 0.95 in the UMS transport cask.

Table 6.4-1 results are based on a web width of 1.0 in. The basket centerline web thickness is 1.5 in. To assure that the most reactive assembly calculation applies to the whole basket and to verify that web spacing does not impact results, Table 6.4-2 (located at the end of this section) is generated to include reactivity data for the highest reactivity assemblies in a 1.5-in. web.

From the 1.0-in. web, dry gap analysis, the Westinghouse 15x15 fuel assembly has a 0.0005 higher  $k_{eff}$  than the Westinghouse 17x17 OFA assembly. However, given the 0.001 Monte Carlo uncertainty associated with the  $k_{eff}$  values calculated, no statistically significant difference exists between the  $k_{eff}$  values. The 1.5-in. web analysis results in a statistically significantly higher  $k_{eff}$  for the Westinghouse 17x17 OFA assembly than for the Westinghouse 15x15 assembly, a  $\Delta k_{eff}$  of +0.005.

#### 6.4.1.2.2 Most Reactive BWR Assembly Analysis

The most reactive assembly analysis is based on the full cask model. Assemblies in the BWR basket are surrounded by the assembly channel, channel-to-tube gap, steel fuel tube, BORAL sheet and BORAL cover sheet on applicable sides of the tube, water-to-disk gap, and steel and aluminum disk material. For the most reactive assembly analysis, the assembly is centered in the tube and the tube centered in the disk opening. To simplify modeling, three basket slices are made at the active fuel elevation: one at the carbon steel disk elevation and thickness, one at the aluminum disk elevation and thickness, and one at the water gap between disk elevation and thickness. Each of the disks containing the fuel tubes is surrounded by the canister shell and transport cask radial shields. By stacking the three cask slices on top of one another and periodically reflecting the stack, an axially infinite cask model is built. Building an axially infinite model eliminates axial leakage. Into each of the basket slices the 56 disk openings are inserted as KENO-Va HOLE's. Each of the disk openings contain a KENO-Va HOLE

representing the fuel tube which in turn has the fuel assembly, including channel, inserted as a HOLE. This modeling approach allows simple component movement, fuel tube or fuel assembly, by simply modifying the HOLE origin coordinate.

Calculated values of  $k_{eff}$  for the BWR assemblies selected for analysis of the most reactive assembly are provided in Table 6.4-3 (located at the end of this section). The table includes data for with no water in the pellet-to-clad gap. As can be seen from the table, the most reactive is the Ex/ANF 9x9 fuel assembly with 79 fuel pins and 2 water rods. It is statistically significantly more reactive than any of the other BWR assemblies analyzed, therefore no "wet" gap cases were analyzed.

#### 6.4.1.3 Universal Transport Cask Criticality Analysis

The KENO-Va models employed in the Universal Transport Cask criticality analysis are built on those developed in the most reactive assembly calculations (See Section 6.4.1.2). The transport cask criticality analysis is performed in three steps.

1. Resolution of the criticality impact of mechanical perturbations and geometric tolerances on the basis of a fuel tube-in-basket model (PWR) and basket-in-cask-model (BWR) using the most reactive assembly.
2. Preparation of a basket-in-cask model (PWR) to evaluate the reactivity variation between normal and worst-case configuration. (A BWR basket-in-cask model having been constructed in step 1 for the most reactive assembly analysis.)
3. Evaluation of  $k_{eff}$  and  $k_s$  for a single cask and for an array of casks on the basis of the worst-case configured cask basket under normal and accident conditions.

Construction of the cask criticality models for normal and accident conditions involves modifications to moderator compositions, cask spacing, material in the gap between fuel pellet and clad, and cask neutron shield material description.

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6.4.1.3.1 Universal Transport Cask Containing PWR Fuel

Mechanical Perturbations and Geometric Tolerance: Fuel Tube in PWR Basket Unit Cell Model

Because of the gaps between the fuel assembly and the fuel tube, and between fuel tube and disk opening, a certain amount of mechanical perturbation to the system is possible. In addition, manufacturing tolerances in the basket cause variation in the gaps and basket disk hole positions. The criticality impact of such mechanical variations is evaluated with a KENO-Va model of the PWR basket unit cell. The following mechanical perturbations and geometric tolerances are evaluated:

- a. Fuel assembly movement in the tube,
- b. Fuel tube movement in the disk opening,
- c. Variation in the basket tube opening,
- d. Variation in disk opening, and
- e. Variation in positioning of the disk opening,

Fuel assembly movement in the tube is based on the physical limits of the inside envelope of the tube and the width of the fuel assembly array. For the design basis fuel, the maximum movement within the tube is  $\pm 0.184$  in. (0.468cm). As a result of PWR basket tube symmetry, only one movement direction requires analysis. Fuel assembly movement is bounded by shifting the fuel assembly to the upper right-hand corner of the basket tube. This corner movement maximizes the reactivity impact of movement in one direction.

Similarly, movement of the fuel tube is maximized by shifting to the upper right hand corner of the basket disk opening. The maximum tube movement in the basket disk opening is  $\pm 0.095$  in. (0.242cm). The tube outer BORAL sheet, and BORAL cover sheet dimensions are moved based on the inner tube dimension plus the relevant material thickness.

Both the fuel assembly movement and the fuel tube movement are analyzed with periodic and mirrored boundary conditions. The periodic boundary condition approximates a shift of all assemblies/fuel tubes in the basket to one side. The mirrored boundary approximates clusters of four assemblies or fuel tubes moved towards a central location.

Variation in tube opening is evaluated by adding and subtracting a tolerance of  $\pm 0.030$  in. (0.076cm) to the nominal dimensions and adjusting the BORAL sheet and cover sheet positions accordingly. Variation in basket disk opening also is modeled by adding or subtracting a tolerance of  $\pm 0.015$  in. (0.038cm) to the nominal dimension of the opening. The tolerance on the opening size modifies the web thickness but does not impact tube positioning.

Variation in basket disk opening position is limited by the positional tolerance within the diameter of 0.015 in. (0.038cm). As with the fuel assembly and tube movements, the reactivity effect of the opening position is maximized by shifting the opening to the upper right hand corner by  $0.0053$  in.  $(0.0075^2/2)^{1/2}$  in both +x and +y directions. This minimizes the webbing and corresponding flux trap gap effectiveness.

The results of the PWR basket unit cell perturbation evaluations are shown in Table 6.4-4.

#### Mechanical Perturbations and Geometric Tolerance: PWR Basket in Cask

To establish the maximum credible  $k_{eff}$  for the PWR basket with design basis fuel, the mechanical perturbations and basket geometric tolerances, shown in previous sections to produce positive reactivity relative to the nominal configuration, are included in the full cask model. The mechanical variations which produced positive reactivity effects are as follows.

- a. Maximum tube size,
- b. Fuel assembly centered in tube,
- c. Fuel tube with assembly centered moved towards the center, and
- d. Disk opening coordinates moved to basket center.

The above conditions define the worst-case PWR basket configuration. The results are shown in Table 6.4-5 (located at the end of this section). Side and corner shifts are included in Table 6.4-5 to provide a  $k_{eff}$  comparison to the realistic orientation of the components in the horizontally transported cask.

An additional evaluation is made addressing tolerances associated with the BORAL sheet. The minimum BORAL sheet widths are included in the most reactive cask configuration in order to



evaluate the potential reactivity effects from both manufacturing tolerances and shifting of the BORAL sheets beneath the cover plates. For this model, BORAL sheet widths are reduced by a total of 0.10 inches to 8.10 inches and all assemblies are shifted radially in towards the center of the cask. This results in a combined  $\Delta k_{\text{eff}}$  of +0.00246. However, incorporating this increase in reactivity, as derived from the worst case accident scenario, results in a  $k_s = 0.94749$  which is below the NRC criticality safety limit of 0.95. This  $\Delta k_{\text{eff}}$  of +0.00246 is, therefore, added to the results of all bounding PWR fuel conditions of the transport cask array reported in Section 6.4.3.2.

#### PWR Criticality Calculations for Single Cask and Array of Casks

Values of  $k_{\text{eff}}$  and  $k_s$  (the bias adjusted  $k_{\text{eff}}$ ) are evaluated for single cask and for an array of casks containing PWR fuel. The evaluation is based on the worst-case configured cask basket under normal operating (dry interior) and accident (wet interior, no neutron shield) conditions of transport. The  $k_{\text{eff}}$  produced by KENO-Va is adjusted according to the following equations to account for code bias and Monte Carlo uncertainty. KENO-Va bias is calculated to be 0.0052 with a one-sided 95/95 uncertainty factor of 0.0087 (See Section 6.5). Base model for the KENO-Va interior and exterior moderator variation is the "worst configuration, highest reactivity" basket inputs.

$$k_s = k_{\text{eff}} + \Delta k_{\text{Bias}} + \sqrt{\sigma_{\text{Bias}}^2 + (2 * \sigma_{\text{Keff}})^2} \leq 0.95$$

$$k_s = k_{\text{eff}} + 0.0052 + \sqrt{0.0087^2 + (2\sigma_{\text{mc}})^2} \leq 0.95$$

where:

$k_s$  = the calculated allowable maximum multiplication factor,  $k_{\text{eff}}$ , of system  
being evaluated for all normal or credible abnormal conditions or events.

$k_{\text{eff}}$  = the KENO - Va calculated  $k_{\text{eff}}$

$\sigma_{\text{mc}}$  = KENO - Va calculated Monte Carlo error.

Results of the criticality calculations are provided in Section 6.4.3.2.

#### 6.4.1.3.2 Universal Transport Cask Containing BWR Fuel

##### Mechanical Perturbations and Geometric Tolerance: BWR Basket in Cask

As with the PWR basket, the BWR basket is subject to the same types of mechanical perturbations and geometric tolerances which have an impact on the criticality evaluation. However, due to the asymmetry of the BWR basket and the two sided BORAL configuration of tube, a full basket surrounded by the cask shield regions is used in the evaluation of mechanical and geometric tolerances. As with the PWR basket, the following mechanical and geometric tolerances are evaluated:

- a. Fuel assembly movement in the tube,
- b. Fuel tube movement in the disk opening,
- c. Variation in the basket tube opening,
- d. Variation in disk opening, and
- e. Variation in positioning of the disk opening,

For the design basis fuel, the maximum fuel movement within the tube is  $\pm 0.231$  in. (0.587cm). The maximum movement of the tube in the disk opening is  $\pm 0.064$  in. (0.165cm). For the movement analysis, the components, fuel tube or assembly, are shifted radial inward, radial outward, left, right, top, bottom and to the four basket corner locations. Due to the asymmetric BORAL sheet pattern of the BWR basket, all ten movement directions are evaluated.

Variations in the tube opening are evaluated by added and subtracting a tolerance of  $\pm 0.02$  in. (0.051cm) to the nominal tube inner width. Tube outer, BORAL sheet, and BORAL cover sheet dimensions are adjusted accordingly. Variations in disk opening by adding and subtracting a tolerance of  $\pm 0.015$  in. to the nominal disk opening.

Variation in basket disk opening position is limited by the positional tolerance within a diameter of 0.015 in. As with the fuel assembly and tube movements, the reactivity effect of the opening position is maximized by shifting the opening to the upper right hand corner by 0.0053 in.  $(0.0075^2/2)^{1/2}$  in both +x and +y directions. This minimizes the webbing and BORAL effectiveness.

The results are shown in Table 6.4-6 (located at the end of this section). The mechanical perturbations that produce a significant positive reactivity are included in a full cask model to establish the maximum credible  $k_{\text{eff}}$  for the Universal Transport Cask loaded with 4.00 wt %  $^{235}\text{U}$  Ex/ANF 9x9 fuel assembly. The combination of the radial movement of the fuel assembly and the fuel tube towards the basket center results in the maximum positive reactivity. This configuration is defined to be the worst-case for the BWR basket.

An additional evaluation is made addressing tolerances associated with the BORAL sheet. The minimum BORAL sheet widths are included in an analysis of the most reactive cask configuration in order to evaluate the potential reactivity effects from both manufacturing tolerances and shifting of the BORAL sheets beneath the cover plates.

For this model, BORAL sheet widths are reduced by a total of 0.08 inches to 6.22 inches. The resulting change in reactivity is within the statistics of the Monte Carlo code. Therefore it is appropriate to neglect these tolerances in the maximum reactivity BWR model.

In addition to the BORAL sheet width evaluation, an analysis modeling the four oversized fuel tubes is included. The oversized fuel tubes are 0.15 inches larger to allow space for assemblies with channels that are bowed or twisted. However, the spacer grids of the fuel assembly maintain the pitch of the fuel rod array. Therefore, the fuel rod lattice and rod dimensions are not changed by the minor distortions that occur in the channel. An additional BWR criticality analysis is added which conservatively models the four 'oversized' fuel tubes (with nominal (straight) fuel assemblies) shifted further in towards the center of the cask as far as physically possible. This geometry minimizes the distance between the absorber sheets of the neighboring fuel tubes. This results in a  $k_{\text{eff}}$  of 0.91032. The change in reactivity, a  $\Delta k_{\text{eff}}$  of +0.00105, is within  $2\sigma$  of the base case. Therefore, no statistically significant conclusion can be made as to the actual impact of the model change, and the existing most reactive configuration is left unchanged.

### BWR Criticality Calculations for Single Cask and Array of Casks

Values of  $k_{\text{eff}}$  and  $k_s$  (the bias adjusted  $K_{\text{eff}}$ ) are evaluated for a single cask and for arrays of casks containing BWR fuel. The evaluation is based on the worst-case configured cask basket under normal operating (dry interior) and accident (wet interior, no neutron shield) conditions. The  $k_{\text{eff}}$  produced by KENO-Va is adjusted according to the following equation (the same equation used for the PWR fuel criticality calculations; (see Section 6.4.1.3.1). A KENO-Va bias of 0.0052 and a one-sided 95/95 uncertainty factor of 0.0087 are used in the BWR fuel criticality calculations.

$$k_s = k_{\text{eff}} + \Delta k_{\text{Bias}} + \sqrt{\sigma_{\text{Bias}}^2 + (2 * \sigma_{\text{Keff}})^2} \leq 0.95$$

$$k_s = k_{\text{eff}} + 0.0052 + \sqrt{0.0087^2 + (2\sigma_{\text{mc}})^2} \leq 0.95$$

where:

- $k_s$  = calculated allowable maximum multiplication factor,  $k_{\text{eff}}$ , of the system being evaluated for all normal or credible abnormal conditions or events
- $k_{\text{eff}}$  = KENO - Va calculated  $k_{\text{eff}}$
- $\sigma_{\text{mc}}$  = KENO - Va calculated Monte Carlo error.

The results of the criticality analysis for a single cask and for arrays of casks under normal and accident conditions are provided in Section 6.4.3.3.

### Homogenous versus Heterogeneous Assembly Enrichment Evaluation

BWR assemblies are typically loaded with a heterogeneous enrichment scheme, implying the presence of multiple fuel pin enrichments in one fuel assembly. For the criticality analysis presented previously, a peak planar-average enrichment is used. The peak planar-average enrichment is the maximum planar-average enrichment at any height along the axis of the fuel assembly. This section demonstrates that the use of a planar-average enrichment provides a conservative eigenvalue compared to the heterogeneous fuel assembly. Three fuel assembly loading patterns are evaluated using both homogeneous and heterogeneous enrichment schemes and the resulting eigenvalues compared. No gadolinium poisons were included in any of the models.

Fuel assembly types studied are the GE 8 x 8 60 and 62 fuel rod assembly types, the GE 9 x 9 74 fuel rod and the Ex/ANF 74 fuel rod assembly type. Each of the fuel assemblies is evaluated at a planar-average homogeneous enrichment and the actual documented enrichment pattern. In addition to actual documented enrichment patterns, BWR assemblies are analyzed at a planar-average enrichment of 3.75 and 4.0 wt %  $^{235}\text{U}$ , with 4.0 wt % being the UMS BWR design basis enrichment. Also evaluated is the impact of water holes orientation relation to rod lattice of the assembly and the generation of a hypothetical enrichment pattern with 5.0 wt % enriched fuel rods surrounding the central water holes. Results of the heterogeneous versus homogeneous analyses, listed in Table 6.4-16, shows that for all cases, the heterogeneous enrichment produces a lower  $k_{\text{eff}}$  than the homogeneous bundle average enrichment case. This demonstrates that applying the bundle average enrichment provides a conservative estimate of the cask  $k_s$ . The maximum and minimum pin enrichments in each of the assemblies evaluated are listed in Table 6.4-16.

In addition to the homogeneous versus heterogeneous eigenvalue comparison an In-Core  $k_{\infty}$  for the GE8x8-62 fuel rod assembly was calculated. The in-core  $k_{\infty}$  of the UMS design basis BWR fuel assembly is 1.41.

#### 6.4.2 Fuel-Loading Optimization

The fuel loading is conservatively optimized in the Universal Transport Cask criticality models by using: 1) fresh fuel; 2) the most reactive PWR or BWR fuel assembly type; 3) the highest possible fuel stack density (95% of theoretical); and 4) the most reactive basket configuration. The cask models represent fully loaded baskets with 24 PWR or 56 BWR design basis fuel assemblies. The models use reflective boundary conditions on the sides and periodic boundary conditions on the top and bottom. These boundary conditions simulate an infinite array of casks of infinite axial extent.

### 6.4.3 Criticality Results

#### 6.4.3.1 Summary of Maximum Criticality Values

The effective neutron multiplication factor,  $k_{\text{eff}}$ , for the Universal Transport Cask containing the most reactive PWR or BWR fuel assemblies in the most reactive configuration is below the 0.95 NRC criticality safety limit, including all biases and uncertainties, under normal and accident conditions.

The maximum multiplication factor with uncertainties for the Universal Transport Cask containing PWR fuel assemblies is 0.9473 under accident conditions involving full moderator intrusion. Corresponding value for the cask containing channeled BWR fuel assemblies is 0.9248 under accident conditions involving full moderator intrusion. These values reflect the following conditions:

- A method bias and uncertainty associated with KENO-Va and the 27 group ENDF/B-IV library
- An infinite cask array
- Normal conditions is defined to be a dry basket, dry heat transfer annulus and dry exterior
- Accident conditions is defined to be full interior, exterior and fuel clad gap moderator (water) intrusion
- Westinghouse 17x17 OFA fuel assemblies at 4.2 wt %  $^{235}\text{U}$  (most reactive PWR fuel assembly type) or 56 Ex/ANF 9x9-79 rod fuel assemblies at 4.0 wt %  $^{235}\text{U}$  (most reactive BWR fuel assembly type)
- No fuel burnup
- 75% of the minimum  $^{10}\text{B}$  loading in the BORAL
- Most reactive mechanical configuration for PWR (Assemblies and fuel tubes moved toward the center of the basket; maximum fuel tube openings; minimum BORAL sheet widths and closely packed disk openings)
- Most reactive mechanical configuration for BWR (Assemblies and fuel tubes moved toward the center of the basket)

Analysis of simultaneous moderator density variation inside and outside the transport cask shows a monotonic decrease in reactivity with decreasing moderator density. Thus, the full moderator density situation bounds any normal or accident condition. Cask pitch and exterior moderator

density does not statistically significantly impact cask reactivity. No statistically significant impact on  $k_{eff}$  is calculated for the removal of the BWR fuel assembly channel. The criticality transport index is 0 for the cask filled with maximum reactivity PWR fuel enriched to 4.2 wt %  $^{235}\text{U}$  and the cask filled with maximum reactivity BWR fuel enriched to 4.00 wt %  $^{235}\text{U}$  under IAEA Series No. 6 and 10 CFR 71.

Analysis of the BWR cask reactivity of the fuel assemblies in the axial region above the top of partial length rods shows this region to be less reactive than the region with all of the fuel rods present. Therefore, it is appropriate to represent partial length rods as full length rods in the BWR fuel models.

#### 6.4.3.2 Criticality Results for PWR

The criticality analysis includes variation of moderator density and cask center-to-center spacing under normal and hypothetical accident conditions. Results of the calculations for the PWR cask are provided in Tables 6.4-7 through 6.4-10 (located at the end of this section). The tables list  $k_s$  without the  $\Delta k$  penalty associated with BORAL plates. A  $\Delta k$  of 0.00246 is added in the  $k_{eff}$  listed below. CSAS input and output for the normal conditions analysis is provided in Figure 6.6.2-1. Figure 6.6.2-2 provides CSAS input and output for the analysis for hypothetical accident conditions.

During normal transport, the cask is expected to be dry inside (i.e., cladding is intact and no water is present in the gap between fuel pellet and clad) and possibly wet outside. Expected reactivity conditions under normal conditions of transport are provided in Table 6.4-8. As the table shows,  $k_{eff}$  of the package is very low and is relatively insensitive to variations of moderator density outside and cask center-to-center spacing. The maximum  $k_{eff}$  for this condition is  $0.3988 \pm 0.0007$ .

Analysis under hypothetical accident conditions conservatively assumes the presence of water in the gap between fuel pellet and clad. Criticality calculations are performed with the cask exterior both wet and misty. Expected reactivities shown in Table 6.4-9 are for conditions where both the inside and outside of the cask are assumed to be equally wet. The maximum  $k_{eff}$  for this condition is calculated to be  $0.9333 \pm 0.0009$ . As seen in Table 6.4-10, for conditions where the

inside of the cask is wet but the outside is misty, the maximum  $k_{\text{eff}}$  is calculated to be  $0.9320 \pm 0.0009$ .

Including the statistical and method uncertainties, all results for the normal and accident conditions for the PWR cask are below the 0.95 NRC criticality safety limit. Thus, compliance with 10 CFR 71.55 (b) and (d) as well as 10 CFR 71.75 (a) is demonstrated for the Universal Transport Cask containing PWR fuel.

#### 6.4.3.3 Criticality Results for BWR

The criticality analysis for the BWR cask is similar to that for the PWR cask and includes variation of moderator density and cask center-to-center spacing under normal and hypothetical accident conditions. Results of the calculations are provided in Tables 6.4-1 through 6.4-15. These tables and the data listed below do not incorporate the  $\Delta k$  penalty associated with the top end drop accident shifting scenario. CSAS input and output for the normal conditions analysis is provided in Figure 6.6.2-3. Figure 6.6.2-4 provides CSAS input and output for the analysis for hypothetical accident conditions.

During normal transport, the cask is expected to be dry inside (i.e., cladding is intact and there is no water is present in the gap between fuel pellet and cladding) and possibly wet outside. Expected reactivity conditions under normal conditions of transport are provided in Table 6.4-12. As the table shows,  $k_{\text{eff}}$  of the package is very low and is relatively insensitive to variations of moderator density outside and cask center-to-center spacing. The maximum  $k_{\text{eff}}$  for this condition is  $0.4005 \pm 0.0008$ .

Analysis under hypothetical accident conditions conservatively assumes the presence of water in the gap between fuel pellet and cladding. Criticality calculations are performed with the cask exterior moderator at various densities. Expected reactivities shown in Table 6.4-13 are for conditions where both the inside and outside of the cask are assumed to be wet with exterior and interior densities varying simultaneously. The maximum  $k_{\text{eff}}$  for this condition is calculated to be  $0.9086 \pm 0.0008$ . For conditions where the inside of the cask is wet but the outside is at optimum moderation, the maximum  $k_{\text{eff}}$  is calculated to be  $0.9108 \pm 0.0008$  (see Table 6.4-14 and Table 6.4-15).



Including the statistical and method uncertainties, all results for the normal and accident conditions for the BWR cask are below the 0.95 NRC criticality safety limit. Thus, compliance with 10 CFR 71.55 (b) and (d) as well as 10 CFR 71.75 (a) is demonstrated for the Universal Transport Cask containing BWR fuel.

#### 6.4.4 Fuel Assembly Lattice Dimension Variations

The nominal lattice dimensions for the most reactive PWR and BWR fuel under the most reactive accident conditions are varied to determine if dimensional perturbations significantly affect the reactivity of the system. Accident conditions are defined to be full interior, exterior and fuel-clad gap moderator (water) intrusion at a density of 1 g/cc and a temperature of 70°F. Flooding the fuel-clad gap magnifies the effect on reactivity from lattice dimensional variations by adding or removing moderator from the undermoderated fuel lattice. The conclusions drawn are then used to establish fuel dimension limits for the PWR and BWR fuel assemblies evaluated as UMS contents. The PWR analysis is performed modeling a Westinghouse 17x17 OFA fuel assembly in an infinite array of infinitely tall fuel tube cells. This prevents any leakage of neutrons from the system. The BWR analysis is performed modeling an infinite array of infinitely tall concrete cask storage units filled with Exxon/ANF 9x9 fuel assemblies. The BWR analysis using the concrete cask is applicable to the transport cask, since the most reactive canister configuration is independent of shield geometry. The large, well-shielded PWR fuel assembly canister, in either transport or storage configuration, produces identical reactions with the uncertainty of the Monte Carlo analysis. Any  $\Delta k_{\text{eff}}$  in reactivity from different fuel basket configurations would behave similarly regardless of the minor differences in the shields. The fuel assembly nominal lattice dimensions that are modified to determine if perturbations significantly affect the reactivity of the system are:

- a) Pellet Radius
- b) Clad Inner Radius
- c) Clad Outer Radius
- d) Water Rod Inner Radius
- e) Water Rod Outer Radius

As shown in Tables 6.4-17 and 6.4-18, the following dimensional perturbations were determined to significantly decrease the reactivity of both the PWR and the BWR systems: decreasing the

clad inner radius and increasing the clad outer radius, i.e. increasing clad thickness. Decreasing the pellet radius of the BWR fuel assembly was also determined to significantly decrease the reactivity. The results are as expected as these perturbations decrease the H/U ratio in the undermoderated fuel lattice. Additionally, varying the BWR water rod dimensions was determined to have an insignificant effect on the reactivity of the system. Therefore, these nominal dimension variations are not of concern with regard to the criticality safety of the system.

The following perturbations were determined to significantly increase the reactivity of both the PWR and BWR systems: increasing the clad inner radius and decreasing the clad outer radius, i.e., decreasing clad thickness. Increasing the guide tube inner radius or decreasing the guide tube outer radius, both decreasing tube thickness, was determined to significantly increase the reactivity of the PWR systems. The increase in reactivity is due to the fact that these perturbations increase the H/U ratio in the undermoderated fuel lattice.

A slight increase in reactivity,  $0.004 \Delta k$ , is also seen in the PWR system when decreasing the pellet diameter. This is due to flooding of the pellet-to-clad gap in the accident model, which provides additional moderator to the lattice. Since 100% of clad failure is not expected during normal or accident operating conditions, no lower bound limit is placed on the fuel pellet diameter.

The effect on reactivity from perturbations in the nominal fuel dimensions require the following limits on the fuel assembly lattice parameters in order to retain the maximum reactivity of the UMS system below existing design basis results:

#### PWR

- a) Fuel Rod Diameter  $\geq$  Nominal Dimension
- b) Clad Thickness  $\geq$  Nominal Dimension
- c) Fuel Rod Pitch  $\leq$  Nominal Dimension
- d) Guide Tube (Instrument Tube) Thickness  $\geq$  Nominal Dimension
- e) Pellet Diameter  $\leq$  Nominal Dimension

## BWR

- a) Fuel Rod Diameter  $\geq$  Nominal Dimension
- b) Clad Thickness  $\geq$  Nominal Dimension
- c) Fuel Rod Pitch  $\leq$  Nominal Dimension
- d) Pellet Diameter  $\leq$  Nominal Dimension

### 6.4.5 Evaluation of Transport Cask End Impact

Axial shifting of the contents of the UMS system is considered as a result of the top end impact accident condition of transport. A bounding hypothetical fuel-shifting scenario is considered. This scenario conservatively shifts all fuel rods to the top of each assembly. The fuel within these rods is assumed to shift into half the height of the plenum, and each assembly is shifted up until it is in contact with the lid. The conservatively toleranced basket is assumed to remain in contact with the canister floor. The MONK8a criticality analysis sequence of the ANSWERS software code was used to evaluate the change in reactivity of the system as result of this scenario. The maximum reactivity worst case UMS PWR fuel and BWR fuel configurations are used as the base case for comparison for each fuel type. MONK8a establishes a base PWR system reactivity,  $k_{\text{eff}} \pm 2\sigma$ , of  $0.9340 \pm 0.0005$  and a base BWR system reactivity,  $k_{\text{eff}} \pm 2\sigma$ , of  $0.9116 \pm 0.0005$ .

As a result of the shifting scenario previously mentioned, some of the active fuel protrudes beyond the top of the BORAL. The fuel assembly dimensions that are used to determine this height are presented in Table 6.2.3 for the bounding fuel type of each UMS fuel class. The height of the active fuel that protrudes beyond the top of the BORAL sheets is calculated for each UMS fuel class by taking the maximum possible height from the canister lid to the top of the BORAL and subtracting the minimum distance from the top of the assembly to the top of the active fuel.

#### Top End Impact Evaluation - PWR Fuel

Analysis of the PWR fuel configuration is performed using the design basis WE 17x17 OFA assembly. Structural evaluations show that in the transport cask hypothetical top end impact event, the PWR top nozzle does not deform. However, for the evaluation, 1.0 inch of the top nozzle is conservatively modeled as crushed. This reduction in top nozzle height, combined with the hypothetical fuel-shifting, results in a maximum of 4.520 inches of active PWR fuel protruding beyond the top of the neutron poison panels for all three classes of PWR fuel. Since, the height of the shifted WE 17x17 OFA fuel that protrudes beyond the top of the BORAL sheets

is only 3.705 inches, the PWR BORAL sheet length is reduced by 0.815 inches for the WE 17x17 OFA analysis. The shifted (4.520 inches of PWR fuel exposed) PWR system reactivity,  $k_{\text{eff}} \pm 2\sigma$ , of  $0.9335 \pm 0.005$  reflects a change in reactivity,  $k_{\text{eff}}$ , of 0.0005. This change is within one standard deviation of the unshifted fuel configuration. Therefore, shifting the PWR fuel as a result of the transport cask top end impact event does not significantly affect the reactivity of the system. Figure 6.4-1 shows the resulting geometry of 4.520 inches of WE 17x17 OFA fuel shifted above the BORAL.

#### Top End Impact Evaluation - BWR Fuel

For both classes of BWR fuel, the lifting bail and the corner posts at the top of each assembly may deform in the hypothetical top end impact. This deformation is bounded by modeling a reduction in top nozzle height of 4.7 inches. The reduction in top nozzle height, combined with the hypothetical fuel-shifting condition, results in a maximum of 7.625 inches of active fuel protruding above the top of the neutron poison sheets for class 4 BWR fuel. For class 5 of BWR fuel, this height is limited to 7.616 inches of exposed fuel. This analysis uses the class 5 EX\ANF 9x9 fuel; therefore, the BORAL length is reduced by 0.009 inches in the model to bound the postulated shifting of all BWR fuels. The shifted (7.625-inches of BWR fuel exposed) BWR system reactivity,  $k_{\text{eff}} \pm 2\sigma$ , of  $0.9365 \pm 0.005$  reflects a change in reactivity,  $\Delta k_{\text{eff}}$ , of 0.0249. Figure 6.4-2 shows the resulting geometry of 7.625 inches of EX\ANF 9x9 fuel shifted above the BORAL.

#### Bottom End Impact Evaluation - PWR Fuel

The maximum distance from the canister floor to the bottom of the BORAL occurs when the conservatively toleranced basket components are shifted up towards the canister lid. For the PWR baskets, this distance is limited to 5.30 inches. Since the PWR fuel types have bottom rod end caps and/or components of the bottom nozzle that do not deform to a total height of less than 0.78 inches, the top end impact event, which exposes 4.52 inches of PWR fuel, bounds the bottom end impact condition.

#### Bottom End Impact Evaluation - BWR Fuel

The maximum distance from the canister floor to the bottom of the BORAL occurs when the conservatively toleranced basket components are shifted up towards the canister lid. For the BWR baskets this distance is limited to 8.2 inches. Given that BWR fuel types have bottom rod end caps and/or tie plates that do not deform to a total height of less than 0.575 inches, the top

end impact event, which exposes 7.625 inches of BWR fuel, bounds the bottom end impact condition.

Given that the bounding PWR end impact event does not significantly affect the reactivity of the system, poison sheet coverage is adequate for all allowed PWR fuel contents of the UMS system. The increase in reactivity due to the bounding BWR end impact event is added to the most reactive accident condition result, with a  $k_{\text{eff}} \pm 2\sigma$  of 0.9108 as determined in Section 6.4.3.3, to establish a maximum BWR system reactivity,  $k_{\text{eff}} \pm 2\sigma$ , of  $0.9357 \pm 0.0008$ . Thus, poison sheet coverage is adequate for all allowed BWR fuel contents of the UMS system.

#### 6.4.6 Regulatory Compliance

The licensing requirements for criticality analyses are provided in 10 CFR 71.55 and 10 CFR 71.59 for shipment of radioactive material.

10 CFR 71.55 and 10 CFR 71.59 require that the fissile material package be subcritical under any credible condition, e.g., optimum interior/exterior moderation and reflection and credible configuration of the material. A criticality transport index is to be assigned to the fissile material package. This transport index must be based on the number of packages (casks in this context) remaining subcritical in an array configuration.

Additional requirements imposed include the reduction in poison plate  $^{10}\text{B}$  from 100 to 75 percent and water in the pellet-to-cladding gap.

#### Undamaged Cask

Compliance with the requirements of paragraphs (b) and (d) of 10 CFR 71.55 is shown by modeling an undamaged cask surrounded by water. Requirements of paragraphs (a) through (c) of 10 CFR 71.59 are satisfied by providing a value of "N" equal to infinity and a criticality transport index of 0 by imposing reflecting boundary conditions on the sides of the model simulating an infinite array of undamaged casks. Optimum interior and exterior moderation, including exterior full reflection by more than 20 cm of water, shows compliance with 10 CFR 71.55 paragraphs (b)(2), (b)(3) and (d)(3). Normal operating conditions for the transport cask include a dry canister cavity. The canister is loaded, dried, and seal welded inside a transfer cask. Only after the canister is dried and sealed is it placed into the transport cask. A set of exterior

moderator density and cask pitch analyses show compliance with 10 CFR 71 under dry cavity conditions.

#### Damaged Cask

Compliance with the requirements of paragraph (e) of 10 CFR 71.55 is shown by modeling a damaged cask surrounded by water. Compliance with 10 CFR 71.59 is automatically demonstrated by imposing reflection boundary conditions on the sides of the model to simulate an infinite array of damaged casks, thereby resulting in a criticality transport index of 0. Optimum interior and exterior moderation, including exterior full reflection by more than 20 cm of water, shows compliance with 10 CFR 55 paragraphs (e)(2) and (e)(3) and 10 CFR 71.59 paragraph (a)(2).

A damaged transport cask is defined as having been subjected to the hypothetical accident conditions specified in 10 CFR 71. Under these conditions the cask containment is maintained, and the cavity therefore remains dry. However, to show the cask's capability to remain subcritical under optimum internal and external moderation, an internally wet cask is analyzed. During the accident, the radial neutron shield is assumed to be lost as a result of fire and is replaced by the external moderator. Even though the fuel is assumed to remain intact following the cask drop, the pellet-to-clad gap is assumed to be filled by the internal-to-cask moderator. Introducing additional moderator into the normally under-moderated fuel assembly lattice increases reactivity.

Figure 6.4-1 Visage Slice - Hypothetical Shifting of PWR Fuel

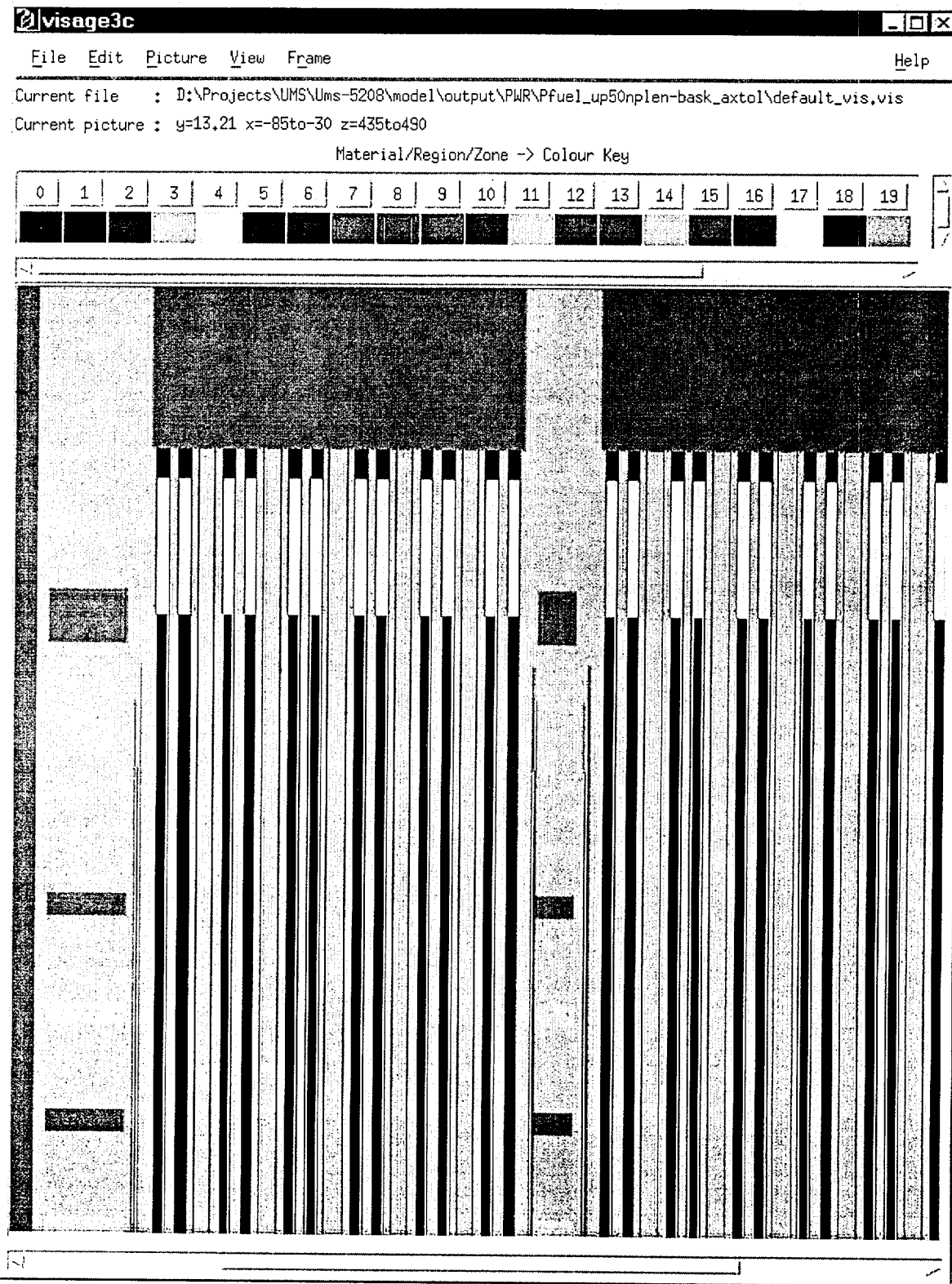


Figure 6.4-2

Visage Slice - Hypothetical Shifting of BWR Fuel

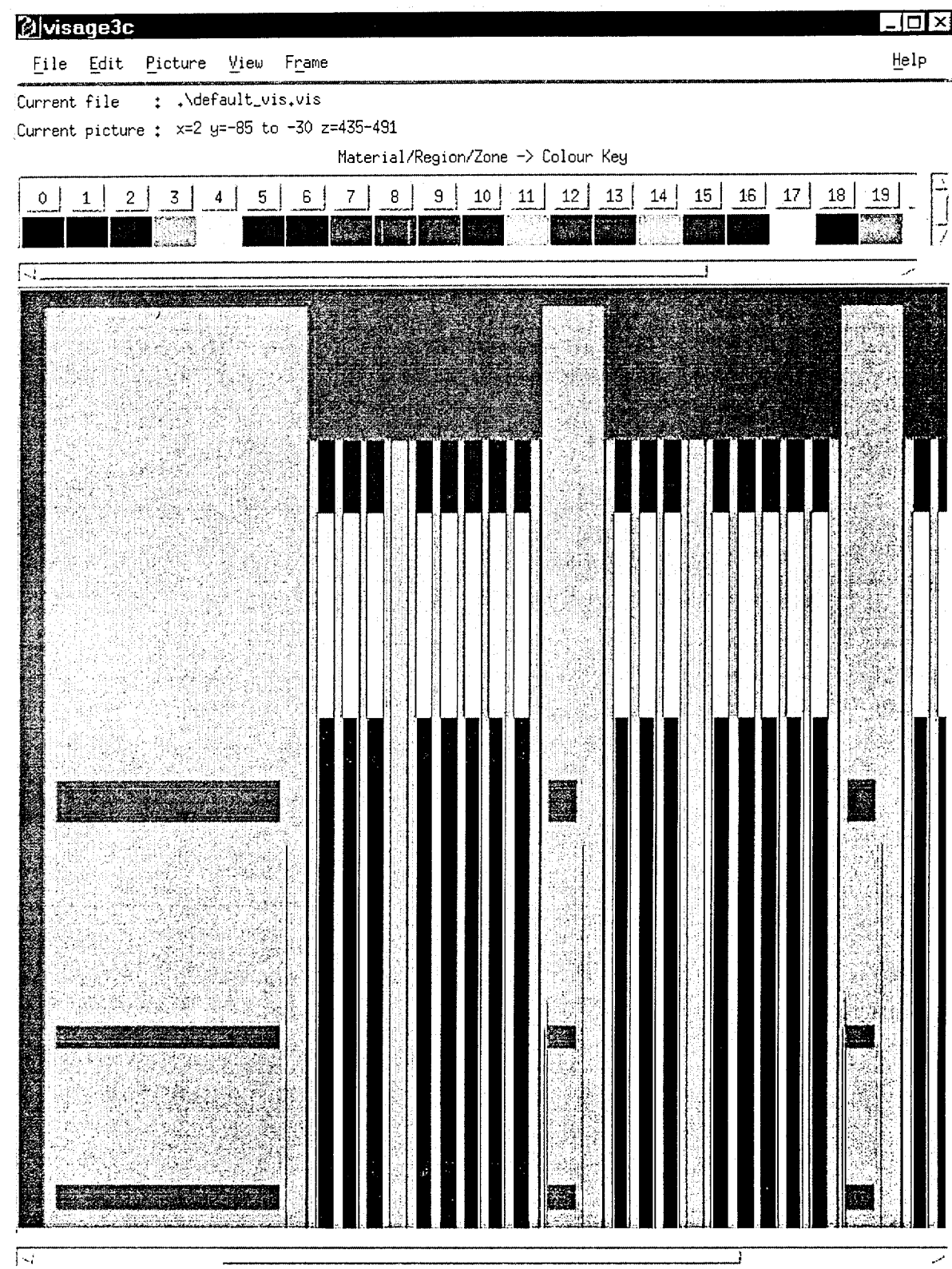




Table 6.4-1  $k_{eff}$  for Most Reactive PWR Fuel Assembly Determination (1.0-in. Web)

Assembly Type	Dry Gap		Wet Gap		$\Delta k_{eff}$ Wet - Dry
	$k_{eff}$	$\sigma$	$k_{eff}$	$\sigma$	
B&W 15x15 Mark B4	0.9613	0.0011	0.9692	0.0012	0.0079
B&W 17x17 Mark C	0.9621	0.0012	0.9705	0.0011	0.0084
CE 14x14	0.9295	0.0013	0.9381	0.0011	0.0085
CE 16x16 SYS 80	0.9356	0.0012	0.9372	0.0012	0.0016
West 14x14	0.9177	0.0013	0.9264	0.0012	0.0086
West 14x14 OFA	0.9238	0.0012	0.9326	0.0012	0.0088
West 15x15	0.9662	0.0011	0.9712	0.0012	0.0050
West 17x17	0.9596	0.0012	0.9673	0.0012	0.0077
West 17x17 OFA	0.9656	0.0013	0.9727	0.0012	0.0070
Ex/ANF 14x14 CE	0.9309	0.0012	0.9362	0.0011	0.0053
Ex/ANF 14x14 WE	0.9065	0.0012	0.9176	0.0011	0.0111
Ex/ANF 15x15 WE	0.9559	0.0012	0.9634	0.0013	0.0074
Ex/ANF 17x17 WE	0.9631	0.0012	0.9704	0.0012	0.0073

Table 6.4-2  $k_{eff}$  for Highest Reactivity Assemblies in 1.5-in. Web (Dry Gap)

Assembly Type	$k_{eff}$	$\sigma$
B&W 15x15 Mark B4	0.9119	0.0011
B&W 17x17 Mark C	0.9141	0.0011
West 15x15	0.9147	0.0013
West 17x17	0.9116	0.0012
West 17x17 OFA	0.9196	0.0012
Ex/ANF 17x17 WE	0.9172	0.0011

Table 6.4-3  $k_{eff}$  for Most Reactive BWR Fuel Assembly Determination

Assembly Type	Number Rods		Channel Thickness	Dry Gap		$\Delta k_{eff}^{(1)}/\sigma$
	Fuel	Water		$k_{eff}$	$\sigma$	
GE 7x7	49	0	80 mil	0.8807	0.0012	-6.678
GE 8x8	63	1	80 mil	0.8765	0.0012	-9.992
GE 8x8	63	1	100 mil	0.8755	0.0012	-10.760
GE 8x8	63	1	120 mil	0.8784	0.0011	-9.098
GE 8x8	62	2	80 mil	0.8821	0.0011	-5.708
GE 8x8	62	2	100 mil	0.8823	0.0011	-5.513
GE 8x8	60	4	2 mm	0.8772	0.0012	-9.644
GE 9x9	79	2	2 mm	0.8796	0.0011	-8.434
GE 9x9	74	2 <sup>(2)</sup>	2 mm	0.8778	0.0011	-9.558
GE 9x9	74	2 <sup>(2)</sup>	80 mil	0.8847	0.0012	-3.342
Ex/ANF 7x7	49	0	80 mil	0.8792	0.0012	-7.634
Ex/ANF 8x8	63	1	80 mil	0.8778	0.0012	-8.861
Ex/ANF 8x8	62	2	80 mil	0.8787	0.0012	-8.517
Ex/ANF 9x9	79	2	2 mm	0.8886	0.0009	0.000
Ex/ANF 9x9	79	2	80 mil	0.8873	0.0008	-1.464
Ex/ANF 9x9	74	2 <sup>(2)</sup>	80 mil	0.8862	0.0012	-2.034

Note:

- (1)  $\Delta k_{eff} = k_{eff} - k_{eff}(\text{Ex/ANF } 9 \times 9 \text{ 79 Fuel rod 80 mil channel})$
- (2) Two large water rods occupying the space of seven fuel rods.

Table 6.4-4 PWR Fuel Tube in Basket Model KENO-Va Results for Geometric Tolerances and Mechanical Perturbations

	$k_{eff}$	$\sigma$	$\Delta k_{eff}$	$\Delta k_{eff}/\sigma$
Reference case	0.9582	0.0006		
Dimensions Tolerance on Disk Opening Center Location				
Minimum web	0.9598	0.0006	0.0015	2.6
Maximum web	0.9575	0.0006	-0.0008	-1.3
Dimensions tolerance on tube opening				
Minimum tube	0.9546	0.0006	-0.0036	-6.2
Maximum tube	0.9627	0.0006	0.0045	7.6
Dimension tolerance on disk opening				
Minimum opening	0.9594	0.0006	0.0012	2.0
Maximum opening	0.9591	0.0006	0.0008	1.4
Fuel movement in tube - tube centered in disk opening				
Mirrored boundary	0.9572	0.0006	-0.0011	-1.8
Periodic boundary	0.9566	0.0006	-0.0016	-2.8
Tube movement in disk opening - fuel assembly centered in tube				
Mirrored boundary	0.9606	0.0006	0.0024	4.0
Periodic boundary	0.9591	0.0006	0.0009	1.5
Move fuel tube in opening and assembly in tube				
Mirrored boundary	0.9595	0.0006	0.0012	2.1
Periodic boundary	0.9567	0.0006	-0.0015	-2.5

Table 6.4-5 PWR Basket in Cask KENO-Va Results for Geometric Tolerances and Tube Movement

Analysis	$k_{eff}$	$\sigma$	$\Delta k_{eff}$	$\Delta k_{eff}/\sigma$
Nominal	0.9192	0.0009	----	----
Geometric Tolerance	0.9227	0.0009	0.0035	4.0
Geo. Tol.+Tube In	0.9286	0.0009	0.0094	11.1
Geo. Tol.+Tube Out	0.9176	0.0009	-0.0017	-1.9
Geo. Tol.+Corner	0.9240	0.0009	0.0048	5.3
Geo. Tol.+Tube Side	0.9235	0.0009	0.0043	4.8

Table 6.4-6 BWR Basket in Cask KENO-Va Results for Geometric Tolerances and Mechanical Perturbations

Analysis	$k_{\text{eff}}$	$\sigma$	$\Delta k_{\text{eff}}$	$\Delta k_{\text{eff}}/\sigma$
Nominal basket	0.8873	0.0008	N/A	N/A
Geometric tolerances				
Min tube	0.8860	0.0008	-0.0013	-1.607
Max tube	0.8864	0.0008	-0.0010	-1.169
Min disk opening	0.8861	0.0008	-0.0012	-1.577
Max disk opening	0.8855	0.0008	-0.0018	-2.244
Shift openings in	0.8879	0.0008	0.0006	0.702
Shift openings out	0.8891	0.0008	0.0018	2.173
Mechanical perturbations				
Assembly shift top right	0.8685	0.0008	-0.0189	-23.886
Assembly shift top	0.8780	0.0008	-0.0093	-11.402
Assembly shift top left	0.8820	0.0008	-0.0053	-6.386
Assembly shift left	0.8915	0.0008	0.0042	4.940
Assembly shift bottom left	0.8942	0.0008	0.0069	8.747
Assembly shift bottom	0.8918	0.0008	0.0045	5.531
Assembly shift bottom right	0.8801	0.0008	-0.0073	-8.667
Assembly shift right	0.8749	0.0008	-0.0124	-14.988
Assembly shift radial in	0.8990	0.0008	0.0116	14.195
Assembly shift radial out	0.8710	0.0008	-0.0163	-19.927
Fuel tube shift top right	0.8873	0.0008	0.0000	-0.048
Fuel tube shift top	0.8856	0.0008	-0.0017	-2.175
Fuel tube shift top left	0.8854	0.0009	-0.0020	-2.329
Fuel tube shift left	0.8873	0.0008	-0.0001	-0.072
Fuel tube shift bottom left	0.8858	0.0008	-0.0015	-1.795
Fuel tube shift bottom	0.8882	0.0008	0.0008	0.976
Fuel tube shift bottom right	0.8868	0.0008	-0.0005	-0.607
Fuel tube shift right	0.8878	0.0008	0.0005	0.563
Fuel tube shift radial in	0.8932	0.0008	0.0058	6.952
Fuel tube shift radial out	0.8827	0.0008	-0.0046	-5.750
Combined analysis				
Tube + assembly radial in	0.9050	0.0008	0.0177	22.075

Table 6.4-7 PWR Single Cask Analysis Criticality Results

Water Density (g/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k <sub>s</sub>
Inside	Outside						
1.0	1.0	Yes	No	100%	0.9135	0.0009	0.9276
1.0	1.0	Yes	No	75%	0.9222	0.0009	0.9362
0.0001	1.0	Yes	No	75%	0.3774	0.0006	0.3914
1.0	1.0	No	Yes	100%	0.9210	0.0009	0.9350
1.0	1.0	No	Yes	75%	0.9295	0.0009	0.9436
0.0001	1.0	No	Yes	75%	0.3782	0.0006	0.3922

Table 6.4-8 PWR Cask Array Analysis Criticality Results - Normal Condition-Dry Interior

Cask Pitch	Water Density (g/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k <sub>s</sub>
	Inside	Outside						
Touching	0.0001	1.0	Yes	No	75%	0.3775	0.0006	0.3914
270 cm	0.0001	1.0	Yes	No	75%	0.3774	0.0006	0.3914
300 cm	0.0001	1.0	Yes	No	75%	0.3770	0.0007	0.3910
Touching	0.0001	0.8	Yes	No	75%	0.3814	0.0006	0.3954
270 cm	0.0001	0.8	Yes	No	75%	0.3820	0.0007	0.3960
300 cm	0.0001	0.8	Yes	No	75%	0.3825	0.0006	0.3965
Touching	0.0001	0.6	Yes	No	75%	0.3874	0.0006	0.4014
270 cm	0.0001	0.6	Yes	No	75%	0.3873	0.0006	0.4013
300 cm	0.0001	0.6	Yes	No	75%	0.3864	0.0006	0.4004
Touching	0.0001	0.4	Yes	No	75%	0.3913	0.0006	0.4052
270 cm	0.0001	0.4	Yes	No	75%	0.3928	0.0006	0.4068
300 cm	0.0001	0.4	Yes	No	75%	0.3915	0.0006	0.4055
Touching	0.0001	0.2	Yes	No	75%	0.3936	0.0007	0.4076
270 cm	0.0001	0.2	Yes	No	75%	0.3941	0.0006	0.4080
300 cm	0.0001	0.2	Yes	No	75%	0.3938	0.0006	0.4078
Touching	0.0001	0.1	Yes	No	75%	0.3960	0.0006	0.4100
270 cm	0.0001	0.1	Yes	No	75%	0.3963	0.0007	0.4103
300 cm	0.0001	0.1	Yes	No	75%	0.3962	0.0006	0.4101

Table 6.4-9 PWR Cask Array Analysis Criticality Results - Accident Condition - Wet Interior

Cask Pitch	Water Density (g/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k <sub>s</sub>
	Inside	Outside						
Touching	1.0	1.0	No	Yes	75%	0.9286	0.0009	0.9427
270 cm	1.0	1.0	No	Yes	75%	0.9308	0.0009	0.9448
300 cm	1.0	1.0	No	Yes	75%	0.9295	0.0009	0.9436
Touching	0.8	0.8	No	Yes	75%	0.8645	0.0008	0.8785
270 cm	0.8	0.8	No	Yes	75%	0.8649	0.0009	0.8790
300 cm	0.8	0.8	No	Yes	75%	0.8634	0.0009	0.8775
Touching	0.6	0.6	No	Yes	75%	0.7832	0.0012	0.7974
270 cm	0.6	0.6	No	Yes	75%	0.7840	0.0012	0.7982
300 cm	0.6	0.6	No	Yes	75%	0.7826	0.0011	0.7967
Touching	0.4	0.4	No	Yes	75%	0.6808	0.0010	0.6950
270 cm	0.4	0.4	No	Yes	75%	0.6800	0.0010	0.6941
300 cm	0.4	0.4	No	Yes	75%	0.6814	0.0011	0.6956
Touching	0.2	0.2	No	Yes	75%	0.5478	0.0013	0.5620
270 cm	0.2	0.2	No	Yes	75%	0.5472	0.0012	0.5614
300 cm	0.2	0.2	No	Yes	75%	0.5445	0.0011	0.5587
Touching	0.1	0.1	No	Yes	75%	0.4762	0.0009	0.4903
270 cm	0.1	0.1	No	Yes	75%	0.4769	0.0009	0.4910
300 cm	0.1	0.1	No	Yes	75%	0.4758	0.0009	0.4899

Table 6.4-10 PWR Cask Array Analysis Criticality Results—Mist Exterior

Cask Pitch	Water Density (g/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k <sub>s</sub>
	Inside	Outside						
Touching	1.0	0.005	No	Yes	75%	0.9285	0.0009	0.9426
300 cm	1.0	0.005	No	Yes	75%	0.9291	0.0009	0.9432
Touching	0.8	0.005	No	Yes	75%	0.8645	0.0009	0.8785
300 cm	0.8	0.005	No	Yes	75%	0.8654	0.0009	0.8795
Touching	0.5	0.005	No	Yes	75%	0.7359	0.0012	0.7501
300 cm	0.5	0.005	No	Yes	75%	0.7363	0.0011	0.7505
Touching	0.2	0.005	No	Yes	75%	0.5508	0.0012	0.5650
300 cm	0.2	0.005	No	Yes	75%	0.5488	0.0012	0.5630

Table 6.4-11 BWR Single Cask Analysis Criticality Results

Water Density (g/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k <sub>s</sub>
Inside	Outside						
1.0	1.0	Yes	No	100%	0.8897	0.0008	0.9037
1.0	1.0	Yes	No	75%	0.9055	0.0008	0.9196
0.0001	1.0	Yes	No	75%	0.3924	0.0007	0.4064
1.0	1.0	No	Yes	100%	0.8949	0.0008	0.9090
1.0	1.0	No	Yes	75%	0.9077	0.0008	0.9217
0.0001	1.0	No	Yes	75%	0.3931	0.0007	0.4071

Table 6.4-12 BWR Cask Array Analysis Criticality Results - Normal Condition - Dry Interior

Cask Pitch	Water Density (gm/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k <sub>s</sub>
	Inside	Outside						
Touching	0.0001	1.0	Yes	No	75%	0.3948	0.0010	0.4089
270 cm	0.0001	1.0	Yes	No	75%	0.3935	0.0010	0.4076
300 cm	0.0001	1.0	Yes	No	75%	0.3919	0.0009	0.4060
Touching	0.0001	0.8	Yes	No	75%	0.3951	0.0010	0.4092
270 cm	0.0001	0.8	Yes	No	75%	0.3971	0.0009	0.4111
300 cm	0.0001	0.8	Yes	No	75%	0.3950	0.0009	0.4091
Touching	0.0001	0.6	Yes	No	75%	0.3983	0.0011	0.4125
270 cm	0.0001	0.6	Yes	No	75%	0.3972	0.0011	0.4114
300 cm	0.0001	0.6	Yes	No	75%	0.3966	0.0008	0.4107
Touching	0.0001	0.4	Yes	No	75%	0.3985	0.0009	0.4125
270 cm	0.0001	0.4	Yes	No	75%	0.3988	0.0009	0.4129
300 cm	0.0001	0.4	Yes	No	75%	0.3989	0.0009	0.4130
Touching	0.0001	0.2	Yes	No	75%	0.3991	0.0010	0.4132
270 cm	0.0001	0.2	Yes	No	75%	0.4005	0.0008	0.4146
300 cm	0.0001	0.2	Yes	No	75%	0.3997	0.0009	0.4138
Touching	0.0001	0.1	Yes	No	75%	0.3985	0.0009	0.4125
270 cm	0.0001	0.1	Yes	No	75%	0.3995	0.0009	0.4136
300 cm	0.0001	0.1	Yes	No	75%	0.3971	0.0010	0.4112

Table 6.4-13 BWR Cask Array Analysis Criticality Results - Accident Condition - Wet Interior

Cask Pitch	Water Density (gm/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k <sub>s</sub>
	Inside	Outside						
Touching	1.0	1.0	No	Yes	75%	<u>0.9086</u>	<u>0.0008</u>	<u>0.9226</u>
270 cm	1.0	1.0	No	Yes	75%	<u>0.9084</u>	<u>0.0008</u>	<u>0.9224</u>
300 cm	1.0	1.0	No	Yes	75%	<u>0.9075</u>	<u>0.0008</u>	<u>0.9215</u>
Touching	0.8	0.8	No	Yes	75%	<u>0.8810</u>	<u>0.0008</u>	<u>0.8950</u>
270 cm	0.8	0.8	No	Yes	75%	<u>0.8785</u>	<u>0.0008</u>	<u>0.8926</u>
300 cm	0.8	0.8	No	Yes	75%	<u>0.8779</u>	<u>0.0008</u>	<u>0.8919</u>
Touching	0.6	0.6	No	Yes	75%	<u>0.8370</u>	<u>0.0011</u>	<u>0.8511</u>
270 cm	0.6	0.6	No	Yes	75%	<u>0.8366</u>	<u>0.0012</u>	<u>0.8508</u>
300 cm	0.6	0.6	No	Yes	75%	<u>0.8378</u>	<u>0.0011</u>	<u>0.8519</u>
Touching	0.4	0.4	No	Yes	75%	<u>0.7653</u>	<u>0.0015</u>	<u>0.7797</u>
270 cm	0.4	0.4	No	Yes	75%	<u>0.7698</u>	<u>0.0014</u>	<u>0.7842</u>
300 cm	0.4	0.4	No	Yes	75%	<u>0.7680</u>	<u>0.0014</u>	<u>0.7824</u>
Touching	0.2	0.2	No	Yes	75%	<u>0.6524</u>	<u>0.0012</u>	<u>0.6666</u>
270 cm	0.2	0.2	No	Yes	75%	<u>0.6562</u>	<u>0.0012</u>	<u>0.6704</u>
300 cm	0.2	0.2	No	Yes	75%	<u>0.6560</u>	<u>0.0012</u>	<u>0.6702</u>
Touching	0.1	0.1	No	Yes	75%	<u>0.5662</u>	<u>0.0013</u>	<u>0.5805</u>
270 cm	0.1	0.1	No	Yes	75%	<u>0.5708</u>	<u>0.0014</u>	<u>0.5851</u>
300 cm	0.1	0.1	No	Yes	75%	<u>0.5668</u>	<u>0.0013</u>	<u>0.5810</u>

Table 6.4-14 BWR Cask Array Analysis Criticality Results —Mist Exterior

Cask Pitch	Water Density (g/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k <sub>s</sub>
	Inside	Outside						
Touching	1.0	0.005	No	Yes	75%	<u>0.9098</u>	<u>0.0008</u>	<u>0.9239</u>
300 cm	1.0	0.005	No	Yes	75%	<u>0.9095</u>	<u>0.0008</u>	<u>0.9235</u>
Touching	0.8	0.005	No	Yes	75%	<u>0.8795</u>	<u>0.0008</u>	<u>0.8935</u>
300 cm	0.8	0.005	No	Yes	75%	<u>0.8793</u>	<u>0.0008</u>	<u>0.8933</u>
Touching	0.5	0.005	No	Yes	75%	<u>0.8078</u>	<u>0.0010</u>	<u>0.8219</u>
300 cm	0.5	0.005	No	Yes	75%	<u>0.8091</u>	<u>0.0011</u>	<u>0.8233</u>
Touching	0.2	0.005	No	Yes	75%	<u>0.6628</u>	<u>0.0012</u>	<u>0.6770</u>
300 cm	0.2	0.005	No	Yes	75%	<u>0.6604</u>	<u>0.0012</u>	<u>0.6746</u>



Table 6.4-15 BWR Cask Array Analysis Criticality Results —Variable Exterior

Cask Pitch	Water Density (g/cm <sup>3</sup> )		Neutron Shield	Water in Gap	<sup>10</sup> B	k <sub>eff</sub>	σ	k
300 cm	1.0	1.0	No	Yes	75%	0.9075	0.0008	0.9215
300 cm	1.0	0.8	No	Yes	75%	0.9081	0.0008	0.9221
300 cm	1.0	0.6	No	Yes	75%	0.9108	0.0008	0.9248
300 cm	1.0	0.4	No	Yes	75%	0.9092	0.0008	0.9233
300 cm	1.0	0.2	No	Yes	75%	0.9094	0.0008	0.9234
300 cm	1.0	0.0	No	Yes	75%	0.9091	0.0008	0.9231

Table 6.4-16 Heterogeneous vs. Homogeneous Enrichment Analysis Results (GE)

Case		Enrichment (% <sup>235</sup> U)			Loading Pattern		k <sub>eff</sub>	σ	Δk/σ
Array	Fuel Rods	Average	Min	Max	Heterog.	Homog.			
8x8	62	2.824	N/A	N/A		X	0.8024	0.0011	---
8x8	62	2.824	1.30	3.80	X		0.7894	0.0011	-12.28
8x8	62	3.750	N/A	N/A		X	0.8683	0.0011	---
8x8	62	3.750	1.73	3.98	X		0.8501	0.0011	-15.93
8x8	60	3.404	N/A	N/A		X	0.8418	0.0012	---
8x8	60	3.404	1.60	3.90	X		0.8364	0.0011	-4.53
8x8	60	3.750	N/A	N/A		X	0.8648	0.0012	---
8x8	60	3.750	1.76	4.35	X		0.8547	0.0011	-8.22
9x9	74	4.085	N/A	N/A		X	0.8884	0.0012	---
9x9	74	4.085	2.00	4.90	X		0.8785	0.0012	-8.37
9x9 <sup>(1)</sup>	74	4.085	2.00	4.90	X		0.8809	0.0012	-6.31
9x9	74	3.750	N/A	N/A		X	0.8707	0.0011	---
9x9	74	3.750	1.84	4.50	X		0.8608	0.0011	-8.84
9x9 <sup>(1)</sup>	74	3.750	1.84	4.50	X		0.8672	0.0011	-7.13
9x9	74	4.000	N/A	N/A		X	0.8839	0.0011	N/A
9x9	74	4.000	1.96	4.80	X		0.8759	0.0012	-7.06
9x9 <sup>(2)</sup>	74	4.000	N/A	N/A		X	0.8890	0.0012	N/A
9x9 <sup>(2)</sup>	74	4.000	1.96	4.80	X		0.8805	0.0012	-7.08
9x9 <sup>(3)</sup>	74	4.000	3.68	5.00	X		0.8821	0.0012	-5.77

Notes:

- (1) Rotated water holes.
- (2) Exxon Assembly.
- (3) ~~Eighteen~~ 5 wt% <sup>235</sup>U enriched rods near center of assembly

Table 6.4-17 PWR Lattice Parameter Study Criticality Analysis Results

Description	$k_{eff}$	$\sigma$	$\Delta k$	$2\sigma$	$\Delta k / 2\sigma$
Base Case - Westinghouse 17x16 OFA	0.9732	0.0008	----	0.0016	----
decreases clad inner radius by 0.005 cm	0.9697	0.0008	-0.0035	----	-2.1875
increases clad inner radius by 0.005 cm	0.9784	0.0008	0.0052	----	3.2500
decreases clad outer radius by 0.005 cm	0.9782	0.0009	0.0050	----	3.1250
increases clad outer radius by 0.005 cm	0.9702	0.0009	-0.0030	----	-1.8750
decreases pellet radius by 0.005 cm	0.9744	0.0008	0.0012	----	0.7500
decreases pellet radius by 0.010 cm	0.9742	0.0008	0.0010	----	0.6250
decreases pellet radius by 0.015 cm	0.9773	0.0008	0.0041	----	2.5625
decreases pellet radius by 0.020 cm	0.9758	0.0008	0.0026	----	1.6250
decreases pellet radius by 0.025 cm	0.9761	0.0008	0.0029	----	1.8125
decreases pellet radius by 0.030 cm	0.9754	0.0008	0.0022	----	1.3750
decreases pellet radius by 0.035 cm	0.9750	0.0008	0.0018	----	1.1250
decreases pellet radius by 0.040 cm	0.9750	0.0008	0.0018	----	1.1250
increases pellet radius by 0.005 cm	0.9714	0.0009	-0.0018	----	-1.1250
decreases pellet & clad inner radii by 0.015 cm	0.9637	0.0008	-0.0095	----	-5.9375
decreases guide tube inner radius by 0.010 cm	0.9710	0.0008	-0.0022	----	-1.3750
increases guide tube inner radius by 0.015 cm	0.9753	0.0008	0.0021	----	1.3125
increases guide tube inner radius by 0.010 cm	0.9740	0.0009	0.0008	----	0.5000
decreases guide tube outer radius by 0.010 cm	0.9755	0.0008	0.0023	----	1.4375
increases guide tube outer radius by 0.015 cm	0.9712	0.0008	-0.0020	----	-1.2500
increases guide tube outer radius by 0.010 cm	0.9720	0.0008	-0.0012	----	-0.7500

Table 6.4-18

BWR Lattice Parameter Study Criticality Analysis Results

Description	$k_{eff}$	$\sigma$	$\Delta k$	$2\sigma$	$\Delta k / 2\sigma$
Base Case - Exxon\ANF 9x9	0.8904	0.0008	---	0.0016	---
decreases clad inner radius by 0.005 cm	0.8889	0.0008	-0.0015	---	-0.9375
decreases clad inner radius by 0.008 cm	0.8874	0.0008	-0.0030	---	-1.8750
increases clad inner radius by 0.005 cm	0.8930	0.0008	0.0026	---	1.6250
decreases clad outer radius by 0.005 cm	0.8919	0.0008	0.0015	---	0.9375
decreases clad outer radius by 0.010 cm	0.8957	0.0008	0.0053	---	3.3125
increases clad outer radius by 0.005 cm	0.8885	0.0009	-0.0019	---	-1.1875
increases clad outer radius by 0.010 cm	0.8830	0.0009	-0.0074	---	-4.6250
decreases pellet radius by 0.005 cm	0.8896	0.0008	-0.0008	---	-0.5000
decreases pellet radius by 0.010 cm	0.8909	0.0008	0.0005	---	0.3125
decreases pellet radius by 0.015 cm	0.8881	0.0008	-0.0023	---	-1.4375
decreases pellet radius by 0.020 cm	0.8832	0.0008	-0.0072	---	-4.5000
decreases pellet radius by 0.025 cm	0.8867	0.0008	-0.0037	---	-2.3125
decreases pellet radius by 0.030 cm	0.8835	0.0008	-0.0069	---	-4.3125
decreases pellet radius by 0.035 cm	0.8837	0.0008	-0.0067	---	-4.1875
decreases pellet radius by 0.040 cm	0.8807	0.0008	-0.0097	---	-6.0625
increases pellet radius by 0.005 cm	0.8908	0.0008	0.0004	---	0.2500
increases pellet radius by 0.008 cm	0.8907	0.0009	0.0003	---	0.1875
decreases water rod inner radius by 0.010 cm	0.8908	0.0008	0.0004	---	0.2500
decreases water rod inner radius by 0.015 cm	0.8916	0.0008	0.0012	---	0.7500
increases water rod inner radius by 0.010 cm	0.8919	0.0008	0.0015	---	0.9375
increases water rod inner radius by 0.015 cm	0.8911	0.0008	0.0007	---	0.4375
decreases water rod outer radius by 0.010 cm	0.8901	0.0008	-0.0003	---	-0.1875
decreases water rod outer radius by 0.015 cm	0.8913	0.0008	0.0009	---	0.5625
increases water rod outer radius by 0.010 cm	0.8916	0.0008	0.0012	---	0.7500
increases water rod outer radius by 0.015 cm	0.8892	0.0009	-0.0012	---	-0.7500
replaces water rod with water	0.8926	0.0008	0.0022	---	1.3750

---

## 6.5 Critical Benchmark Experiments

This section provides the validation of the CSAS25 criticality analysis sequence contained in Version 4.3 of the SCALE package. This validation is required by the criticality safety standards ANSI/ANS-8.1 [18]. The section describes the method, computer program and cross-section libraries used, experimental data, areas of applicability, and bias and margins of safety.

ANSI/ANS-8.17 [19] prescribes the criterion to establish subcriticality safety margins. This criterion is as follows:

$$k_s \leq k_c - \Delta k_s - \Delta k_c - \Delta k_m \quad (1)$$

where:

$k_s$  = calculated allowable maximum multiplication factor,  $k_{eff}$ , of system being evaluated for all normal or credible abnormal conditions or events.

$k_c$  = mean  $k_{eff}$  that results from calculation of benchmark criticality experiments using particular calculational method. If calculated  $k_{eff}$  values for criticality experiments exhibit trend with parameter, then  $k_c$  shall be determined by extrapolation based on best fit to calculated values. Criticality experiments used as benchmarks in computing  $k_c$  should have physical compositions, configurations, and nuclear characteristics (including reflectors) similar to those of system being evaluated.

$\Delta k_s$  = allowance for

- a. statistical or convergence uncertainties, or both, in computation of  $k_s$ ,
- b. material and fabrication tolerances, and
- c. geometric or material representations used in computational method.

$\Delta k_c$  = margin for uncertainty in  $k_c$  which includes allowance for

- a. uncertainties in critical experiments,
- b. statistical or convergence uncertainties, or both, in computation of  $k_c$ ,
- c. uncertainties resulting from extrapolation of  $k_c$  outside range of experimental data, and

- d. uncertainties resulting from limitations in geometrical of material representations used in computational method.

$\Delta k_m$  = arbitrary margin to ensure subcriticality of  $k_s$ .

The various uncertainties are combined statistically if they are independent. Correlated uncertainties are combined additively.

Equation 1 can be rewritten as:

$$k_s \leq 1 - \Delta k_m - \Delta k_s - (1 - k_c) - \Delta k_c \quad (2)$$

Noting that the NRC requires a 5% subcriticality margin ( $\Delta k_m = 0.05$ ) and the definition of the bias ( $\beta = 1 - k_c$ ), the equation 2 can then be written as:

$$k_s \leq 0.95 - \Delta k_s - \beta - \Delta \beta \quad (3)$$

where  $\Delta \beta = \Delta k_c$ . Thus, the  $k_s$  (the maximum allowable value for  $k_{eff}$ ) must be below 0.95 minus the bias, uncertainties in the bias, and uncertainties in the system being analyzed (i.e., Monte Carlo, mechanical, and modeling). This is an upper safety limit criteria often used in the DOE criticality safety community.

Alternatively, equation 3 can be rewritten applying the bias and uncertainties to the  $k_{eff}$  of the system being analyzed as:

$$k_s \equiv k_{eff} + \Delta k_s + \beta + \Delta \beta \leq 0.95 \quad (4)$$

In Equation 4,  $k_{eff}$  replaces  $k_s$ , and  $k_s$  has been redefined as the effective multiplication factor of the system being analyzed, including the method bias and all uncertainties. This is a maximum calculated  $k_{eff}$  criteria often used in LWR spent fuel storage and transport analyses.

For use in criticality evaluations of LWR fuel in storage and transport casks, both  $\beta$  and  $\Delta \beta$  are evaluated below for KENO-Va with the 27-group ENDF/B-IV library.

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### 6.5.1 Benchmark Experiments and Applicability

The criticality safety method is CSAS embedded in SCALE version 4.3 for the PC. CSAS includes the SCALE Material Information Processor, BONAMI-S, NITAWL-S, and KENO-Va. The Material Information Processor generates number densities for standard compositions, prepares geometry data for resonance self-shielding, and creates data input files for the cross-section processing codes. The BONAMI-S and NITAWL-S codes are used to prepare a resonance-corrected cross-section library in AMPX working format. The KENO-Va code uses Monte Carlo techniques to calculate the model  $k_{eff}$ . The 27-group ENDF/B-IV neutron cross-section library is used in this validation.

#### 6.5.1.1 Description of Experiments

The 63 critical experiments selected are as follows: 9 B&W 2.46 wt%  $^{235}\text{U}$  fuel storage (Baldwin et al., July 1979) [10], 10 PNL 4.31 wt%  $^{235}\text{U}$  lattice (Bierman and Clayton, July 1980) [12], 21 PNL 2.35 and 4.31 wt%  $^{235}\text{U}$  with metal reflectors (Bierman, April 1979 and August 1981) [13, 14], 12 PNL flux trap (Bierman, July 1980 and June 1988) [12, 15] and 11 VCML 4.74 wt %  $^{235}\text{U}$  experiments, some involving moderator density variations (Manaranche, September 1980) [16]. These experiments span a range of fuel enrichments, fuel rod pitches, neutron absorber sheet characteristics, shielding materials and geometries that are typical of LWR fuel in a cask.

To achieve accurate results, three-dimensional models, as close to the actual experiment as possible, are used to evaluate the experiments. Stochastic Monte Carlo error is kept within  $\pm 0.1\%$  by executing at least 1,000 neutrons/generation for more than 400 generations.

#### 6.5.1.2 Applicability of Experiments

All of the experiments chosen in this validation are applicable to either PWR or BWR fuel. Fuel enrichments have covered a range from 2.35 up to 4.74 wt %  $^{235}\text{U}$ , typical of LWR fuel presently used. The experiment fuel rod and pitch characteristics are within the range of standard PWR or BWR fuel rods (i.e., pellet OD from 0.78 to 1.2 cm, rod OD from 0.95 to 1.88 cm, and pitch from 1.26 to 1.87 cm). This is particularly true of the VCML (PWR rod type) and B&W experiments (BWR rod type). The H/U volume ratios of the experimental fuel arrays is within the range of PWR fuel assemblies (1.6 to 2.32) and BWR fuel assemblies (1.6 to 1.9). Experiments covered the

geometry and neutron absorber sheet arrangements typical of NAC basket designs. Flux trap gap spacings of 3.81 cm such as those in the NAC-STC and UMS PWR baskets and gap spacings as low 1.91 cm as in the NAC-MPC were included.  $^{10}\text{B}$  neutron absorber loadings, also typical of NAC basket designs (0.005 to 0.025), were included as well. The experiments addressed the influence of water and metal reflector regions, including steel and lead, that would be present in storage and transport cask shielding.

Confidence in predicting subcriticality, including bias and uncertainty, has been demonstrated for LWR fuel with enrichments up to 4.74 wt %  $^{235}\text{U}$  and results indicate confidence well above 5 wt %  $^{235}\text{U}$ . Confidence in predicting subcriticality has been demonstrated for storage and transport arrays in which critical controls consist of flux trap or single neutron absorber sheets or simple spacing. Confidence in predicting subcriticality has been demonstrated for LWR fuel storage and transport arrays next to water and metal reflector regions.

#### 6.5.2 Results of Benchmark Calculations

The k-effective results for the experiments are shown in Table 6.5-1 and a frequency plot is provided in Figure 6.5-1. Five sets of cases are presented: Set 1, B&W; Set 2, PNL lattice; Set 3, PNL reflector; Set 4, PNL flux trap, and Set 5, VCML critical experiments. Sixty-three results are reported.

The overall average and standard deviation of the 63 cases is  $0.9948 \pm 0.0044$ . The average Monte Carlo error (statistical convergence) is  $\pm 0.0012$  for the 63 cases. This uncertainty component is statistically subtracted from the uncertainties, because it is previously included in the standard deviation. The KENO-Va models are three-dimensional, fully explicit representations (no homogenization) of the experimental geometry. Therefore, the uncertainty resulting from limitations of geometrical modeling is taken to be 0.0. The experiments modeled cover the range of fuel types, enrichments, neutron absorber configurations, neutron absorber  $^{10}\text{B}$  loading, and metal reflector effects so that no extrapolations are necessary outside the range of data, and the uncertainty resulting from extrapolation is also taken to be 0.0. On the basis of the reported experimental error for the B&W cases, the reported error of the critical size number of rods for the PNL cases and the reported error for the critical height in the VCML cases, the experimental error is conservatively taken to be  $\pm 0.001$ . Criticality can then be represented as  $1.000 \pm 0.001$ . This uncertainty component is statistically added to the sum of the other uncertainties, because the bias is

the difference between two random variates (i.e., criticality and code prediction, and the uncertainty in the difference between two random variates is the statistical sum [(rms)] of their individual uncertainties).

Thus, the bias or average difference between code calculated and the critical condition is  $\beta = 1 - 0.9948 = 0.0052$ . The uncertainty in the bias, accounting for the statistical convergence (Monte Carlo error) and the uncertainty in criticality is  $(0.0044^2 - 0.0012^2 + 0.0010^2)^{1/2} = 0.0043$ . For 63 samples of criticality, the 95/95 one-side tolerance factor is 2.012 (Owen, 1963) [17]. The result is a 95/95 one-sided uncertainty in the bias of  $\Delta\beta = 2.012 \times 0.0043 = 0.0087$ . Equation 3 now becomes:

$$k_{\text{eff}} + \Delta k_s + 0.0052 + 0.0087 \leq 0.95 \quad (5)$$

where  $\Delta k_s$  becomes the uncertainty in  $k_s$  resulting from Monte Carlo error, mechanical and material tolerances, and geometric or material representations. If the nominal representation of the system is evaluated for  $k_s$ , then the mechanical and material perturbations can be evaluated independently and can be combined statistically as the root sum of squares. If the worst-case mechanical and material tolerances are used to calculate  $k_s$  (e. g., 75% of boron loading and most reactive positioning of fuel or basket components), then  $\Delta k_s$  becomes 0.0 and the Monte Carlo error,  $\sigma_{\text{mc}}$ , can be combined statistically, because it is independent, with the uncertainty in the bias as:

$$k_{\text{eff}} + 0.0052 + \sqrt{0.0087^2 + (2\sigma)^2} \leq 0.95 \quad (6)$$

### 6.5.3 Trends

Scatter plots of  $k_{\text{eff}}$  versus wt %  $^{235}\text{U}$ , rod pitch, H/U volume ratio, average neutron group causing fission,  $^{10}\text{B}$  loading for flux trap cases, and flux trap gap thickness are shown in Figures 6.5-2 through 6.5-7. Included in these scatter plots are linear regression lines with a corresponding correlation coefficient to statistically indicates any trend or lack thereof. In particular, the correlation coefficient is a measure of the linear relationship between  $k_{\text{eff}}$  and a critical experiment parameter. If  $r$  is +1, a perfect linear relationship with a positive slope is indicated, and if  $r$  is -1, a perfect linear relationship with a negative slope is indicated. When  $r$  is 0, no linear relationship is indicated. The largest correlation coefficient indicated in the plots is 0.1302 ( $k_{\text{eff}}$  versus enrichment) and the lowest is 0.0048 ( $k_{\text{eff}}$  versus  $^{10}\text{B}$  loading in flux trap experiments). On the basis



of the correlation coefficients, no statistically significant trends exist over the range of variables studied. Most importantly, no trend is shown with flux trap gap spacing and/or  $^{10}\text{B}$  loading. This is the major criticality control feature of the NAC-STC and the Universal Transport Cask basket.

#### 6.5.4 Comparison of NAC Method to NUREG/CR-6361

NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages" (NUREG), provides a guide to LWR criticality benchmark calculations and the determination of bias and subcritical limits in critical safety evaluations. In Section 2 of the NUREG, a series of LWR critical experiments are described in sufficient detail for independent modeling. In Section 3, the critical experiments are modeled, and the results ( $k_{\text{eff}}$  values) are presented. The method utilized in the NUREG is KENO-Va with the 44 group ENDF/B-V cross section library embedded in SCALE 4.3. Inputs are provided in Appendix A of the NUREG. In Section 4, a guide for the determination of bias and subcritical safety limits is provided based on ANSI/ANS-8.17 and statistical analysis of the trending in the bias. Finally, guidelines for experiment selection and applicability are presented in Section 5. The approach outlined in Section 4 of the NUREG is described in detail below and is compared to the NAC approach presented in Sections 6.5, 6.5.1 and 6.5.2.

NAC has performed an extensive LWR critical benchmarking as documented in Sections 6.5.1 and 6.5.2. The method used in NAC benchmarking/validation included the CSAS25 (KENO-Va) criticality analysis sequence, with the 27 group ENDF/B-IV library, contained in SCALE 4.3. Trending in  $k_{\text{eff}}$  was evaluated for the following independent variables: wt %  $^{235}\text{U}$ , rod pitch, H/U volume ratio, average neutron group causing fission,  $^{10}\text{B}$  loading for flux trap cases, and flux trap gap thickness. No statistically significant trends were found, and a constant bias with associated uncertainty was determined for criticality evaluation.

Both the NUREG/CR-6361 and the NAC approach to criticality evaluation start with ANSI/ANS-8.17 criticality safety criterion. This criterion is as follows:

$$k_s \leq k_c - \Delta k_s - \Delta k_c - \Delta k_m \quad (1)$$

where:

$k_s$  = calculated allowable maximum multiplication factor,  $k_{\text{eff}}$ , of the system being evaluated for all normal or credible abnormal conditions or events.

$k_c$  = mean  $k_{eff}$  that results from a calculation of benchmark criticality experiments using a particular calculation method. If the calculated  $k_{eff}$  values for the criticality experiments exhibit a trend with an independent parameter, then  $k_c$  shall be determined by extrapolation based on best fit to calculated values. Criticality experiments used as benchmarks in computing  $k_c$  should have physical compositions, configurations, and nuclear characteristics (including reflectors) similar to those of the system being evaluated.

$\Delta k_s$  = allowance for:

- a) statistical or convergence uncertainties, or both, in computation of  $k_s$ ,
- b) material and fabrication tolerances, and
- c) geometric or material representations used in computational method.

$\Delta k_c$  = margin for uncertainty in  $k_c$  which includes allowance for:

- a) uncertainties in critical experiments,
- b) statistical or convergence uncertainties, or both, in computation of  $k_c$ ,
- c) uncertainties resulting from extrapolation of  $k_c$  outside range of experimental data, and
- d) uncertainties resulting from limitations in geometrical or material representations used in the computational method.

$\Delta k_m$  = arbitrary administrative margin to ensure subcriticality of  $k_s$

The various uncertainties are combined statistically if they are independent. Correlated uncertainties are combined by addition.

Equation 1 can be rewritten as:

$$k_s \leq 1 - \Delta k_m - \Delta k_s - (1 - k_c) - \Delta k_c \quad (2)$$

Noting that the definition of the bias is  $\beta = 1 - k_c$ , Equation 2 can be written as:

$$k_s + \Delta k_s \leq 1 - \Delta k_m - \beta - \Delta \beta \quad (3)$$

where  $\Delta\beta = \Delta k_c$ . Thus, the maximum allowable value for  $k_{eff}$  plus uncertainties in the system being analyzed must be below 1 minus an administrative margin (typically 0.05), which includes the bias and the uncertainty in the bias. This can also be written as:

$$k_s + \Delta k_s \leq \text{Upper Safety Limit (USL)} \quad (4)$$

where:

$$\text{USL} = 1 - \Delta k_m - \beta - \Delta\beta \quad (5)$$

This is the Upper Safety Limit criterion as described in Section 4 of NUREG/CR-6361. Two methods are prescribed for the statistical determination of the USL: Confidence Band with Administrative Margin (USL-1) and Single Sided Uniform with Close Approach (USL-2). In the first method,  $\Delta k_m = 0.05$  and a lower confidence band (usually 95%) is specified based on a linear regression of  $k_{eff}$  as a function of some system parameter. In the second method, the arbitrary administrative margin is set to zero and a uniform lower tolerance band is determined based on a linear regression. The second method provides a criticality safety margin that is generally less than 0.05. In cases where there are a limited number of data points, this method may indicate the need for a larger administrative margin. In both cases, all of the significant system parameters need to be studied to determine the strongest correlation.

In the analyses presented in Section 6.5.1 and 6.5.2, the bias and uncertainties are applied directly to the estimate of the system  $k_{eff}$ . Noting that the NRC requires a 5% subcriticality margin ( $\Delta k_m = 0.05$ ), Equation 3 can be rewritten applying the bias and uncertainty in the bias to the  $k_{eff}$  of the system being analyzed as:

$$k_s + \Delta k_s + \beta + \Delta\beta \leq 0.95 \quad (6)$$

In Equation 6, the method bias and all uncertainties are added to  $k_s$ . This is the maximum  $k_{eff}$  criterion defined in Section 6.5.2.

To this point, both the USL criterion and maximum  $k_{eff}$  criterion are equivalent. The effects of trending in the bias or the uncertainty in the bias can be directly incorporated into either Equation 5 or Equation 6. Trending is established by performing a regression analysis of  $k_{eff}$  as a function of the principle system variables such as: enrichment, rod pitch, H to U ratio, average group of fission,  $^{10}\text{B}$  absorber loading and flux trap gap spacing. Usually, simple linear regression is performed, and the line with the greatest correlation is used to functionalize  $\beta$ . This approach is recommended in

NUREG/CR-6361. However, if no strong correlation can be determined, then a constant bias adjustment can be made. This is typically done with a one-side tolerance factor that guarantees 95% confidence in the uncertainty in the bias. This is the approach taken in the UMS criticality analysis.

Both NUREG/CR-6361 and the NAC evaluation perform regression analysis on key system parameters. For all of the major system parameters, the evaluation found no strong correlation. This is based on the observation that the correlation coefficients are all much less than  $\pm 1$ . Thus a constant bias with a 95/95 confidence factor is applied to the system  $k_{\text{eff}}$ . NAC's statistical analysis of the  $k_{\text{eff}}$  results produced a bias of 0.0052 and a 95/95 uncertainty of 0.0087. Adding the two together and subtracting from 0.95 yields an effective constant USL of 0.9361.

To assure compliance with NUREG/CR-6361, an upper safety limit is generated using USLSTATS and is compared to the constant NAC bias and bias uncertainty used in Section 6.5.2.

To evaluate the relative importance of the trend analysis to the upper safety limits, correlation coefficients are required for all independent parameters. Table 6.5-2 contains the correlation coefficient,  $R$ , for each linear fit of  $k_{\text{eff}}$  versus experimental parameter (data is extracted from Figure 6.5-2 through Figure 6.5-7 by taking the square root of the  $R^2$  value). Based on the highest correlation coefficient and the method presented in NUREG/CR-6361, a USL is established based on the variation of  $k_{\text{eff}}$  with enrichment. Note that even the enrichment function shows a low statistical correlation coefficient (an  $|R|$  equal or near 1 would indicate a good fit). The output generated by USLSTATS is shown in Figure 6.5-8.

The NAC applied USL of 0.9361 bounds the calculated upper safety limits for all enrichment values above 3.0 wt %  $^{235}\text{U}$ . Since the maximum reactivities in the UMS are calculated at enrichments well above this level, the existing bias bounds the NUREG calculated USL. The most reactive UMS configuration is the PWR basket configuration with Westinghouse 17x17 OFA fuel assemblies. The parameters of the most reactive fuel configuration for the UMS design basis fuel and for the Maine Yankee fuel are presented in Table 6.5-3. This table also compares the most reactive fuel parameters to the minimum and maximum benchmark values to demonstrate the applicability of the critical benchmarks.

#### 6.5.5 MONK Validation in Accordance with NUREG/CR-6361

NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages" (NUREG), provides a guide to LWR criticality benchmark calculations and the determination of bias and subcritical limits in critical safety evaluations. Section 6.5.1 contains detail on the implementation of the NUREG in subcritical limit evaluations for the UMS Transport Cask. This section implements the ULSTATS method of the NUREG for MONK8A application with JEF 2.2 point energy libraries in LWR transport and storage applications.

AEA Technologies has performed an extensive benchmarking of MONK8A. Critical benchmarks relevant to LWR fuel evaluations were extracted from the total benchmark set and listed in Table 6.5-6. The range of the parameters to be benchmarked is summarized in Table 6.5-4. Trending in  $k_{\text{eff}}$  was evaluated for the following independent variables: enrichment, rod pitch, fuel pellet diameter, fuel rod diameter, H/U ratio, average neutron group causing fission,  $^{10}\text{B}$  loading for flux trap cases, and flux trap gap thickness. The data is plotted in Figures 6.5-9 through 6.5-16.

To evaluate the relative importance of the trend analysis to the upper safety limits, correlation coefficients are required for all independent parameters. Table 6.5-5 contains the correlation coefficient,  $R$ , for each linear fit of  $k_{\text{eff}}$  versus experimental parameter (data is extracted from Figure 6.5-9 through Figure 6.5-16 by taking the square root of the  $R^2$  value). Based on the highest correlation coefficient and the method presented in NUREG/CR-6361, a USL is established based on the variation of  $k_{\text{eff}}$  with flux trap thickness. Note that even the flux trap function shows a low statistical correlation coefficient (an  $|R|$  equal or near 1 would indicate a good fit). The output generated by USLSTATS is shown in Figure 6.5-17.

The NAC applied USL is 0.9425, and bounds the calculated upper safety limits for the typical flux trap spacing found in multi-purpose casks. The parameters of the most reactive CY-MPC payload are included in Table 6.5-4.

Figure 6.5-1 KENO-Va Validation - 27 Group Library Results: Frequency Distribution of  $k_{eff}$  Values

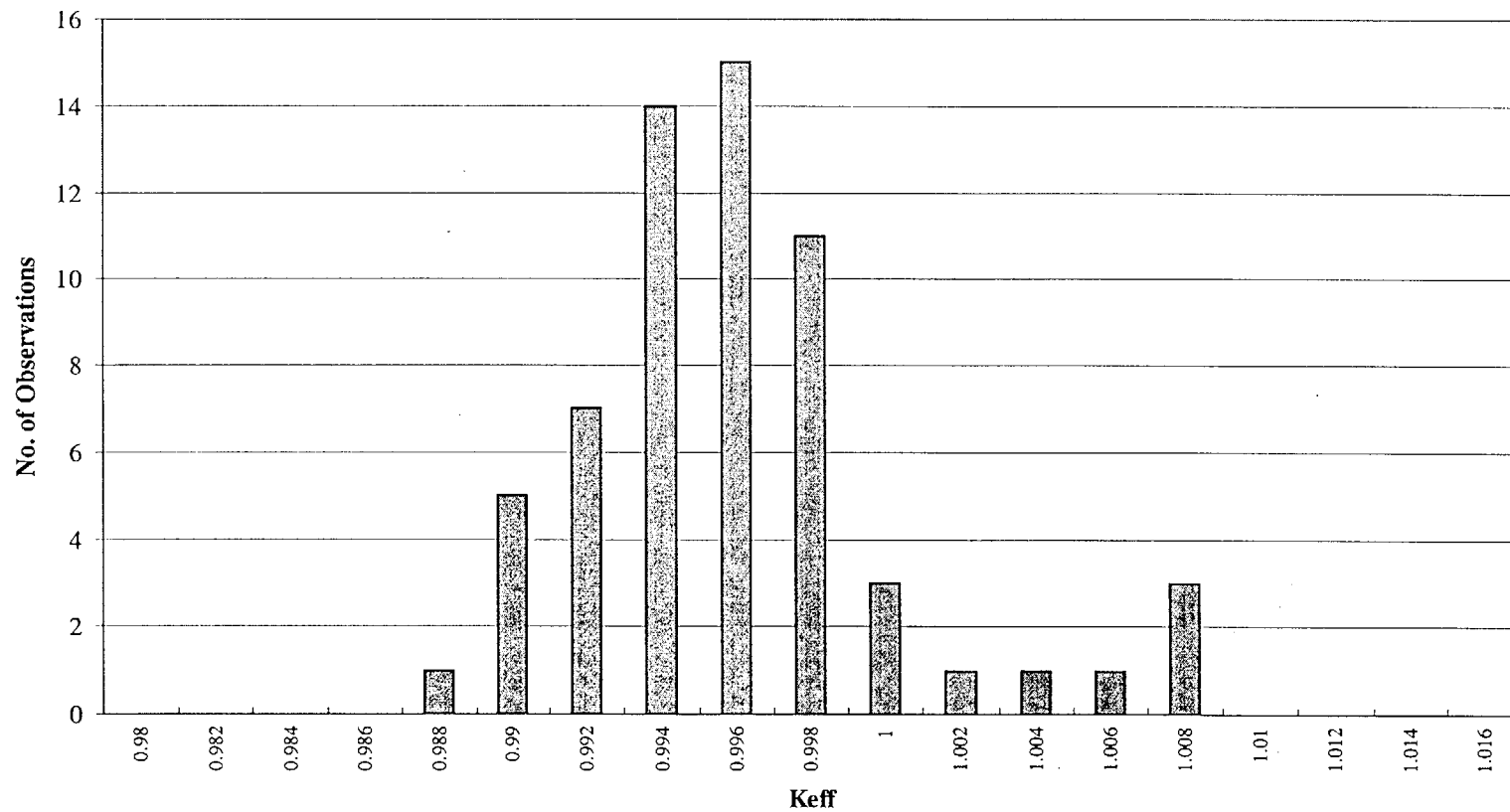


Figure 6.5-2 KENO-Va Validation - 27-Group Library Results:  $k_{eff}$  versus Enrichment

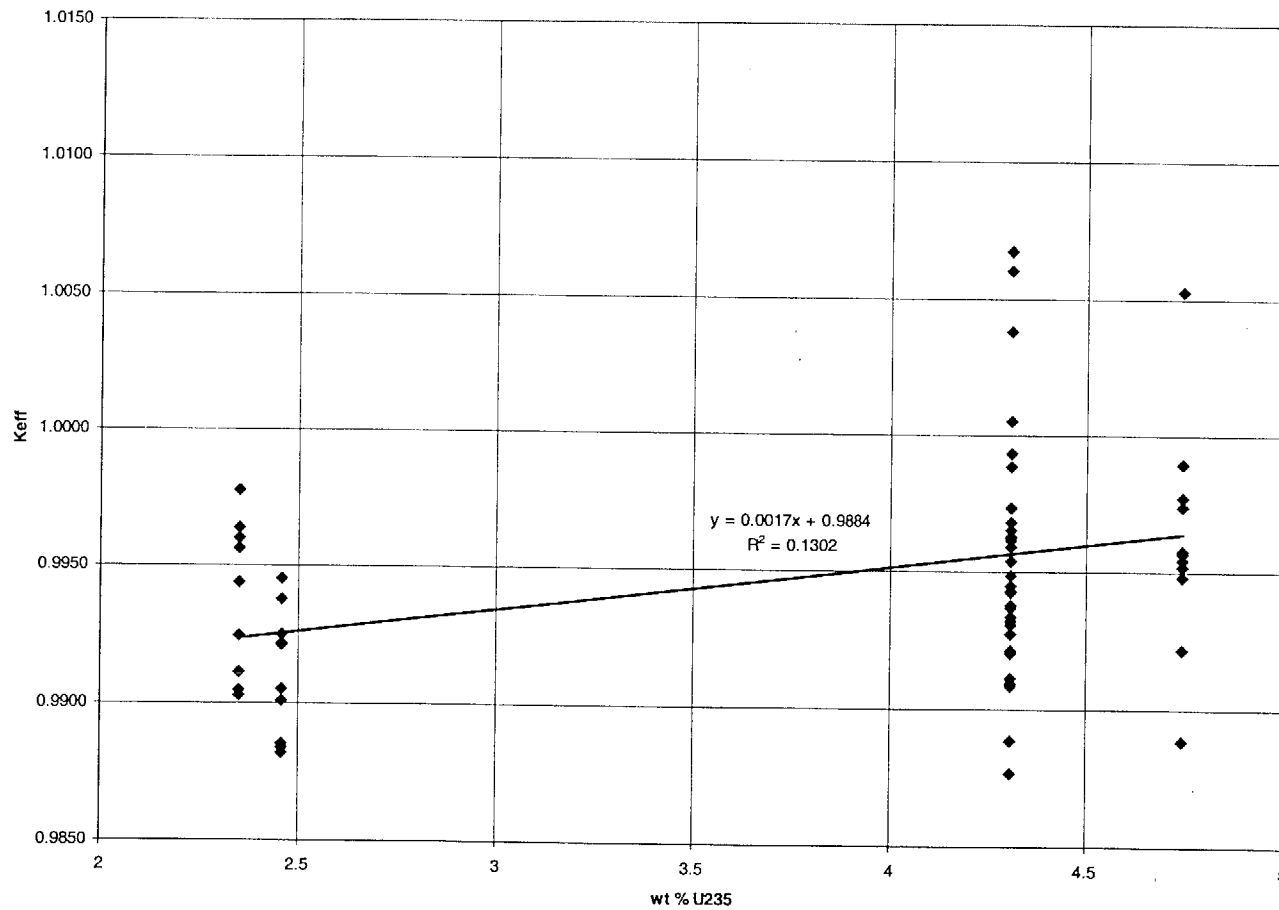


Figure 6.5-3 KENO-Va Validation - 27-Group Library Results:  $k_{\text{eff}}$  versus Rod Pitch

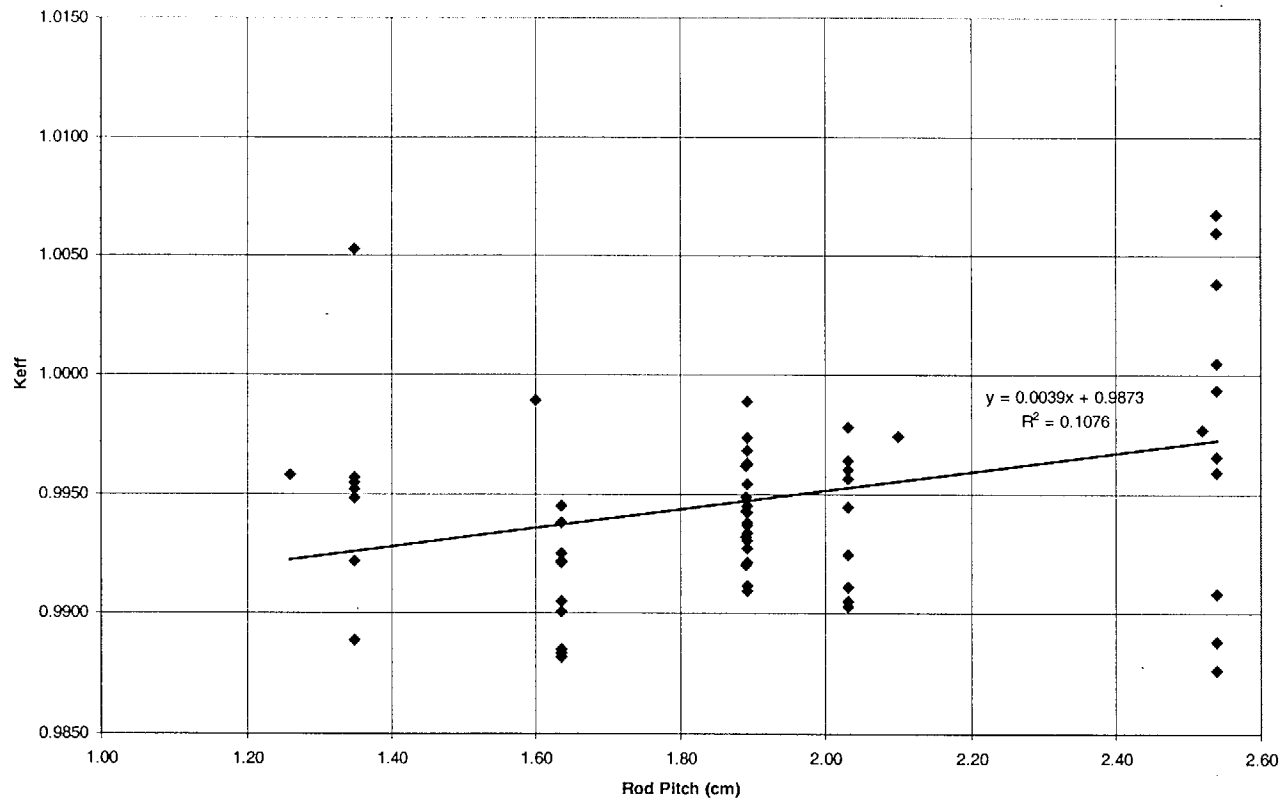




Figure 6.5-4 KENO-Va Validation - 27-Group Library Results:  $k_{\text{eff}}$  versus H/U Volume Ratio

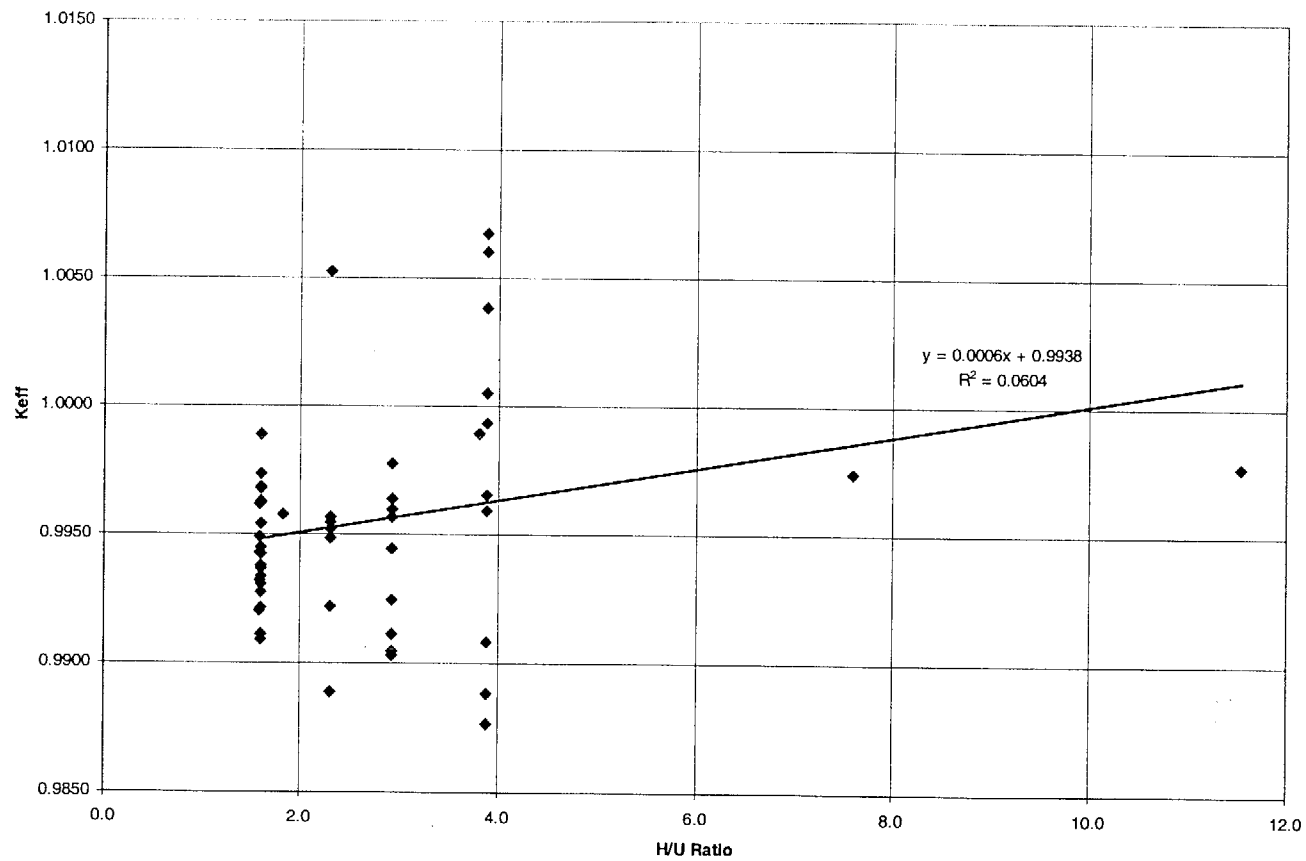


Figure 6.5-5 KENO-Va Validation - 27-Group Library Results:  $k_{eff}$  versus Average Group of Fission

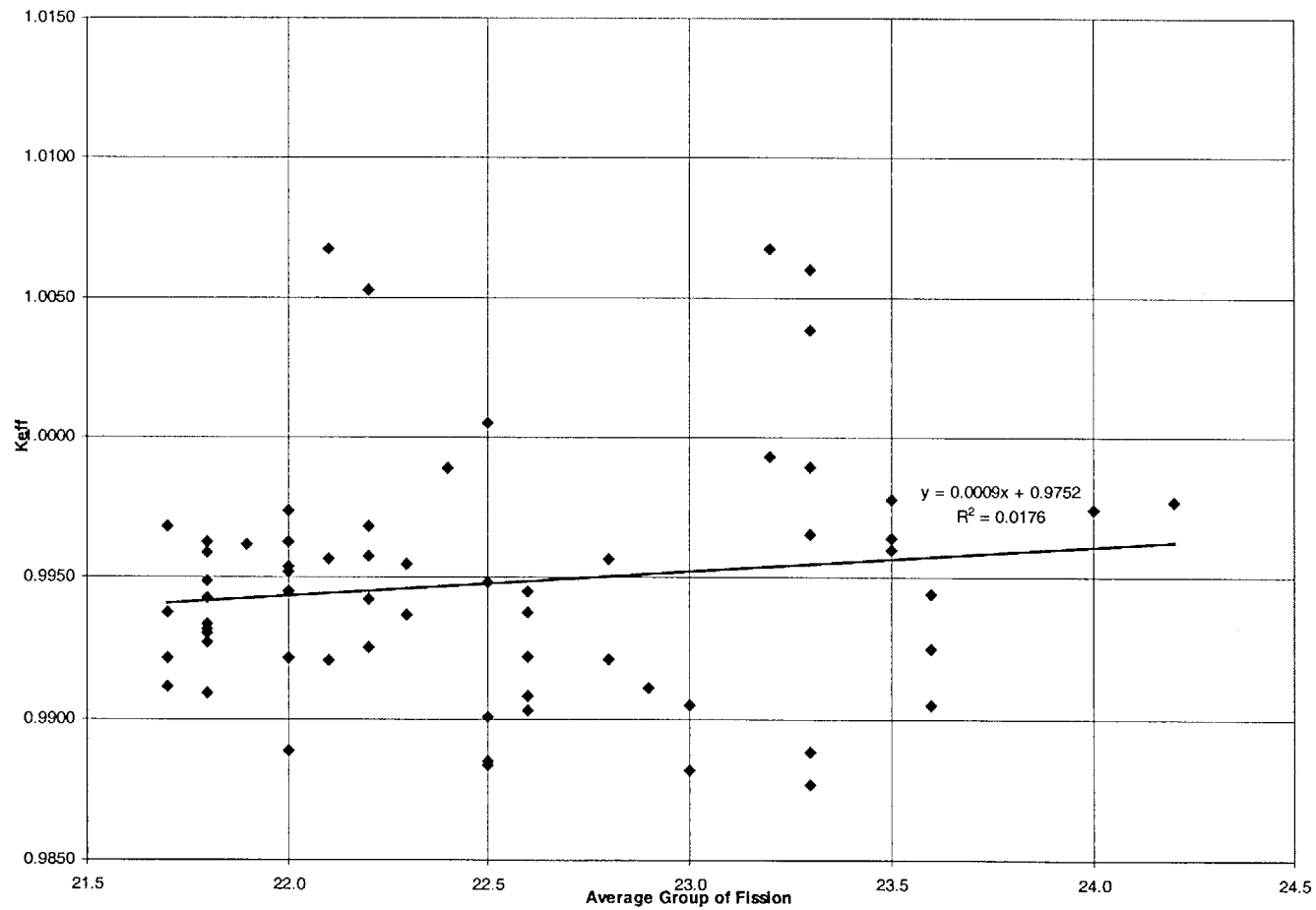


Figure 6.5-6 KENO-Va Validation - 27-Group Library Results:  $k_{eff}$  versus  $^{10}\text{B}$  Loading for Flux Trap Criticals

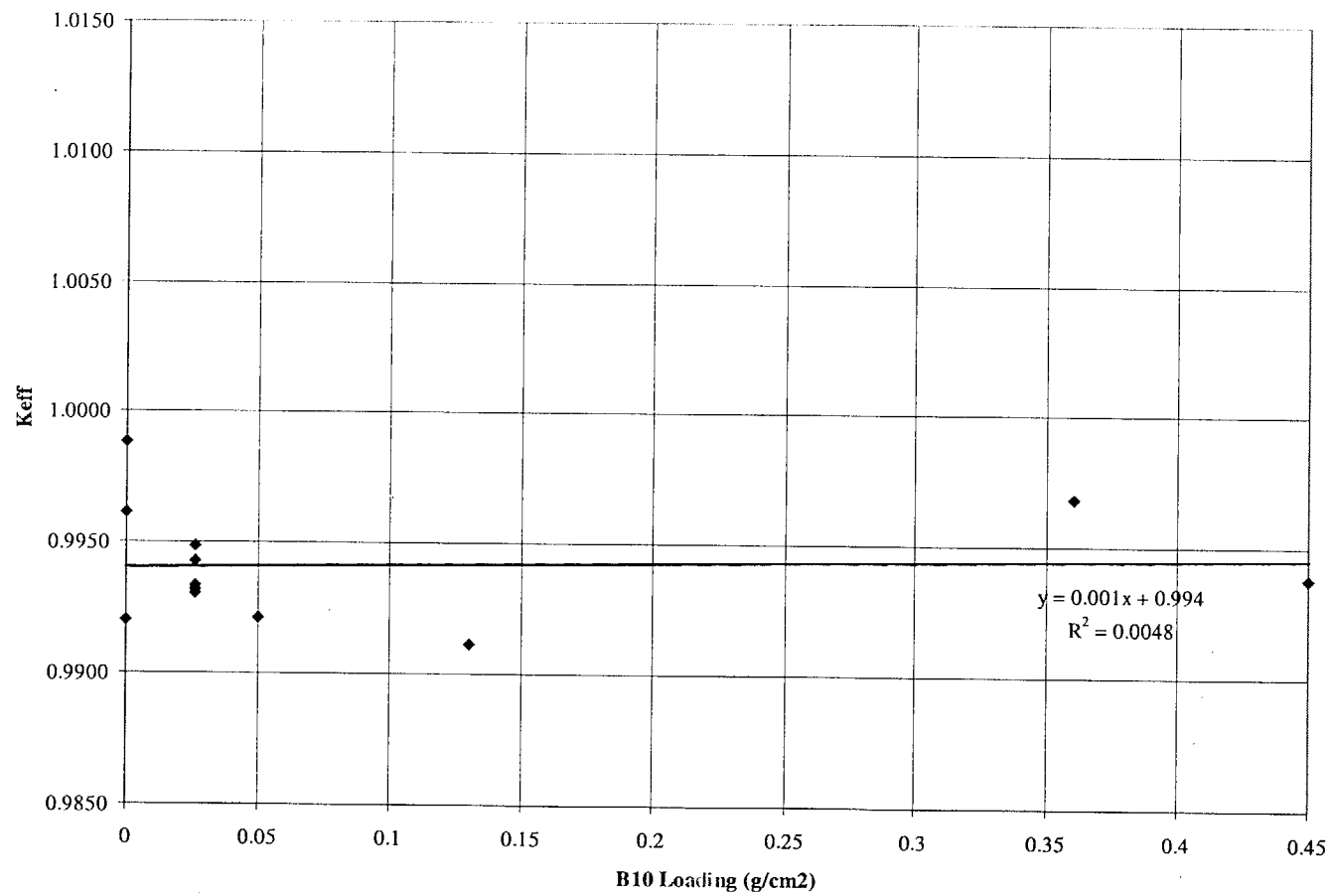


Figure 6.5-7 KENO-Va Validation - 27-Group Library Results:  $k_{\text{eff}}$  versus Flux Trap Critical Gap Thickness

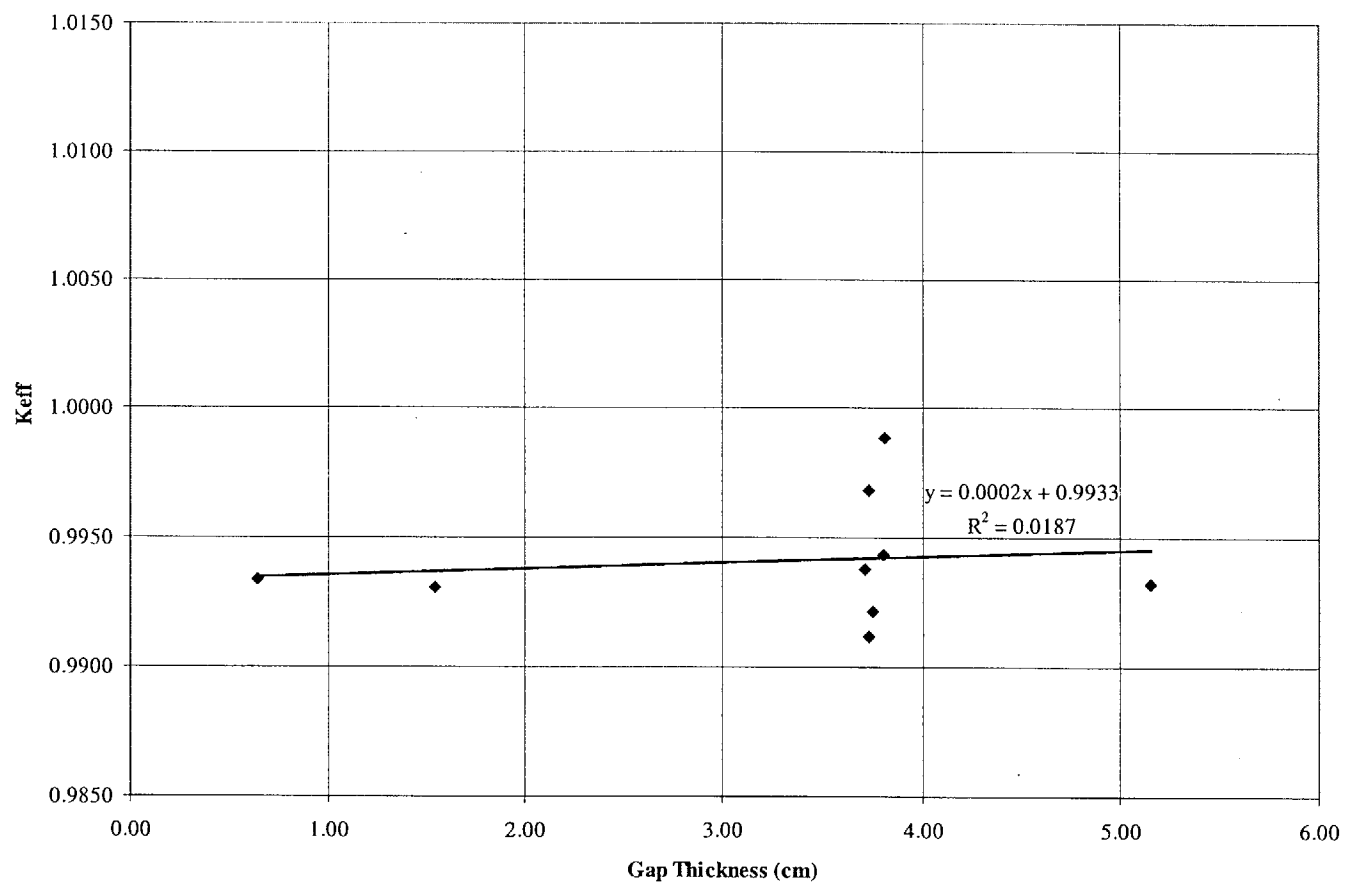


Figure 6-5-8 USLSTATS Output for Fuel Enrichment Study

USLSTATS: a utility to calculate upper subcritical  
limits for critically safety applications

\*\*\*\*\*  
Version 1.3.4, February 12, 1998  
Oak Ridge National Laboratory  
\*\*\*\*\*

Input to statistical treatment from file: EN KEFF.TXT  
File: 63 LWR CRITICAL EXPERIMENT KEFF VS ENRICHMENT

Proportion of the population = .995  
Confidence of fit = .950  
Confidence on proportion = .950  
Number of observations = 63  
Minimum value of closed band = 0.00  
Maximum value of closed band = 0.00  
Administrative margin = 0.05

independent	dependent	variable - x	in y	independent	dependent	variable - y	in y
-------------	-----------	--------------	------	-------------	-----------	--------------	------

2.3500E+00	9.9640E-01	1.0000E-03	4.3100E+00	9.9650E-01	1.1000E-03	4.3100E+00	9.9650E-01
2.3500E+00	9.9440E-01	1.0000E-03	4.3100E+00	1.0068E+00	2.1000E-03	4.3100E+00	1.0068E+00
2.3500E+00	9.9050E-01	1.0000E-03	4.3100E+00	1.0038E+00	1.2000E-03	4.3100E+00	1.0038E+00
2.3500E+00	9.9600E-01	1.1000E-03	4.3100E+00	1.0030E+00	1.1000E-03	4.3100E+00	1.0030E+00
2.3500E+00	9.9780E-01	1.0000E-03	4.3100E+00	9.9590E-01	1.1000E-03	4.3100E+00	9.9590E-01
2.3500E+00	9.9250E-01	1.0000E-03	4.3100E+00	9.9250E-01	1.0000E-03	4.3100E+00	9.9250E-01
2.3500E+00	9.9030E-01	9.0000E-04	4.3100E+00	1.0067E+00	1.0000E-03	4.3100E+00	1.0067E+00
2.3500E+00	9.9570E-01	1.0000E-03	4.3100E+00	9.9080E-01	1.1000E-03	4.3100E+00	9.9080E-01
2.3500E+00	9.9110E-01	1.0000E-03	4.3100E+00	9.8890E-01	1.2000E-03	4.3100E+00	9.8890E-01
2.4600E+00	9.9210E-01	1.1000E-03	4.3100E+00	9.9210E-01	1.2000E-03	4.3100E+00	9.9210E-01
2.4600E+00	9.9250E-01	9.0000E-04	4.3100E+00	9.9110E-01	1.2000E-03	4.3100E+00	9.9110E-01
2.4600E+00	9.9380E-01	9.0000E-04	4.3100E+00	9.9680E-01	1.3000E-03	4.3100E+00	9.9680E-01
2.4600E+00	9.9050E-01	1.0000E-03	4.3100E+00	9.9380E-01	1.2000E-03	4.3100E+00	9.9380E-01
2.4600E+00	9.8820E-01	1.0000E-03	4.3100E+00	9.9340E-01	1.0000E-03	4.3100E+00	9.9340E-01
2.4600E+00	9.9450E-01	1.0000E-03	4.3100E+00	9.9310E-01	1.0000E-03	4.3100E+00	9.9310E-01
2.4600E+00	9.9220E-01	1.0000E-03	4.3100E+00	9.9430E-01	1.0000E-03	4.3100E+00	9.9430E-01
2.4600E+00	9.8850E-01	1.0000E-03	4.3100E+00	9.9320E-01	1.0000E-03	4.3100E+00	9.9320E-01
2.4600E+00	9.8840E-01	1.0000E-03	4.3100E+00	9.9490E-01	1.0000E-03	4.3100E+00	9.9490E-01
2.4600E+00	9.9010E-01	9.0000E-04	4.3100E+00	9.9200E-01	1.0000E-03	4.3100E+00	9.9200E-01
2.4600E+00	9.9540E-01	1.4000E-03	4.3100E+00	9.9200E-01	1.0000E-03	4.3100E+00	9.9200E-01
4.3100E+00	9.9450E-01	1.3000E-03	4.7400E+00	9.9620E-01	1.3000E-03	4.7400E+00	9.9620E-01
4.3100E+00	9.9630E-01	1.3000E-03	4.7400E+00	9.9570E-01	1.3000E-03	4.7400E+00	9.9570E-01
4.3100E+00	9.9090E-01	1.2000E-03	4.7400E+00	1.00530E+00	1.1000E-03	4.7400E+00	1.00530E+00
4.3100E+00	9.9620E-01	1.2000E-03	4.7400E+00	9.9550E-01	1.2000E-03	4.7400E+00	9.9550E-01
4.3100E+00	9.9970E-01	1.2000E-03	4.7400E+00	9.9480E-01	1.3000E-03	4.7400E+00	9.9480E-01
4.3100E+00	9.9270E-01	1.3000E-03	4.7400E+00	9.9580E-01	1.2000E-03	4.7400E+00	9.9580E-01
4.3100E+00	9.9420E-01	1.2000E-03	4.7400E+00	9.9520E-01	1.2000E-03	4.7400E+00	9.9520E-01
4.3100E+00	9.9680E-01	1.2000E-03	4.7400E+00	9.9690E-01	1.3000E-03	4.7400E+00	9.9690E-01
4.3100E+00	9.8730E-01	2.3000E-03	4.7400E+00	9.9740E-01	1.2000E-03	4.7400E+00	9.9740E-01
4.3100E+00	9.9930E-01	1.2000E-03	4.7400E+00	9.9770E-01	1.1000E-03	4.7400E+00	9.9770E-01
4.3100E+00	1.0060E+00	2.2000E-03	4.7400E+00	9.9770E-01	1.1000E-03	4.7400E+00	9.9770E-01

chi = 2.1587 (upper bound = 9.49) The data tests normal

Figure 6.5-8 USLSTATS Output for Fuel Enrichment Study (Continued)

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Output from statistical treatment
63 LWR CRITICAL EXPERIMENT KEFF VS ENRICHMENT
Number of data points (n) 63
Linear regression, k(X) 0.9884 + ( 1.6748E-03)*X
Confidence on fit (1-gamma) [input] 95.0%
Confidence on proportion (alpha) [input] 95.0%
Proportion of population falling above
lower tolerance interval (rho) [input] 99.5%
Minimum value of X 2.3500
Maximum value of X 4.7400
Average value of X 3.81143
Average value of k 0.99482
Minimum value of k 0.98770
Variance of fit, s(k,X)^2 1.6973E-05
Within variance, s(w)^2 1.4306E-06
Pooled variance, s(p)^2 1.8404E-05
Pooled std. deviation, s(p) 4.2900E-03
C(alpha,rho)*s(p) 1.5488E-02
student-t @ (n-2,1-gamma) 1.67078E+00
Confidence band width, W 7.3606E-03
Minimum margin of subcriticality, C*s(p)-W 8.1273E-03
Upper subcritical limits: ( 2.35000 <= X <= 4.74000)
*****
USL Method 1 (Confidence Band with
Administrative Margin) USL1 = 0.9311 + ( 1.6748E-03)*X
USL Method 2 (Single-Sided Uniform
Width Closed Interval Approach) USL2 = 0.9729 + ( 1.6748E-03)*X
USLs Evaluated Over Range of Parameter X:
****
X: 2.35 2.69 3.03 3.37 3.72 4.06 4.40 4.74
USL-1: 0.9350 0.9356 0.9362 0.9367 0.9373 0.9379 0.9384 0.9390
USL-2: 0.9769 0.9775 0.9780 0.9786 0.9792 0.9797 0.9803 0.9809
*****
Thus spake USLSTATS
Finis

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Figure 6.5-9

MONK8A – JEF 2.2 Library Validation Statistics –  $k_{\text{eff}}$  versus Fuel Enrichment

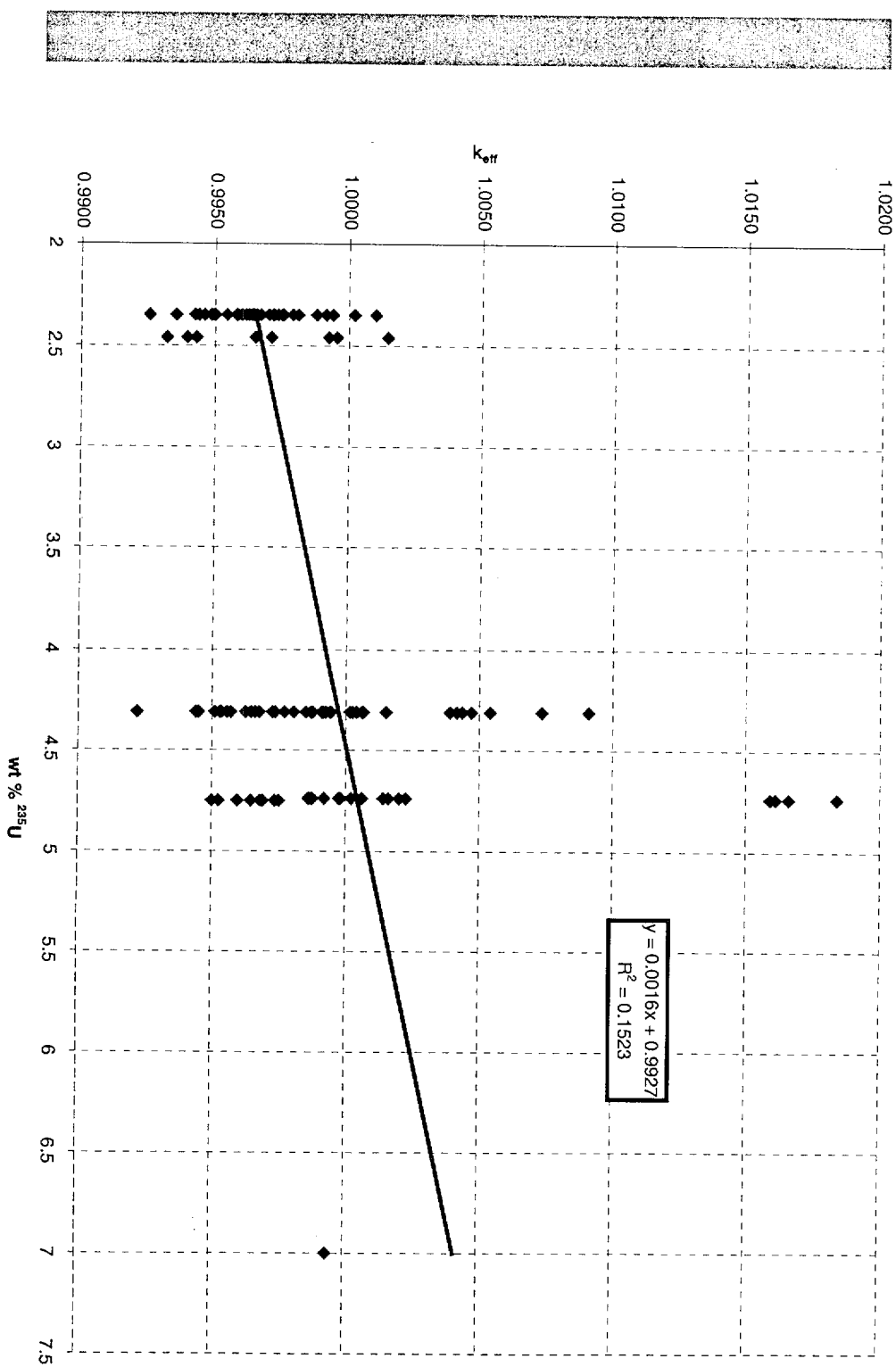


Figure 6.5-10 MONK8A – JEF 2.2 Library –  $k_{\text{eff}}$  versus Rod Pitch

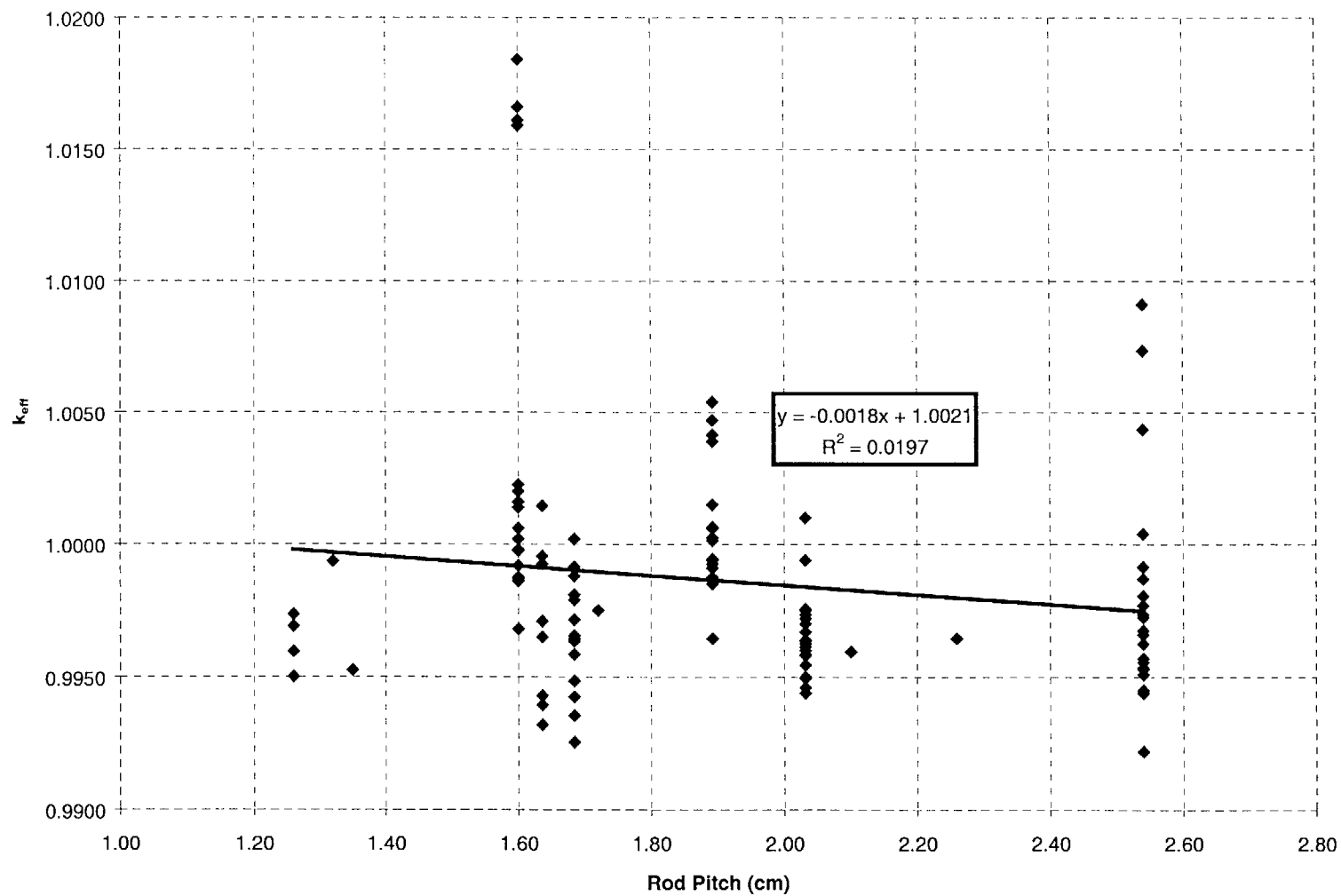




Figure 6.5-11 MONK8A – JEF 2.2 Library -  $k_{\text{eff}}$  versus H/U (fissile) Atom Ratio

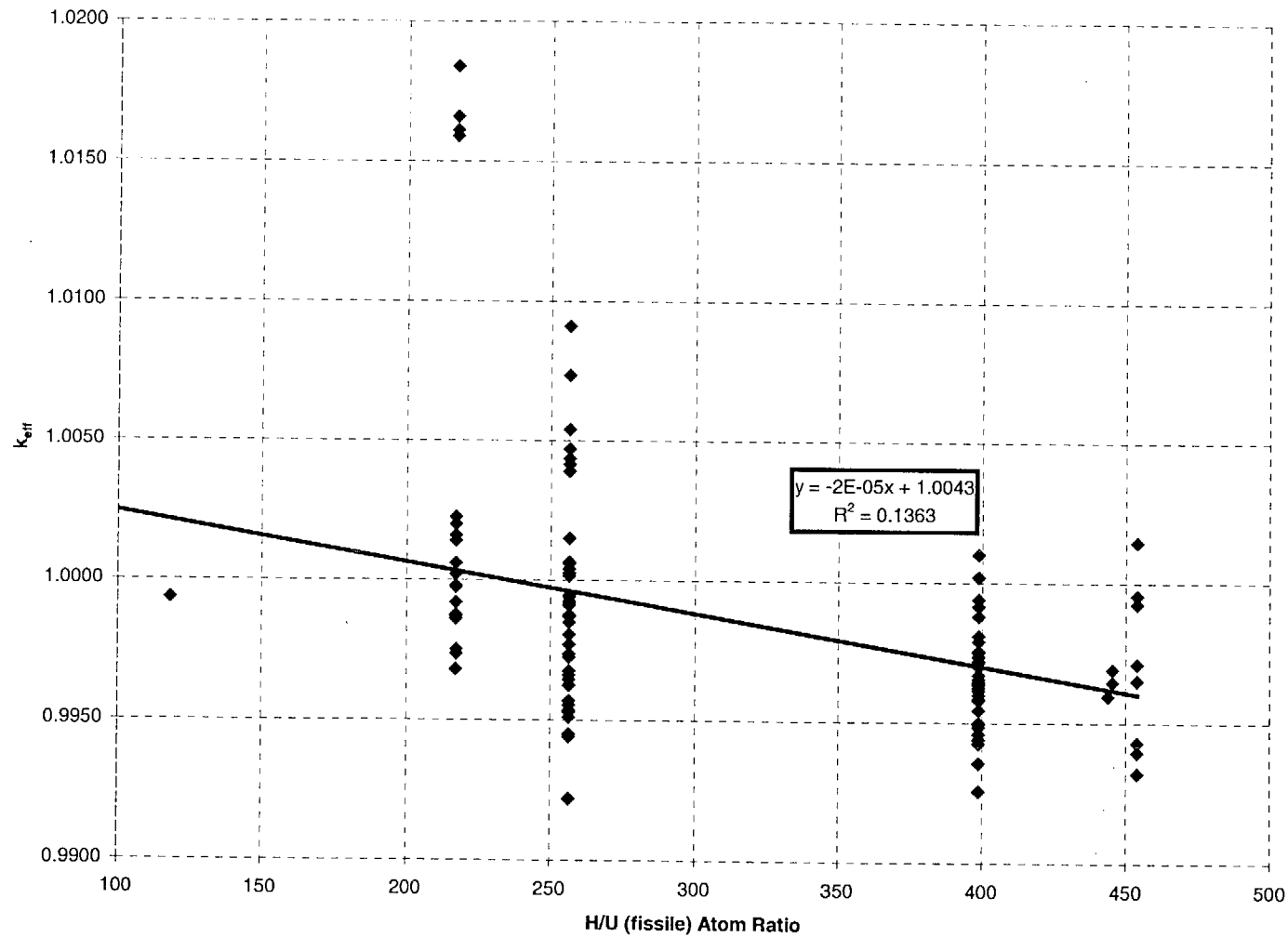


Figure 6.5-12 MONK8A – JEF 2.2 Library -  $k_{\text{eff}}$  versus  $^{10}\text{B}$  Loading

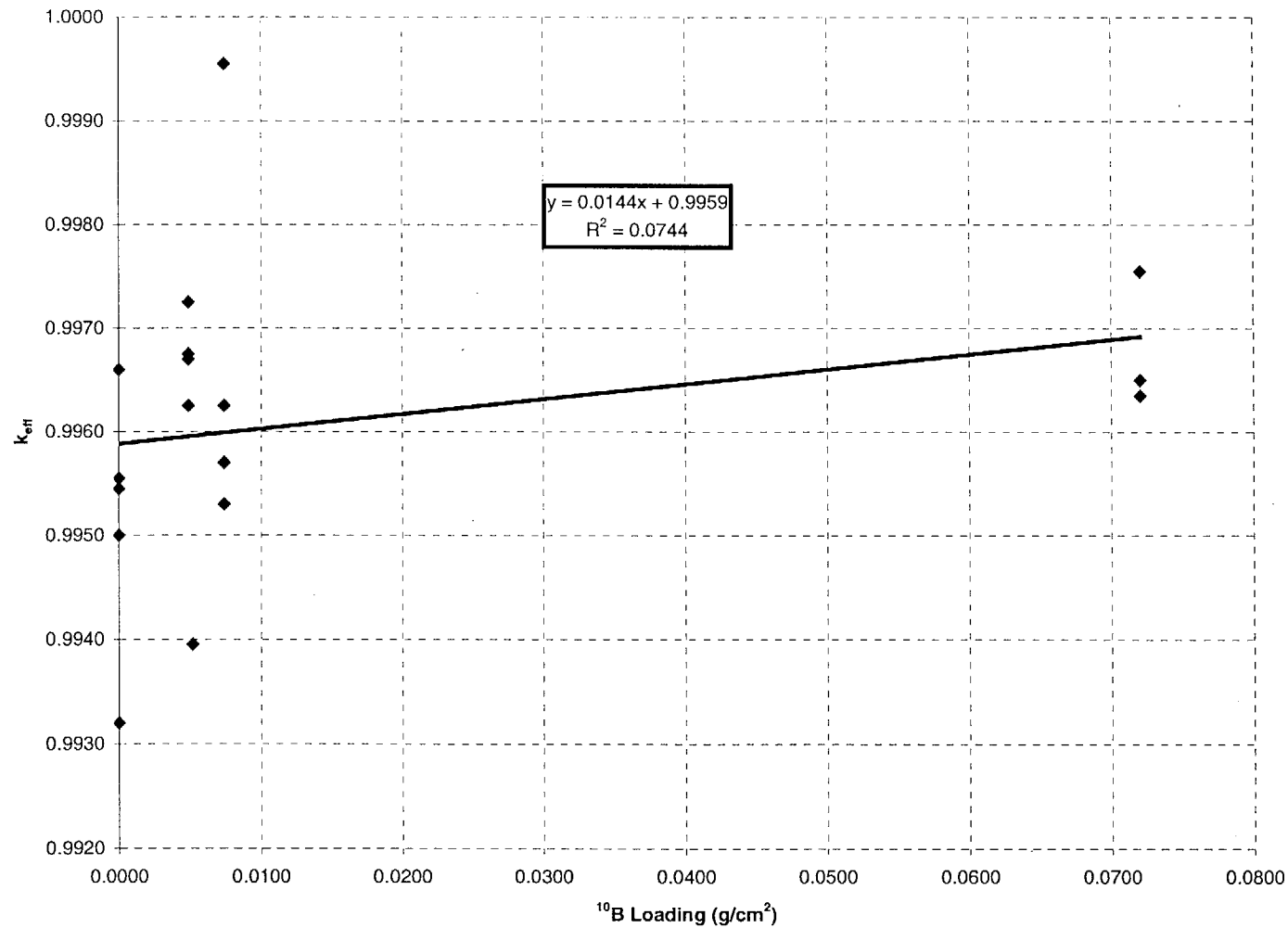


Figure 6.5-13

MONK8A - JEF 2.2 Library -  $k_{eff}$  versus Mean Neutron Log(E) Causing Fission

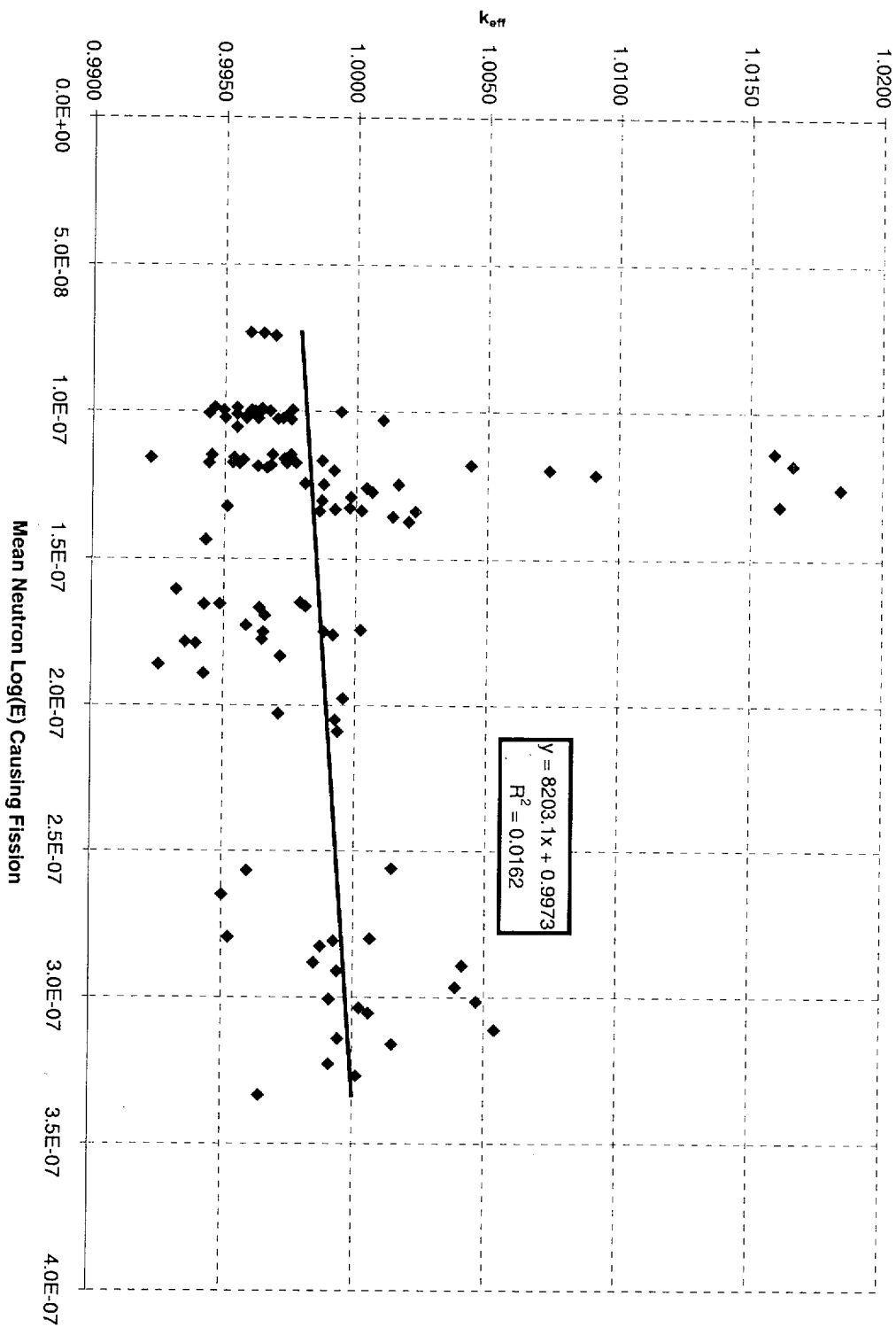


Figure 6.5-14 MONK8A – JEF 2.2 Library -  $k_{\text{eff}}$  versus Cluster Gap Thickness

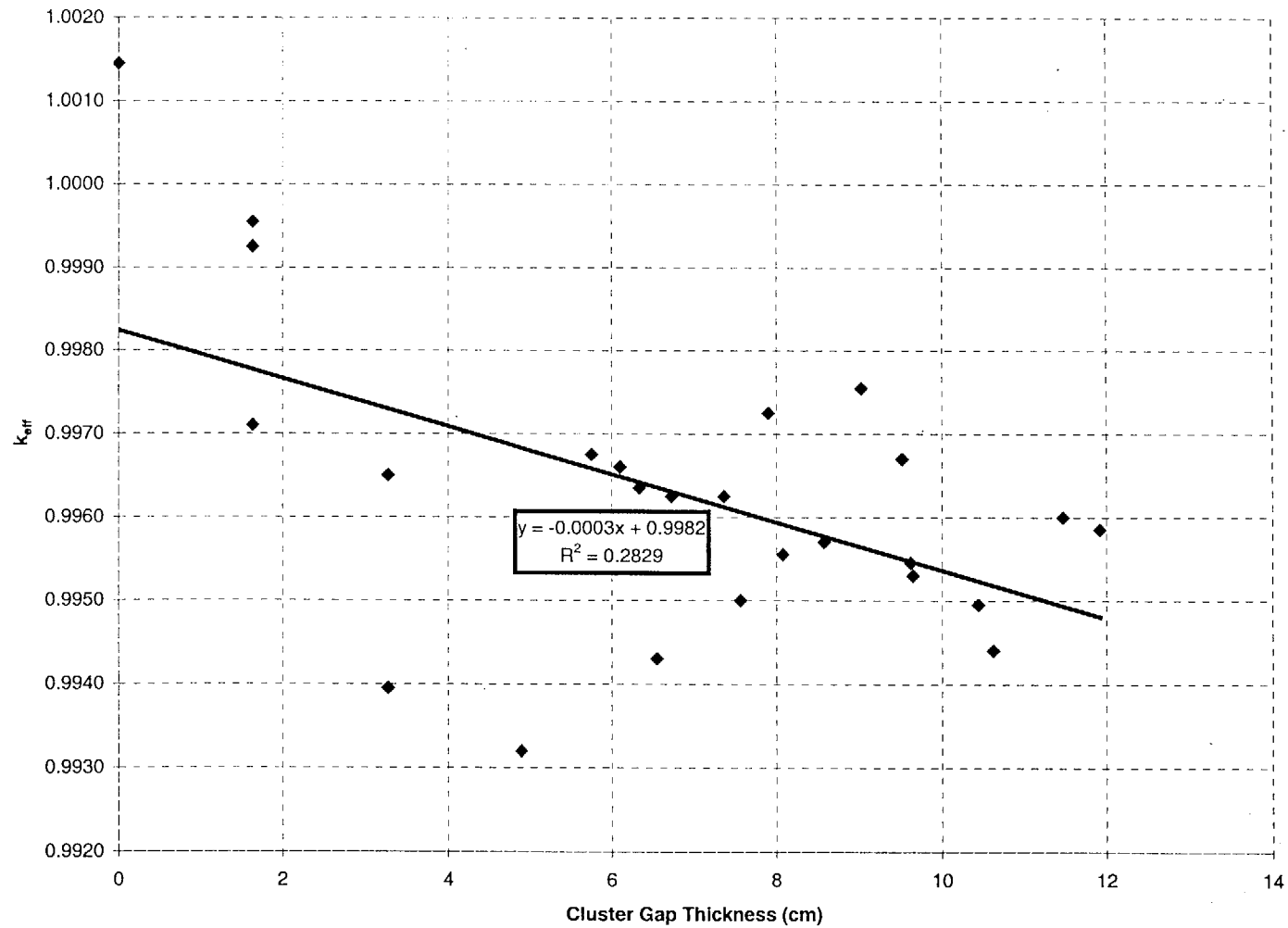


Figure 6.5-15 MONK8A – JEF 2.2 Library -  $k_{\text{eff}}$  versus Fuel Pellet Outside Diameter

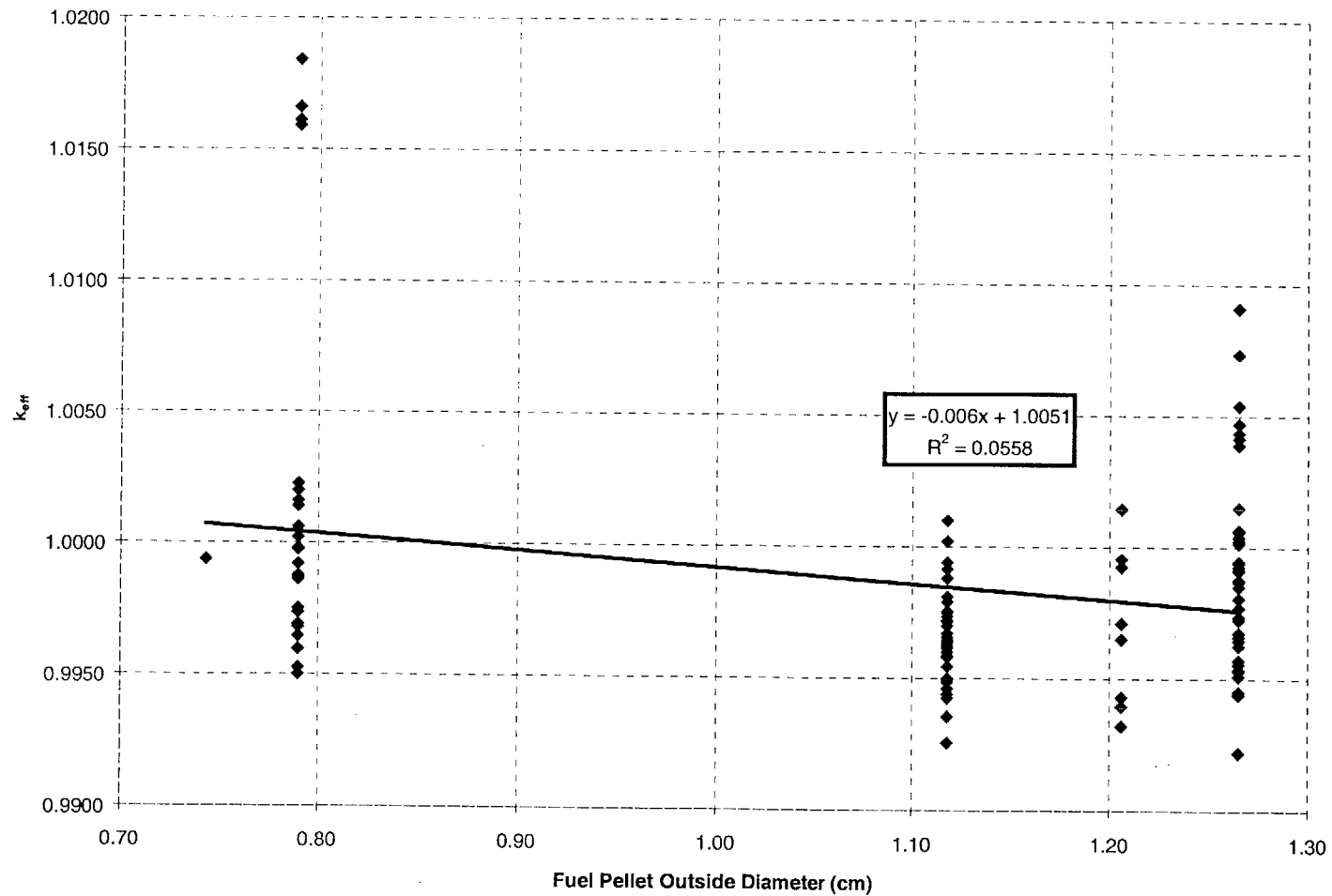
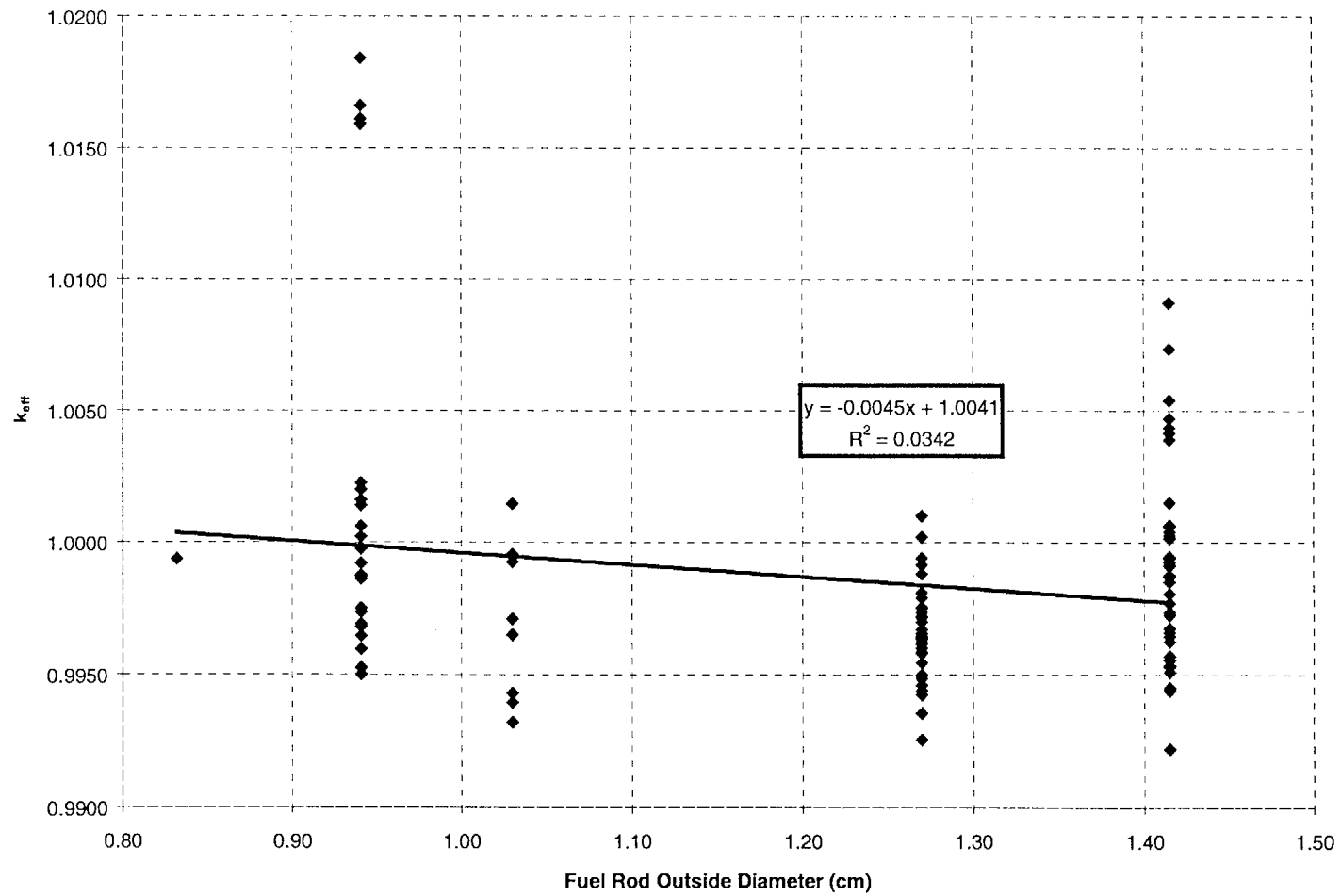


Figure 6.5-16 MONK8A – JEF 2.2 Library -  $k_{eff}$  versus Fuel Rod Outside Diameter



USLSTATS Output -  $k_{eff}$  versus Gap Thickness

Figure 6.5-17

USLSTATS: a utility to calculate upper subcritical limits for criticality safety applications  
 Version 1.3.4, February 12, 1998  
 Oak Ridge National Laboratory  
 \*\*\*\*\*

Input to statistical treatment from file:gap\_keff.txt

Title: 110 LWR CRITICAL EXPERIMENT KEFF VS GAP THICKNESS

Proportion of the population = .995  
 Confidence of fit = .950  
 Confidence on proportion = .950  
 Number of observations = 54  
 Minimum value of closed band = 0.00  
 Maximum value of closed band = 0.00  
 Administrative margin = 0.05

independent	dependent	deviation	in y	variable - x	independent	deviation	in y	variable - y
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6.3300E+00	9.96400E-01	1.0000E-03	1.0510E+01	9.96200E-01	1.0000E-03	1.0000E-03	9.96200E-01	1.0000E-03
9.0300E+00	9.97600E-01	1.0000E-03	1.10900E+01	9.95500E-01	1.0000E-03	1.0000E-03	9.95500E-01	1.0000E-03
1.04400E+01	9.95000E-01	1.0000E-03	1.31900E+01	9.97200E-01	1.0000E-03	1.0000E-03	9.97200E-01	1.0000E-03
1.14700E+01	9.96000E-01	1.0000E-03	1.33700E+01	9.97400E-01	1.0000E-03	1.0000E-03	9.97400E-01	1.0000E-03
7.5600E+00	9.95000E-01	1.0000E-03	1.29600E+01	9.96700E-01	1.0000E-03	1.0000E-03	9.96700E-01	1.0000E-03
9.6200E+00	9.95500E-01	1.0000E-03	9.95000E+00	9.94400E-01	1.0000E-03	1.0000E-03	9.94400E-01	1.0000E-03
7.3600E+00	9.96300E-01	1.0000E-03	7.8200E+00	9.94600E-01	1.0000E-03	1.0000E-03	9.94600E-01	1.0000E-03
9.5200E+00	9.96700E-01	1.0000E-03	9.88800E+00	9.97500E-01	1.0000E-03	1.0000E-03	9.97500E-01	1.0000E-03
1.1920E+01	9.95900E-01	1.0000E-03	1.04380E+01	9.97000E-01	1.0000E-03	1.0000E-03	9.97000E-01	1.0000E-03
1.0620E+01	9.94400E-01	1.0000E-03	1.04380E+01	9.97000E-01	1.0000E-03	1.0000E-03	9.97000E-01	1.0000E-03
8.5800E+00	9.95700E-01	1.0000E-03	9.59800E+00	9.96400E-01	1.0000E-03	1.0000E-03	9.96400E-01	1.0000E-03
9.6500E+00	9.95300E-01	1.0000E-03	8.74800E+00	9.95500E-01	1.0000E-03	1.0000E-03	9.95500E-01	1.0000E-03
6.1000E+00	9.96600E-01	1.0000E-03	8.56600E+00	9.94300E-01	1.0000E-03	1.0000E-03	9.94300E-01	1.0000E-03
8.0800E+00	9.95600E-01	1.0000E-03	9.16600E+00	9.97200E-01	1.0000E-03	1.0000E-03	9.97200E-01	1.0000E-03
5.7600E+00	9.96800E-01	1.0000E-03	9.09600E+00	9.98800E-01	1.0000E-03	1.0000E-03	9.98800E-01	1.0000E-03
7.9000E+00	9.97300E-01	1.0000E-03	9.24600E+00	9.96500E-01	1.0000E-03	1.0000E-03	9.96500E-01	1.0000E-03
6.7200E+00	9.96300E-01	1.0000E-03	8.86600E+00	9.96600E-01	1.0000E-03	1.0000E-03	9.96600E-01	1.0000E-03
0.0000E+00	1.00150E+00	1.0000E-03	8.64600E+00	9.95900E-01	1.0000E-03	1.0000E-03	9.95900E-01	1.0000E-03
1.6400E+00	9.99300E-01	1.0000E-03	8.12600E+00	9.94300E-01	1.0000E-03	1.0000E-03	9.94300E-01	1.0000E-03
1.6400E+00	9.97100E-01	1.0000E-03	7.25600E+00	9.94900E-01	1.0000E-03	1.0000E-03	9.94900E-01	1.0000E-03
1.6400E+00	9.99600E-01	1.0000E-03	9.64600E+00	9.99200E-01	1.0000E-03	1.0000E-03	9.99200E-01	1.0000E-03
3.2700E+00	9.96500E-01	1.0000E-03	9.69600E+00	1.00020E+00	1.0000E-03	1.0000E-03	1.00020E+00	1.0000E-03
3.2700E+00	9.94000E-01	1.0000E-03	8.08600E+00	9.97900E-01	1.0000E-03	1.0000E-03	9.97900E-01	1.0000E-03
4.9100E+00	9.93200E-01	1.0000E-03	7.64600E+00	9.92600E-01	1.0000E-03	1.0000E-03	9.92600E-01	1.0000E-03
6.5400E+00	9.94300E-01	1.0000E-03	9.08600E+00	9.93600E-01	1.0000E-03	1.0000E-03	9.93600E-01	1.0000E-03
1.3100E+01	1.00100E+00	1.0000E-03	9.41600E+00	9.98100E-01	1.0000E-03	1.0000E-03	9.98100E-01	1.0000E-03
1.29800E+01	9.99400E-01	1.0000E-03	9.77600E+00	9.96400E-01	1.0000E-03	1.0000E-03	9.96400E-01	1.0000E-03

chi = 1.7407 (upper bound = 9.49). The data tests normal

Figure 6.5-17

USLSTATS Output -  $k_{eff}$  versus Gap Thickness (Continued)

Output from statistical treatment

110 LWR CRITICAL EXPERIMENT KEFF VS GAP THICKNESS

Number of data points (n)	54
Linear regression, $k(X)$	$0.9968 + (-3.5885E-05)*X$
Confidence on fit (1-gamma) [input]	95.0%
Confidence on proportion (alpha) [input]	95.0%
Proportion of population falling above	
lower tolerance interval (rho) [input]	99.5%
Minimum value of X	0.0000
Maximum value of X	13.3700
Average value of X	8.44389
Average value of k	0.99646
Minimum value of k	0.99260
Variance of fit, $s(k,X)^2$	3.6340E-06
Within variance, $s(w)^2$	1.0000E-06
Pooled variance, $s(p)^2$	4.6340E-06
Pooled std. deviation, $s(p)$	2.1527E-03
$C(\alpha, \rho) * s(p)$	8.6255E-03

student-t @ (n-2, 1-gamma)	1.67620E+00
Confidence band width, W	3.8972E-03
Minimum margin of subcriticality, $C*s(p)-W$	4.7283E-03

Upper subcritical limits: ( 0.00000 <= X <= 13.37000)

\*\*\*\*\*

USL Method 1 (Confidence Band with  
Administrative Margin)  $USL1 = 0.9429 + (-3.5885E-05)*X$

USL Method 2 (Single-Sided Uniform  
Width Closed Interval Approach)  $USL2 = 0.9881 + (-3.5885E-05)*X$

USLs Evaluated Over Range of Parameter X:

\*\*\*\*\*

X: 0.00 1.91 3.82 5.73 7.64 9.55 11.46 13.37

USL-1: 0.9429 0.9428 0.9427 0.9427 0.9426 0.9425 0.9425 0.9424

USL-2: 0.9881 0.9881 0.9880 0.9879 0.9879 0.9878 0.9877 0.9877

\*\*\*\*\*



Table 6.5-1 KENO-Va and 27-Group Library Validation Statistics

Criticals	Configuration	wt % 235U	Pitch (cm)	Pellet OD (cm)	Clad OD (cm)	H/U	Sol. B (ppm)	Poison	g B10/cm <sup>2</sup>	Gap(cm)	Gap Den.	Ave. Gfis	Keff	s
Set 1										Gap				
B&W-I	Cylindrical	2.46	1.636	1.03	1.206	1.6	0	na	na	0		22.8	0.9921	0.0011
B&W-II	3X3-14X14	2.46	1.636	1.03	1.206	1.6	1037	na	na	0		22.2	0.9925	0.0009
B&W-III	3X3-14X14	2.46	1.636	1.03	1.206	1.6	764	na	na	1.636		22.6	0.9938	0.0009
B&W-IX	3X3-14X14	2.46	1.636	1.03	1.206	1.6	0	na	na	6.543		23	0.9905	0.0010
B&W-X	3X3-14X14	2.46	1.636	1.03	1.206	1.6	143	na	na	4.907		23	0.9882	0.0010
B&W-XI	3X3-14X14	2.46	1.636	1.03	1.206	1.6	514	Steel	0	1.636		22.6	0.9945	0.0010
B&W-XIII	3X3-14X14	2.46	1.636	1.03	1.206	1.6	15	B-Al	0.0052	1.636		22.6	0.9922	0.0010
B&W-XIV	3X3-14X14	2.46	1.636	1.03	1.206	1.6	92	B-Al	0.0040	1.636		22.5	0.9885	0.0010
B&W-XVII	3X3-14X14	2.46	1.636	1.03	1.206	1.6	487	B-Al	0.0008	1.636		22.5	0.9884	0.0010
B&W-XIX	3X3-14X14	2.46	1.636	1.03	1.206	1.6	634	B-Al	0.0003	1.636		22.5	0.9901	0.0009
												Average	0.9911	0.0023
Set 2										Gap				
PNL-043	17X13 Lattice	4.31	1.892	1.415	1.265	1.6	0	na	na	na	na	22.0	0.9954	0.0014
PNL-044	16X14 Lattice	4.31	1.892	1.415	1.265	1.6	0	na	na	na	na	22.0	0.9945	0.0013
PNL-045	14X16 Lattice	4.31	1.892	1.415	1.265	1.6	0	na	na	na	na	22.0	0.9974	0.0013
PNL-046	12x19 Lattice	4.31	1.892	1.415	1.265	1.6	0	na	na	na	na	22.0	0.9963	0.0013
PNL-087	4 11X14 Arrays	4.31	1.892	1.415	1.265	1.6	0	BORAL	0.066	2.83		21.8	0.9927	0.0012
PNL-079	4 11X14 Arrays	4.31	1.892	1.415	1.265	1.6	0	BORAL	0.030	2.83		21.8	0.9909	0.0012
PNL-093	4 11X14 Arrays	4.31	1.892	1.415	1.265	1.6	0	BORAL	0.026	2.83		21.8	0.9962	0.0012
PNL-115	4 9X12 Arrays	4.31	1.892	1.415	1.265	1.6	0	Aluminum	0	2.83		22.3	0.9937	0.0013
PNL-064	4 9X12 Arrays	4.31	1.892	1.415	1.265	1.6	0	Steel (.302)	0	2.83		22.2	0.9942	0.0012
PNL-071	4 9X12 Arrays	4.31	1.892	1.415	1.265	1.6	0	Steel (.485)	0	2.83		22.2	0.9968	0.0012
												Average	0.9948	0.0020

Table 6.5-1 KENO-Va and 27-Group Library Validation Statistics (continued)

Criticals	Configuration	wt % 235U	Pitch (cm)	Pellet OD (cm)	Clad OD (cm)	H/U	Sol. B (ppm)	Poison	g B10/cm <sup>2</sup>	Gap(cm)	Gap Den.	Ave. Gfis	Keff	s
Set 3										Cluster	Wall/Cluster			
PNL-STA	3X1 St Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	10.65	0.00	23.5	0.9964	0.0010
PNL-STB	3X1 St Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	11.20	1.32	23.6	0.9944	0.0010
PNL-STC	3X1 St Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	10.36	2.62	23.6	0.9905	0.0010
PNL-PBA	3X1 Pb Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	13.84	0.00	23.5	0.9960	0.0011
PNL-PBB	3X1 Pb Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	13.72	0.66	23.5	0.9978	0.0010
PNL-PBC	3X1 Pb Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	11.25	2.62	23.6	0.9925	0.0010
PNL-DUA	3X1 DU Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	11.83	0.00	22.6	0.9903	0.0009
PNL-DUB	3X1 DU Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	14.11	1.96	22.8	0.9957	0.0010
PNL-DUC	3X1 DU Refl.	2.35	2.032	1.1176	1.27	2.9	0	na	na	13.70	2.62	22.9	0.9911	0.0010
PNL-H20	3X1 H2O Refl	4.31	2.54	1.265	1.415	3.9	0	na	na	8.24	inf	23.3	0.9877	0.0023
PNL-ST0	3X1 St Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	12.89	0	23.2	0.9993	0.0012
PNL-ST1	3X1 St Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	14.12	1.32	23.3	1.0060	0.0022
PNL-ST26	3X1 St Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	12.44	2.62	23.3	0.9965	0.0011
PNL-PB0	3X1 Pb Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	20.62	0	23.2	1.0068	0.0021
PNL-PB13	3X1 Pb Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	19.04	1.32	23.3	1.0038	0.0012
PNL-PB5	3X1 Pb Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	10.3	5.41	23.3	0.9889	0.0011
PNL-DU0	3X1 DU Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	15.38	0	21.8	0.9959	0.0011
PNL-DU13	3X1 DU Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	19.04	1.32	22.1	1.0067	0.0010
PNL-DU39	3X1 DU Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	18.05	3.91	22.5	1.0005	0.0011
PNL-DU54	3X1 DU Refl.	4.31	2.54	1.265	1.415	3.9	0	na	na	13.49	5.41	22.6	0.9908	0.0011
												Average	0.9964	0.0060

Table 6.5-1 KENO-Va and 27-Group Library Validation Statistics (continued)

Criticals	Configuration	wt % 235U	Pitch (cm)	Pellet OD (cm)	Clad OD (cm)	H/U	Sol. (ppm)	B	Poison	g B10/cm <sup>2</sup>	Gap(cm)	Gap Den.	Ave. Gfis	Keff	s
<b>Set 4</b>															
PNL-229	2x2 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		Aluminum	0	3.81	0.9982	22.4	0.9989	0.0012
PNL-230	2x2 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.05	3.75	0.9982	21.7	0.9921	0.0012
PNL-228	2x2 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.13	3.73	0.9982	21.7	0.9911	0.0012
PNL-214	2x2 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.36	3.73	0.9982	21.7	0.9968	0.0013
PNL-231	2x2 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.45	3.71	0.9982	21.7	0.9938	0.0012
PNL-127	2x1 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.026	0.64	0.9982	21.8	0.9934	0.0010
PNL-126	2x1 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.026	1.54	0.9982	21.8	0.9931	0.0010
PNL-123	2x1 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.026	3.80	0.9982	21.8	0.9943	0.0010
PNL-125	2x1 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.026	5.16	0.9982	21.8	0.9932	0.0010
PNL-124	2x1 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		BORAL	0.026	INF	0.9982	21.8	0.9949	0.0010
PNL-123-S	2x1 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		Steel	0	3.80	0.9982	22.1	0.9920	0.0010
PNL-124-S	2x1 Flux Trap	4.31	1.89	1.265	1.415	1.6	0		Steel	0	INF	0.9982	21.9	0.9962	0.0010
													Average	0.9941	0.0022
<b>Set 5</b>											<b>Gap(cm)</b>	<b>Gap Den.</b>			
VCML	2x2 Water Gap	4.74	1.35	0.79	0.94	2.3	0		na	na	1.90	0	22.0	0.9922	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.79	0.94	2.3	0		na	na	1.90	0.0323	22.0	0.9889	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.79	0.94	2.3	0		na	na	1.90	0.2879	22.1	0.9957	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.79	0.94	2.3	0		na	na	1.90	0.5540	22.2	1.0053	0.0011
VCML	2x2 Water Gap	4.74	1.35	0.79	0.94	2.3	0		na	na	2.50	0.9982	22.3	0.9955	0.0012
VCML	2x2 Water Gap	4.74	1.35	0.79	0.94	2.3	0		na	na	5.00	0.9982	22.5	0.9948	0.0013
VCML	Square Lattice	4.74	1.26	0.79	0.94	1.8	0		na	na	na	na	22.2	0.9958	0.0012
VCML	Square Lattice	4.74	1.35	0.79	0.94	2.3	0		na	na	na	na	22.0	0.9952	0.0012
VCML	Square Lattice	4.74	1.60	0.79	0.94	3.8	0		na	na	na	na	23.3	0.9989	0.0013
VCML	Square Lattice	4.74	2.10	0.79	0.94	7.6	0		na	na	na	na	24.0	0.9974	0.0012
VCML	Square Lattice	4.74	2.52	0.79	0.94	11.5	0		na	na	na	na	24.2	0.9977	0.0011
													Average	0.9961	0.0041

Table 6.5-2 Correlation Coefficient for Linear Curve-Fit of Critical Benchmarks

Correlation Studied	Correlation Coefficient (R)
$k_{\text{eff}}$ versus enrichment	0.361
$k_{\text{eff}}$ versus rod pitch	0.328
$k_{\text{eff}}$ versus H/U volume ratio	0.246
$k_{\text{eff}}$ versus $^{10}\text{B}$ loading	0.069
$k_{\text{eff}}$ versus average group causing fission	0.133
$k_{\text{eff}}$ versus flux gap thickness	0.137

Table 6.5-3 Most Reactive Configuration System Parameters

Parameter	Benchmark Minimum Value	Benchmark Maximum Value	UMS Design Basis PWR Fuel Most Reactive Configuration	Maine Yankee Fuel Most Reactive Configuration
Enrichment (wt. % $^{235}\text{U}$ )	2.35	4.74	4.2	4.2
Rod pitch (cm)	1.26	2.54	1.26	1.50
H/U volume ratio	1.6	11.5	1.9	2.6
$^{10}\text{B}$ areal density ( $\text{g}/\text{cm}^2$ )	0.00	0.45	0.025	0.025
Average energy group causing fission	21.7	24.2	22.3	22.5
Flux gap thickness (cm)	0.64	5.16	2.2 to 3.8	2.22 to 3.8

Table 6.5-4 Range of Correlated Parameters for Design Basis Fuel

Parameter	Benchmark Minimum Value	Benchmark Maximum Value	Design Basis (WE 17x17 OFA)
Enrichment (wt % $^{235}\text{U}$ )	2.35	7.00	4.20
Rod pitch (cm)	1.26	2.54	1.26
H/U (fissile) atomic ratio	97.08	453.84	111.31
$^{10}\text{B}$ loading (g/cm <sup>2</sup> )	0.000	0.072	0.025
Log energy causing fission	7.31E-08	3.33E-07	2.39E-07
Cluster gap thickness (cm)	0.0	11.92	2.22-3.81
Fuel diameter (cm)	0.743	1.265	0.7844
Clad diameter (cm)	0.8324	1.4150	0.9144

Table 6.5-5 MONK8A – Correlation Coefficient for Linear Curve-Fit of Critical Benchmarks

Correlation Studied	Correlation Coefficient (R)
$k_{\text{eff}}$ versus enrichment	0.390
$k_{\text{eff}}$ versus rod pitch	0.140
$k_{\text{eff}}$ versus H/U (fissile) atomic ratio	0.369
$k_{\text{eff}}$ versus $^{10}\text{B}$ loading	0.273
$k_{\text{eff}}$ versus log energy causing fission	0.127
$k_{\text{eff}}$ versus cluster gap thickness	0.532
$k_{\text{eff}}$ versus fuel diameter	0.236
$k_{\text{eff}}$ versus clad diameter	0.185

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	σ
1.01	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Boral	0.0720	6.33	Inf	Water	1.00E-07	0.9964	0.0010
1.02	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Boral	0.0720	9.03	Inf	Water	9.95E-08	0.9976	0.0010
1.03	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (no boron)	0	10.44	Inf	Water	9.97E-08	0.9950	0.0010
1.04	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (no boron)	0	11.47	Inf	Water	9.95E-08	0.9960	0.0010
1.05	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (1.05% boron)	0.0049	7.56	Inf	Water	1.02E-07	0.9950	0.0010
1.06	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (1.05% boron)	0.0049	9.62	Inf	Water	1.01E-07	0.9955	0.0010
1.07	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (1.62% boron)	0.0074	7.36	Inf	Water	1.02E-07	0.9963	0.0010
1.08	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (1.62% boron)	0.0074	9.52	Inf	Water	9.99E-08	0.9967	0.0010
1.09	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	None	Na	11.92	Inf	Water	1.01E-07	0.9959	0.0010
2.01	1.26 (square)	4.75	1.26	0.79	0.94	Al	98.21	0	Na	Na	Na	Na	Water	2.57E-07	0.9960	0.0010
2.02	1.60 (square)	4.75	1.60	0.79	0.94	Al	217.26	0	Na	Na	Na	Na	Water	1.15E-07	0.9968	0.0010
2.03	2.10 (square)	4.75	2.10	0.79	0.94	Al	443.75	0	Na	Na	Na	Na	Water	7.31E-08	0.9960	0.0010
2.04	1.35 (triangular)	4.75	1.35	0.79	0.94	Al	97.08	0	Na	Na	Na	Na	Water	2.80E-07	0.9953	0.0010

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	$\frac{\sigma_f}{\sigma_a}$
1.01	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Boral	0.0720	6.33	Inf	Water	1.00E-07	0.9964	0.0010
1.02	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Boral	0.0720	9.03	Inf	Water	9.95E-08	0.9976	0.0010
1.03	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (no boron)	0	10.44	Inf	Water	9.97E-08	0.9950	0.0010
1.04	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (no boron)	0	11.47	Inf	Water	9.95E-08	0.9960	0.0010
1.05	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (1.05% boron)	0.0049	7.56	Inf	Water	1.02E-07	0.9950	0.0010
1.06	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (1.05% boron)	0.0049	9.62	Inf	Water	1.01E-07	0.9955	0.0010
1.07	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (1.62% boron)	0.0074	7.36	Inf	Water	1.02E-07	0.9963	0.0010
1.08	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	304L Steel (1.62% boron)	0.0074	9.52	Inf	Water	9.99E-08	0.9967	0.0010
1.09	3 clusters; 20x17 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	None	Na	11.92	Inf	Water	1.01E-07	0.9959	0.0010
2.01	1.26 (square)	4.75	1.26	0.79	0.94	Al	98.21	0	Na	Na	Na	Na	Water	2.57E-07	0.9960	0.0010
2.02	1.60 (square)	4.75	1.60	0.79	0.94	Al	217.26	0	Na	Na	Na	Na	Water	1.15E-07	0.9968	0.0010
2.03	2.10 (square)	4.75	2.10	0.79	0.94	Al	443.75	0	Na	Na	Na	Na	Water	7.31E-08	0.9960	0.0010

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	σ
2.04	1.35 (triangular)	4.75	1.35	0.79	0.94	Al	97.08	0	Na	Na	Na	Na	Water	2.80E-07	0.9953	0.0010
2.05	1.72 (triangular)	4.75	1.72	0.79	0.94	Al	217.51	0	Na	Na	Na	Na	Water	1.15E-07	0.9975	0.0010
2.06	2.26 (triangular)	4.75	2.26	0.79	0.94	Al	445.38	0	Na	Na	Na	Na	Water	7.34E-08	0.9965	0.0010
2.07	1.26 (square-1 in 5 missing)	4.75	1.26	0.79	0.94	Al	97.08	0	Na	Na	Na	Na	Water	2.65E-07	0.9950	0.0010
2.08	1.26 (square-1 in 2 missing)	4.75	1.26	0.79	0.94	Al	217.51	0	Na	Na	Na	Na	Water	1.16E-07	0.9974	0.0010
2.09	1.26 (square-1 in 3 missing)	4.75	1.26	0.79	0.94	Al	445.38	0	Na	Na	Na	Na	Water	7.42E-08	0.9969	0.0010
3.01	3 clusters; 8x15 pins	4.31	2.54	1.265	1.415	Al	256.38	0	None	Na	10.62	Inf	Water	1.18E-07	0.9944	0.0010
3.02	3 clusters; 8x15 pins	4.31	2.54	1.265	1.415	Al	256.38	0	304L Steel (no boron)	0	8.58	Inf	Water	1.17E-07	0.9957	0.0010
3.03	3 clusters; 8x15 pins	4.31	2.54	1.265	1.415	Al	256.38	0	304L Steel (no boron)	0	9.65	Inf	Water	1.18E-07	0.9953	0.0010
3.04	3 clusters; 8x15 pins	4.31	2.54	1.265	1.415	Al	256.38	0	304L Steel (1.05% boron)	0.0049	6.10	Inf	Water	1.19E-07	0.9966	0.0010
3.05	3 clusters; 8x15 pins	4.31	2.54	1.265	1.415	Al	256.38	0	304L Steel (1.05% boron)	0.0049	8.08	Inf	Water	1.18E-07	0.9956	0.0010
3.06	3 clusters; 8x15 pins	4.31	2.54	1.265	1.415	Al	256.38	0	304L Steel (1.62% boron)	0.0074	5.76	Inf	Water	1.18E-07	0.9968	0.0010
3.07	3 clusters; 8x15 pins	4.31	2.54	1.265	1.415	Al	256.38	0	304L Steel (1.62% boron)	0.0074	7.90	Inf	Water	1.16E-07	0.9973	0.0010



Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	$\frac{\sigma_{f,235}}{\sigma_{t,235}}$
3.08	3 clusters; 8x15 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Boral	0.0720	6.72	Inf	Water	1.19E-07	0.9963	0.0010
7.01	3x3 clusters; 14x14 pins	2.46	1.6358	1.206	1.03	Al	453.84	1037	None	Na	0	Inf	Water	2.56E-07	1.0015	0.0010
7.02	3x3 clusters; 14x14 pins	2.46	1.6358	1.206	1.03	Al	453.84	769	None	Na	1.64	Inf	Water	2.05E-07	0.9993	0.0010
7.03	3x3 clusters; 14x14 pins	2.46	1.6358	1.206	1.03	Al	453.84	0	B <sub>4</sub> C Pins	Na	1.64	Inf	Water	2.03E-07	0.9971	0.0010
7.04	3x3 clusters; 14x14 pins	2.46	1.6358	1.206	1.03	Al	453.84	15	B/Al (1.61wt% B)	0.0052	1.64	Inf	Water	1.98E-07	0.9996	0.0010
7.05	3x3 clusters; 14x14 pins	2.46	1.6358	1.206	1.03	Al	453.84	217	Stainless Steel	0	3.27	Inf	Water	1.75E-07	0.9965	0.0010
7.06	3x3 clusters; 14x14 pins	2.46	1.6358	1.206	1.03	Al	453.84	320	B/Al (0.1wt% B)	0.0003	3.27	Inf	Water	1.79E-07	0.9940	0.0010
7.07	3x3 clusters; 14x14 pins	2.46	1.6358	1.206	1.03	Al	453.84	72	B/Al (0.1wt% B)	0.0003	4.91	Inf	Water	1.61E-07	0.9932	0.0010
7.08	3x3 clusters; 14x14 pins	2.46	1.6358	1.206	1.03	Al	453.84	0	None	Na	6.54	Inf	Water	1.44E-07	0.9943	0.0010
27.01	Cylindrical	7.00	1.32	0.743	0.8324	SS	118.39	0	Na	Na	Na	Na	Water	2.09E-07	0.9994	0.0010
32.01	14x14 array	4.74	1.60	0.79	0.94	Al	217.31	0	Na	Na	Na	0.0	Lead and light water	1.32E-07	1.0161	0.0010

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	σ
32.02	14x14 array	4.74	1.60	0.79	0.94	Al	217.31	0	Na	Na	Na	0.5	Lead and light water	1.26E-07	1.0184	0.0010
32.03	14x14 array	4.74	1.60	0.79	0.94	Al	217.31	0	Na	Na	Na	1.0	Lead and light water	1.18E-07	1.0166	0.0010
32.04	14x14 array	4.74	1.60	0.79	0.94	Al	217.31	0	Na	Na	Na	1.5	Lead and light water	1.14E-07	1.0159	0.0010
40.01	22x22	4.74	1.60	0.79	0.94	Al	217.31	0	Hafnium plate	Na	0.0978	Na	Water	1.33E-07	0.9992	0.0010
40.02	22x22	4.74	1.60	0.79	0.94	Al	217.31	0	Hafnium plate	Na	0.1956	Na	Water	1.34E-07	1.0002	0.0010
40.03	22x22	4.74	1.60	0.79	0.94	Al	217.31	0	Hafnium plate	Na	0.2934	Na	Water	1.33E-07	0.9998	0.0010
40.04	22x22	4.74	1.60	0.79	0.94	Al	217.31	0	Hafnium plate	Na	0.3912	Na	Water	1.34E-07	0.9986	0.0010
40.05	22x22	4.74	1.60	0.79	0.94	Al	217.31	0	Hafnium plate	Na	0.489	Na	Water	1.37E-07	1.0020	0.0010
40.06	21x21	4.74	1.60	0.79	0.94	Al	217.31	0	Hafnium plate	Na	0.0978	Na	Water	1.36E-07	1.0014	0.0010
40.07	20x21	4.74	1.60	0.79	0.94	Al	217.31	0	Hafnium plate	Na	0.0978	Na	Water	1.34E-07	1.0023	0.0010
40.08	20x20	4.74	1.60	0.79	0.94	Al	217.31	0	Hafnium plate	Na	0.0978	Na	Water	1.30E-07	0.9987	0.0010
40.09	22x22	4.74	1.60	0.79	0.94	Al	217.31	0	None	Na		Na	Water	1.29E-07	0.9998	0.0010
40.10	21x21	4.74	1.60	0.79	0.94	Al	217.31	0	None	Na		Na	Water	1.27E-07	1.0006	0.0010
40.11	21x20	4.74	1.60	0.79	0.94	Al	217.31	0	None	Na		Na	Water	1.25E-07	1.0016	0.0010
40.12	20x20	4.74	1.60	0.79	0.94	Al	217.31	0	None	Na		Na	Water	1.25E-07	0.9988	0.0010

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	σ
17.01	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	13.100	0.000	Lead	1.03E-07	1.0010	0.0010
17.02	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	12.980	0.660	Lead	1.00E-07	0.9994	0.0010
17.03	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	10.510	2.616	Lead	1.00E-07	0.9962	0.0010
17.04	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	11.090	0.000	Uranium	1.05E-07	0.9955	0.0010
17.05	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	13.190	1.321	Uranium	1.02E-07	0.9972	0.0010
17.06	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	13.370	1.956	Uranium	1.02E-07	0.9974	0.0010
17.07	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	12.960	2.616	Uranium	1.00E-07	0.9967	0.0010
17.08	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	9.950	5.405	Uranium	1.01E-07	0.9944	0.0010
17.09	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	7.820	10.676	Uranium	9.86E-08	0.9946	0.0010
17.10	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	9.888	0.000	Steel	1.03E-07	0.9975	0.0010
17.11	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	10.438	0.660	Steel	1.03E-07	0.9970	0.0010
17.12	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	10.438	1.321	Steel	1.02E-07	0.9958	0.0010

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	σ
17.13	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	9.598	2.616	Steel	9.91E-08	0.9964	0.0010
17.14	3 clusters; 16x19 pins	2.35	2.032	1.1176	1.27	Al	398.80	0	Na	Na	8.748	3.912	Steel	9.88E-08	0.9955	0.0010
17.15	18x25(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	8.566	0.000	Steel	1.89E-07	0.9943	0.0010
17.16	18x25(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	9.166	0.660	Steel	1.83E-07	0.9972	0.0010
17.17	18x25(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	9.096	1.321	Steel	1.75E-07	0.9988	0.0010
17.18	18x25(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	9.246	1.684	Steel	1.77E-07	0.9965	0.0010
17.19	18x25(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	8.866	2.344	Steel	1.69E-07	0.9966	0.0010
17.20	18x25(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	8.646	3.005	Steel	1.73E-07	0.9959	0.0010
17.21	18x25(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	8.126	3.912	Steel	1.66E-07	0.9943	0.0010
17.22	18x25(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	7.256	6.726	Steel	1.65E-07	0.9949	0.0010
17.23	18x23(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	9.646	0.000	Lead	1.76E-07	0.9992	0.0010
17.24	18x23(center), 18x20(two outer)	2.35	1.684	1.1176	1.27	Al	398.80	0	Na	Na	9.696	0.660	Lead	1.74E-07	1.0002	0.0010

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	σ
17.25	18x23(center), 18x20(two outer)	2.35	1.684	1.117 6	1.27	Al	398.80	0	Na	Na	8.086	3.276	Lead	1.65E-07	0.9979	0.0010
17.26	18x23(center), 18x20(two outer)	2.35	1.684	1.117 6	1.27	Al	398.80	0	Na	Na	7.646	0.000	Uranium	1.86E-07	0.9926	0.0010
17.27	18x23(center), 18x20(two outer)	2.35	1.684	1.117 6	1.27	Al	398.80	0	Na	Na	9.086	1.321	Uranium	1.78E-07	0.9936	0.0010
17.28	18x23(center), 18x20(two outer)	2.35	1.684	1.117 6	1.27	Al	398.80	0	Na	Na	9.416	2.616	Uranium	1.66E-07	0.9981	0.0010
17.29	18x23(center), 18x20(two outer)	2.35	1.684	1.117 6	1.27	Al	398.80	0	Na	Na	9.776	3.912	Uranium	1.67E-07	0.9964	0.0010
10.01	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	19.495	0.000	Lead	1.22E-07	1.0091	0.0010
10.02	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	19.655	0.660	Lead	1.20E-07	1.0074	0.0010
10.03	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	17.915	1.321	Lead	1.18E-07	1.0044	0.0010
10.04	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	9.175	5.405	Lead	1.15E-07	0.9945	0.0010
10.05	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	14.255	0.000	Uranium	1.32E-07	0.9951	0.0010
10.06	3 clusters; 8x12 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	14.195	1.956	Uranium	1.18E-07	0.9974	0.0010
10.07	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	16.925	3.912	Uranium	1.18E-07	0.9977	0.0010

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	σ
10.08	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	12.365	5.405	Uranium	1.16E-07	0.9922	0.0010
10.09	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	11.765	0.000	Steel	1.26E-07	1.0004	0.0010
10.10	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	13.125	0.660	Steel	1.25E-07	0.9981	0.0010
10.11	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	12.995	1.321	Steel	1.20E-07	0.9992	0.0010
10.12	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	11.315	2.616	Steel	1.17E-07	0.9987	0.0010
10.13	3 clusters; 8x13 pins	4.31	2.54	1.265	1.415	Al	256.38	0	Na	Na	8.675	5.405	Steel	1.16E-07	0.9954	0.0010
10.14	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	14.393	0.000	Steel	3.27E-07	1.0002	0.0010
10.15	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	15.263	0.660	Steel	3.16E-07	1.0015	0.0010
10.16	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	15.393	1.321	Steel	3.04E-07	1.0003	0.0010
10.17	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	15.363	1.956	Steel	2.97E-07	1.0039	0.0010
10.18	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	14.973	2.616	Steel	2.91E-07	0.9994	0.0010
10.19	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	13.343	5.405	Steel	2.80E-07	1.0007	0.0010

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics (Continued)

Case	Configuration	wt % <sup>235</sup> U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Ab sorber	G <sup>10</sup> B/cm <sup>2</sup>	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k <sub>eff</sub> (JEF2.2)	σ
10.20	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	17.263	0.000	Lead	3.11E-07	1.0054	0.0010
10.21	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	17.703	0.660	Lead	3.01E-07	1.0047	0.0010
10.22	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	16.953	1.956	Lead	2.89E-07	1.0042	0.0010
10.23	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	13.873	5.001	Lead	2.81E-07	0.9993	0.0010
10.24	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	14.853	0.000	Uranium	3.33E-07	0.9965	0.0010
10.25	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	16.233	0.660	Uranium	3.23E-07	0.9991	0.0010
10.26	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	17.793	1.321	Uranium	3.14E-07	0.9995	0.0010
10.27	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	18.763	1.956	Uranium	3.05E-07	1.0006	0.0010
10.28	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	18.893	2.616	Uranium	3.01E-07	0.9991	0.0010
10.29	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	18.303	3.276	Uranium	2.88E-07	0.9985	0.0010
10.30	3 clusters; 12x16 pins	4.31	1.892	1.265	1.415	Al	256.38	0	Na	Na	15.923	5.405	Uranium	2.83E-07	0.9988	0.0010

6.6        Appendices

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#### 6.6.1 Criticality Evaluation for Site Specific Contents

This section describes fuel assembly characteristics and configurations, or waste configurations, which are unique to specific reactor sites. These site specific content configurations result from conditions that occurred during reactor operations, participation in research and development programs, testing programs intended to improve reactor operations, and from decommissioning activities.

Site specific fuel assembly configurations are either shown to be bounded by the analysis of the standard design basis fuel assembly configuration of the same type (PWR or BWR), or are shown to be acceptable contents by specific evaluation of the configuration.

##### 6.6.1.1 Criticality Evaluation for Maine Yankee Site Specific Spent Fuel

Loading the transport cask with the standard CE 14x14 fuel assembly is shown in Section 6.4 to be less reactive than loading the cask with the most reactive Westinghouse 17x17 OFA criticality design basis spent fuel. This analysis addresses variations in fuel assembly dimensions, variable enrichment axial zoning patterns, annular axial fuel blankets, removed fuel rods or empty rod positions, fuel rods placed in guide tubes, and consolidated fuel assemblies. These configurations are not included in the standard fuel analysis, but are present in the site fuel inventory that must be transported.

##### 6.6.1.1.1 Maine Yankee Fuel Criticality Model

The criticality evaluations of the Maine Yankee fuel inventory require the basket cell and basket in cask models described in Section 6.3 and 6.4. The basket cell model is principally employed in the most reactive dimension evaluation for the Maine Yankee intact fuel types. The basket cell model represents an infinite array of fuel tubes separated by one-inch flux traps and neglects the radial neutron leakage of the basket. This will result in  $k_{\text{eff}}$  values greater than 0.95. The basket cell model is, therefore, only used to determine relative reactivities of the various physical dimensions of the Maine Yankee fuel inventory, not to establish maximum  $k_s$  values for the basket loaded with Maine Yankee fuel assemblies. The basket in cask model is used for the evaluation of the remaining fuel configurations. The basket criticality model uses the nominal basket configuration with full moderation under accident conditions, where accident conditions implying the loss of fuel cladding integrity and flooding of the pellet to cladding gap in all fuel rods. The analyses presented are performed using the UMS<sup>®</sup> transport cask shield geometry.

### Transport Cask Model

The infinite array geometry is used only to determine the most reactive dimensions. The most reactive lattice dimensions determined by the basket cell model are incorporated into the basket in cask model. The Universal Transport Cask geometry is evaluated using the nominal basket configuration with full moderation. The Transport Cask accident event is modeled assuming that the fuel clad gap is flooded, the basket is flooded and the neutron shield material is replaced with water. Evaluating 24 hybrid 14x14 fuel assemblies with the most reactive pellet diameter for the accident condition produces a  $k_{\text{eff}} + 2\sigma$  of 0.91014. This is less reactive than the accident condition for the transport cask loaded with the Westinghouse 17 x 17 OFA assemblies ( $k_{\text{eff}} + 2\sigma$  of 0.9210). Therefore, the Westinghouse 17 x 17 OFA fuel criticality evaluation is bounding.

#### 6.6.1.1.2 Maine Yankee Intact Spent Fuel

The evaluation of the intact Maine Yankee spent fuel inventory demonstrates that under all conditions the maximum reactivity of the UMS<sup>®</sup> basket loaded with Maine Yankee fuel assemblies is bounded by the Westinghouse 17 x 17 OFA evaluation presented in Section 6.4. The intact fuel assembly evaluation includes the determination of maximum reactivity dimensions of the Maine Yankee fuel assemblies, and the reactivity effects of variably enriched assemblies, annular axial end blankets, removed rods, fuel in guide tubes, and consolidated fuel assemblies. Where necessary, loading restrictions are applied to limit the number and location of the basket payload evaluated.

### Fuel Assembly Lattice Dimensional Variations

Maine Yankee 14x14 PWR fuel has been provided by Combustion Engineering, Exxon/ANF and Westinghouse. The range of fuel assembly dimensions evaluated for Maine Yankee are shown in Table 6.6.1.1-1.

### Most Reactive Fuel Dimensions

Bounding fuel assembly dimensions are determined using the guidelines set in Section 6.4.4 and are reported in Table 6.6.1.1-2. The dimensional perturbations that can increase the reactivity of any undermoderated array of fuel assemblies in a flooded system (including flooding the fuel-clad gap) are:

- Decreasing the clad outside diameter (OD)
- Increasing the clad inside diameter (ID) (i.e., increasing the gap)
- Decreasing the pellet diameter
- Decreasing the guide tube thickness

To conservatively model the clad thickness of the Maine Yankee standard fuel, the outside diameter of the clad is iteratively decreased until the clad thickness reaches the minimum. The pellet diameter is studied separately to determine which diameter maximizes the reactivity of the assembly. This study is performed using an infinite array of hybrid 14x14 fuel assemblies. These hybrid assemblies have the combination of most reactive dimensional parameters listed in Table 6.6.1.1-2 and are used in the evaluation of site specific fuel configurations. The pellet diameter is modeled first at the maximum diameter, and then it is iteratively decreased until a peak reactivity (H/U ratio) is reached. The results of this study are reported in Table 6.6.1.1-3. The maximum reactivity occurs at a pellet diameter of 0.3527 inches. This pellet diameter, which produces the most reactive system, is conservatively used in the analyses of an assembly with 176 fuel rods.

The reactivity of an infinite array of basket unit cells containing infinitely tall, hybrid 14x14 fuel assemblies and a flooded fuel-clad gap is  $k_{\text{eff}} + 2\sigma = 0.96268$ . This is less reactive than the same array of Westinghouse 17x17 OFA assemblies ( $k_{\text{eff}} + 2\sigma = 0.9751$  from Table 6.4-1). Therefore, the design basis Westinghouse 17x17 OFA fuel criticality analysis is bounding. The conservatism obtained by decreasing the pellet diameter below that of the reported Maine Yankee fuel pellet diameter results in a  $\Delta k_{\text{eff}}$  of 0.00247.

#### 6.6.1.1.3 Variably Enriched Fuel Assemblies

Two batches of fuel used at Maine Yankee contain variably enriched fuel rods. Fuel rod enrichments of one batch are 4.21 wt % <sup>235</sup>U and 3.5 wt % <sup>235</sup>U. The maximum planar average enrichment of this batch is 3.99 wt % <sup>235</sup>U. In the other batch, the fuel rod enrichments are 4.0 wt % <sup>235</sup>U and 3.4 wt % <sup>235</sup>U. The maximum planar average enrichment of this batch is 3.92 wt % <sup>235</sup>U. Loading 24 variably enriched fuel assemblies having both a maximum fuel rod enrichment of 4.21 wt % <sup>235</sup>U and a maximum planar average enrichment of 3.99 wt % <sup>235</sup>U results in a  $k_{\text{eff}} + 2\sigma$  of 0.89940. Using a planar fuel rod enrichment of 4.2 wt % <sup>235</sup>U results in a  $k_{\text{eff}} + 2\sigma$  of 0.91014. Therefore, all of the fuel rods are conservatively modeled as if enriched to 4.2 wt % <sup>235</sup>U for the remaining Maine Yankee analyses.

#### 6.6.1.1.4 Assemblies with Annular Axial End Blankets

One batch of variably enriched fuel also incorporates 2.6 wt%  $^{235}\text{U}$  axial end blankets with annular fuel pellets. The top and bottom 5% of the active fuel length of each fuel rod in this batch contains annular fuel pellets having an inner diameter of 0.183 inches. This geometry is discretely modeled as approximately 5% annular fuel, 90% solid fuel and then 5% annular fuel, with all fuel materials enriched to 4.2 wt%  $^{235}\text{U}$ . The diameter of all pellets is modeled first as the most reactive pellet diameter. The accident case model is used for this evaluation, which includes flooding the cladding annulus. The periodic boundary conditions remain, which keeps the conservatism of the infinite fuel height.

Use of the smaller pellet diameter is not considered to be conservative when evaluating the annular fuel pellets. The smaller pellet diameter is the most reactive under the assumption that the fuel pellet is solid, not an annulus. Therefore, the diameter of the annular pellets is also modeled as the maximum pellet diameter of 0.3800 inches to regain a small portion of the fuel that is missing. The 0.3800 inch diameter is applied only to the annular pellets, while the smaller diameter of the solid pellets remains. The results of this study are reported in Table 6.6.1.1-4.

As shown in the table, the most reactive annular fuel model for the axial annular fuel end blankets results in a slightly more reactive system than the hybrid fuel accident evaluation. However, this annular condition is less reactive than the accident evaluation including Westinghouse 17x17 OFA assemblies. Therefore, the Westinghouse 17x17 OFA fuel criticality evaluation is bounding.

#### 6.6.1.1.5 Assemblies with Removed Fuel Rods

Some of the Maine Yankee fuel assemblies have had fuel rods removed from the 14 x 14 lattice or have had poison rods replaced by hollow Zircaloy rods. The exact number and location of removed rods and hollow rods differs from one assembly to another. To determine a bounding reactivity for these assemblies, an analysis changing the location and the number of removed rods is performed. The removed rod analysis bounds that of the hollow rod analysis since the Zircaloy tubes displace moderator in the under moderated assembly lattice. For each case, all 24 assemblies are centered in the fuel tubes and have the same number and location of removed fuel rods. Various patterns of removed fuel rod locations are analyzed when the number of removed fuel rods is small enough to allow a different and possibly more reactive geometry. As the

number of removed fuel rods increases, the number of possible highly reactive locations for these removed rods decreases. As described in Section 6.6.1.1.2, the fuel pellet diameter of every fuel rod is modeled first using the most reactive pellet diameter (0.3527 inches), and then as the maximum pellet diameter (0.380 inches).

The results of these analyses, which determine the most reactive number and geometry of removed rods for any Maine Yankee assembly, are presented in Tables 6.6.1.1-5 and 6.6.1.1-6. Table 6.6.1.1-5 contains the results based on a 0.3527-inch fuel pellet. All of the removed fuel rod cases using the smaller pellet diameter show cask reactivity levels lower than those of Westinghouse 17 x 17 OFA fuel. Table 6.6.1.1-6 contains the results of the evaluation using the maximum pellet diameter of 0.380 inch. Using the maximum pellet diameter provides for a more reactive system, since moderator is added (at the removed rod locations), to an assembly that contains more fuel. The most reactive removed fuel rod case occurs when 24 fuel rods are removed in the diamond shaped geometry shown in Figure 6.6.1.1-1, from the model containing the largest allowed pellet diameter. This case represents the bounding number and geometry of removed fuel rods for the Maine Yankee fuel assemblies. It results in a more reactive system than either the Maine Yankee hybrid 14 x 14 fuel accident case or the Westinghouse 17 x 17 OFA accident case assuming unrestricted loading. However, as shown in Table 6.6.1.1-8, when the loading of any assembly with less than 176 fuel rods or filler rods is restricted to the four corner fuel tubes, the reactivity of the worse case drops well below that of the Westinghouse 17 x 17 OFA fuel assemblies. Therefore, loading of Maine Yankee fuel assemblies with removed fuel rods, or with hollow Zircaloy rods, is restricted to the four corner fuel tube positions of the basket. With this loading restriction, the Westinghouse 17 x 17 OFA criticality evaluation remains bounding.

#### 6.6.1.1.6 Assemblies with Fuel Rods in the Guide Tubes

A few of the Maine Yankee intact assemblies may contain up to two intact fuel rods in some of the guide tubes (i.e., allowing for the potential storage of individual intact fuel rods in an intact fuel assembly). To evaluate loading of these assemblies into the canister, an analysis adding 1 and then 2 intact fuel rods into 1, 2, 3 and then 5 guide tubes is made. Since the additional fuel rods are added to a fuel assembly, the evaluation considers a fuel assembly with up to 186 fuel rods. The results of the evaluation of these configurations are shown in Table 6.6.1.1-7. While higher in reactivity than the Maine Yankee hybrid base case, any fuel configuration with up to 2 fuel rods per guide tube is less reactive than the accident case for the Westinghouse 17 x 17 OFA

fuel assemblies. Therefore, the Westinghouse 17 x 17 OFA fuel criticality evaluation is bounding.

Fuel rods may also be inserted in the guide tubes of fuel assemblies from which the fuel rods were removed (i.e., fuel rods removed from a fuel assembly and re-installed in the guide tubes of the same fuel assembly). The maximum number of fuel rods in these assemblies, including fuel rods in the guide tubes remains 176. These configurations are restricted to loading in a Maine Yankee fuel can in a corner fuel position in the basket. As shown in Section 6.6.1.1.5 for the removed fuel rods, the maximum reactivity of Maine Yankee assemblies containing 176 fuel rods in various configurations is bounded by the Westinghouse 17 x 17 OFA evaluation. These non-standard Maine Yankee assemblies are restricted to the corner fuel positions.

In addition to the fuel rods, some Maine Yankee assemblies may contain poison shim rods in guide tubes. These solid fill rods will serve as parasitic absorber and displace moderator and are, therefore, not included in the criticality model but are bounded by the evaluation performed.

#### 6.6.1.1.7 Consolidated Fuel

The consolidated assemblies are a 17x17 array of rods with a pitch of 0.492 inches. Some of the locations contain solid fill rods and some are empty. To determine the reactivity of the consolidated fuel lattice with empty fuel rod positions, an analysis changing the location and the number of empty positions is performed. This consolidated fuel analysis considers 24 consolidated fuel lattices in the basket. All 24 consolidated fuel lattices are centered in the fuel tubes and have the same number and location of empty fuel rod positions. As shown in Section 6.6.1.1.5, the removed fuel rod configuration with a 0.380-inch pellet diameter provides a more reactive system than a system using the optimum pellet diameter from Section 6.6.1.1.2. The larger pellet cases are more reactive, since moderator is added at the empty fuel rod positions to an assembly that contains more fuel. Therefore, the consolidated assembly empty rod position evaluation is performed with the 0.380-inch pellet diameter.

The most reactive consolidated assembly case occurs with 113 empty rod positions in the geometry shown in Figure 6.6.1.1-2. However, when the loading of the consolidated fuel is restricted to the four corner fuel tubes, the reactivity of the cask is lower than the accident condition of the cask loaded with Westinghouse 17x17 OFA assemblies. Therefore, loading of the consolidated fuel is restricted to the four corner fuel tube positions of the basket. With this



loading restriction, the Westinghouse 17 x 17 OFA fuel criticality evaluation is bounding.

#### 6.6.1.1.8 Conclusions

The criticality analyses for the Maine Yankee site specific fuel demonstrates that the UMS® basket loaded with these fuel assemblies results in a system that is less reactive than loading the basket with the Westinghouse 17 x 17 OFA fuel assemblies, provided that loading is restricted to the four corner fuel tube positions in the basket for:

- All 14 x 14 fuel assemblies with less than 176 fuel rods or solid filler rods
- All 14 x 14 fuel assemblies with hollow rods
- All 17 x 17 consolidated fuel lattices
- All 14 x 14 fuel assemblies with fuel rods in the guide tubes and a maximum of 176 fuel rods or solid rods and fuel rods.

The following Maine Yankee fuels are not restricted as to loading position within the basket:

- All 14x14 fuel assemblies with 176 fuel rods or solid filler rods at a maximum enrichment of 4.2 wt %  $^{235}\text{U}$ .
- Variably enriched fuel with a maximum fuel rod enrichment of 4.21 wt %  $^{235}\text{U}$  with a maximum planar average enrichment of 3.99 wt %  $^{235}\text{U}$ .
- Fuel with solid stainless steel filler rods, solid Zircaloy filler rods or solid poison shim rods in any location.
- Fuel with annular axial end blankets of up to 4.2 wt %  $^{235}\text{U}$ .
- Fuel with a maximum of 2 intact fuel rods in each guide tube for a total of 186 fuel rods.

Assemblies defined as unrestricted may be loaded into the basket in any basket location and may be mixed in the same basket. While not analyzed in detail, CEAs and ICI thimble assemblies may be loaded into any intact assemblies. These components displace a significant amount of water in the fuel lattice while adding parasitic absorber, thereby reducing system reactivity.

#### 6.6.1.1.9 Transport Cask Top End Drop Event

The exposed fuel evaluation performed for the design basis WE 17x17 OFA fuel in Section 6.4.5 bounds that of the less reactive Maine Yankee Fuel.



Figure 6.6.1.1-1

24 Removed Fuel Rods - Diamond Shaped Geometry, Maine Yankee Site

Specific Fuel

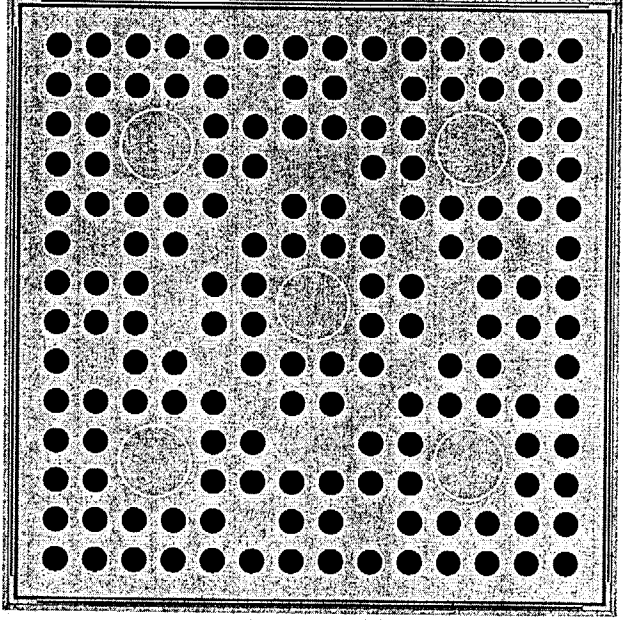


Figure 6.6.1.1-2

Consolidated Fuel Geometry, 113 Empty Fuel Rod Positions, Maine  
Yankee Site Specific Fuel

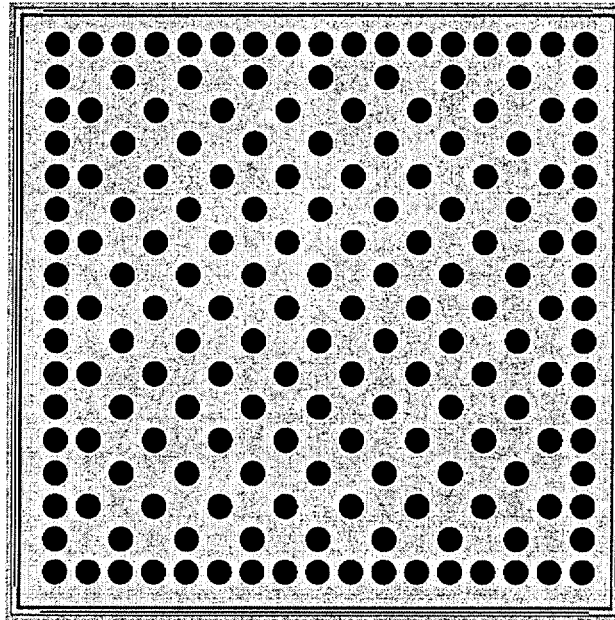


Table 6.6.1.1-1 Maine Yankee Standard Fuel Characteristics

Fuel Class <sup>1</sup>	Vendor	Array	Version	Number of Fuel Rods	Pitch (in.)	Rod Diameter (in.)	Clad ID (in.)	Clad Thickness (in.)	Pellet Diameter (in.)	GT <sup>2</sup> Thickness (in.)
1	CE	14x14	Std.	160 <sup>3</sup> -176	0.570-0.590	0.438-0.442	0.3825-0.3895	0.024-0.028	0.376-0.380	0.036-0.040
1	Ex/ANF	14x14	CE	164 <sup>4</sup> -176	0.580	0.438-0.442	0.3715-0.3795	0.0294-0.031	0.3695-0.3705	0.036-0.040
1	WE	14x14	CE	176	0.575-0.585	0.438-0.442	0.3825-0.3855	0.0262-0.028	0.376-0.377	0.034-0.038

1. All fuel rods are Zircaloy clad.
2. Guide Tube thickness.
3. Up to 16 fuel rod positions may have solid filler rods or burnable poison rods.
4. Up to 12 fuel rod positions may have solid filler rods or burnable poison rods.

Table 6.6.1.1-2 Maine Yankee Most Reactive Fuel Dimensions

Parameter	Bounding Dimensional Value
Maximum Rod Enrichment <sup>1</sup>	4.2 wt % <sup>235</sup> U
Maximum Number of Fuel Rods <sup>2</sup>	176
Maximum Pitch (in.)	0.590
Maximum Active Length (in.)	N/A - Infinite Model
Minimum Clad OD (in.)	0.4375
Maximum Clad ID (in.)	0.3895
Minimum Clad Thickness (in.)	0.024
Maximum Pellet Diameter (in.)	0.3800 - Study
Minimum Guide Tube OD (in.)	1.108
Maximum Guide Tube ID (in.)	1.040
Minimum Guide Tube Thickness (in.)	0.034

1. Variably enriched fuel assemblies may have a maximum fuel rod enrichment of 4.21 wt % <sup>235</sup>U with a maximum planar average enrichment of 3.99 wt % <sup>235</sup>U.
2. Assemblies with less than 176 fuel rods or solid dummy rods are addressed after the determination of the most reactive dimensions.

Table 6.6.1.1-3 Maine Yankee Pellet Diameter Study

Diameter (inches)	k-eff	$\sigma$	k-eff +2 $\sigma$
0.3800	0.95585	0.00085	0.95755
0.3779	0.95784	0.00080	0.95944
0.3758	0.95714	0.00085	0.95884
0.3737	0.95863	0.00082	0.96027
0.3716	0.95862	0.00084	0.96030
0.3695	0.95855	0.00083	0.96021
0.3674	0.95863	0.00085	0.96033
0.3653	0.95982	0.00084	0.96150
0.3632	0.95854	0.00088	0.96030
0.3611	0.95966	0.00083	0.96132
0.3590	0.95990	0.00084	0.96158
0.3569	0.96082	0.00082	0.96246
0.3548	0.96053	0.00083	0.96219
0.3527	0.96104	0.00082	0.96268
0.3506	0.95964	0.00087	0.96138
0.3485	0.95993	0.00086	0.96165
0.3464	0.95916	0.00084	0.96084
0.3443	0.95847	0.00083	0.96013
0.3422	0.95876	0.00083	0.96042
0.3401	0.95865	0.00081	0.96027
0.3380	0.95734	0.00084	0.95902

Table 6.6.1.1-4 Maine Yankee Annular Fuel Results

Case Description	k <sub>eff</sub>	$\sigma$	k <sub>eff</sub> + 2 $\sigma$
All pellets with a diameter of 0.3527 inches	0.90896	0.00083	0.91061
Annular pellet diameter changed to 0.3800 inches	0.91013	0.00087	0.91187

Table 6.6.1.1-5 Maine Yankee Removed Rod Results with Small Pellet Diameter

Number of Removed Rods	Number of Fuel Rods	$k_{eff}$	$\sigma$	$k_{eff} + 2\sigma$
4	172	0.91171	0.00088	0.91347
4	172	0.91292	0.00086	0.91464
4	172	0.91479	0.00081	0.91640
4	172	0.91125	0.00087	0.91299
6	170	0.91418	0.00087	0.91592
6	170	0.91264	0.00085	0.91435
6	170	0.91314	0.00086	0.91487
6	170	0.90322	0.00086	0.90493
8	168	0.91555	0.00087	0.91729
8	168	0.91490	0.00093	0.91676
8	168	0.91457	0.00088	0.91633
8	168	0.91590	0.00087	0.91764
8	168	0.89729	0.00088	0.89905
12	164	0.91654	0.00086	0.91827
12	164	0.91469	0.00085	0.91639
12	164	0.91149	0.00083	0.91315
16	160	0.91725	0.00084	0.91893
16	160	0.91567	0.00084	0.91735
16	160	0.90986	0.00088	0.91162
16	160	0.90849	0.00083	0.91015
16	160	0.90704	0.00086	0.90876
24	152	0.91572	0.00083	0.91739
32	144	0.91037	0.00088	0.91213
48	128	0.89385	0.00085	0.89554
48	128	0.84727	0.00079	0.84886
64	112	0.79602	0.00083	0.79768
96	80	0.69249	0.00077	0.69402
Westinghouse 17x17 OFA		0.9192	0.0009	0.9210

Table 6.6.1.1-6 Maine Yankee Removed Fuel Rod Results with Maximum Pellet Diameter

Number of Removed Rods	Number of Fuel Rods	$k_{eff}$	$\sigma$	$k_{eff} + 2\sigma$
4	172	0.91078	0.00086	0.91250
4	172	0.90916	0.00085	0.91085
4	172	0.91164	0.00087	0.91338
4	172	0.90809	0.00085	0.90979
6	170	0.91223	0.00085	0.91393
6	170	0.91223	0.00080	0.91384
6	170	0.91270	0.00086	0.91442
6	170	0.90245	0.00086	0.90416
6	170	0.89801	0.00086	0.89972
8	168	0.91567	0.00085	0.91736
8	168	0.91448	0.00085	0.91618
8	168	0.91355	0.00086	0.91526
8	168	0.91293	0.00085	0.91463
12	164	0.91639	0.00090	0.91818
12	164	0.91803	0.00086	0.91974
12	164	0.91235	0.00083	0.91401
16	160	0.91665	0.00091	0.91847
16	160	0.92136	0.00087	0.92310
16	160	0.91231	0.00084	0.91400
16	160	0.90883	0.00087	0.91057
24	152	0.92227	0.00087	0.92400
32	144	0.92164	0.00088	0.92340
48	128	0.91212	0.00081	0.91373
48	128	0.86308	0.00082	0.86472
64	112	0.81978	0.00080	0.82138
88	88	0.72087	0.00083	0.72247
24 (Four Corners)	152	0.91153	0.00085	0.91323
Westinghouse 17x17 OFA		0.9192	0.0009	0.9210

Table 6.6.1.1-7 Maine Yankee Fuel Rods in Guide Tubes Results

Number of Guide Tubes with Rods	Number of Rods in Each	$k_{eff}$	$\sigma$	$k_{eff} + 2\sigma$
1	1	0.91102	0.00089	0.91280
2	1	0.91059	0.00088	0.91234
3	1	0.91172	0.00087	0.91346
5	1	0.91411	0.00086	0.91583
1	2	0.91169	0.00090	0.91349
2	2	0.91201	0.00087	0.91375
3	2	0.91173	0.00086	0.91344
5	2	0.91357	0.00086	0.91529
Design Basis Westinghouse 17x17 OFA		0.9192	0.0009	0.9210

Table 6.6.1.1-8 Maine Yankee Consolidated Fuel Empty Fuel Rod Position Results

Number of Empty Positions	Number of Fuel Rods	$k_{eff}$	$\sigma$	$k_{eff} + 2\sigma$
4	285	0.79684	0.00082	0.79848
9	280	0.80455	0.00081	0.80616
9	280	0.80812	0.00079	0.80970
13	276	0.81573	0.00083	0.81739
24	265	0.84187	0.00080	0.84347
25	264	0.84017	0.00083	0.84182
25	264	0.84634	0.00081	0.84795
25	264	0.84583	0.00083	0.84750
25	264	0.85524	0.00083	0.85690
25	264	0.83396	0.00081	0.83558
25	264	0.84625	0.00083	0.84790
27	262	0.85438	0.00083	0.85604
29	260	0.85179	0.00081	0.85340
31	258	0.85930	0.00084	0.86098
33	256	0.86407	0.00082	0.86571
35	254	0.86740	0.00082	0.86904
37	252	0.87372	0.00084	0.87541
45	244	0.88630	0.00081	0.88793
45	244	0.87687	0.00079	0.87844
52	237	0.90062	0.00083	0.90228
57	232	0.87975	0.000870	0.88149
61	258	0.89055	0.00083	0.89221
73	216	0.90967	0.00082	0.91131
84	205	0.93261	0.00091	0.93443
85	204	0.94326	0.00086	0.94499
113	176	0.95626	0.00084	0.95794
117	172	0.95373	0.00088	0.95549
119	170	0.95315	0.00085	0.95485
125	164	0.95020	0.00086	0.95192
141	148	0.94348	0.00086	0.94521
145	144	0.93868	0.00089	0.94047
113 (Four Corners)	176	0.91292	0.00087	0.91466
Design Basis Westinghouse 17x17 OFA		0.9192	0.0009	0.9210



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#### 6.6.2      CSAS Inputs and Outputs

This section contains sample CSAS25 input/output for the criticality analysis of the NAC-UMS Universal Transport Cask under normal conditions of transport and hypothetical accident conditions. These summaries include: the input file echo, the CSAS25 and the KENO-Va output sections. BONAMI and NITAWL-II output sections are not included for brevity.

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel

```
PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25 WILL BE CALLED
UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PICH
27GROUPNDF4 LATTICECELL
UO2 1 0.95 293.0 92235 4.20 92238 95.80 END
ZIRCALLOY 2 1.0 293.0 END
H2O 3 0.0001 293.0 END
AL 4 1.0 293.0 END
SS304 5 1.0 293.0 END
AL 6 DEN=2.6041 0.4635 293.0 END
B-10 6 DEN=2.6041 0.0567 293.0 END
B-11 6 DEN=2.6041 0.3444 293.0 END
C 6 DEN=2.6041 0.1165 293.0 END
PB 7 1.0 293.0 END
B-10 8 0.0 8.553-5 293.0 END
B-11 8 0.0 3.422-4 293.0 END
AL 8 0.0 7.763-3 293.0 END
H 8 0.0 5.854-2 293.0 END
O 8 0.0 2.609-2 293.0 END
C 8 0.0 2.264-2 293.0 END
N 8 0.0 1.394-3 293.0 END
H2O 9 0.1 293.0 END
H2O 10 0.0001 293.0 END
END COMP
SQUAREPITCH 1.2598 0.7844 1 3 0.9144 2 0.8001 0 END
UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH
READ PARAM RUN=YES PLT=NO TME=5000 GEN=203 NPG=1000 END PARAM
READ GEOM
UNIT 1
COM='FUEL PIN CELL - BETWEEN DISKS'
CYLINDER 1 1 0.3922 2P2.4892
CYLINDER 0 1 0.4001 2P2.4892
CYLINDER 2 1 0.4572 2P2.4892
CUBOID 3 1 4P0.6299 2P2.4892
UNIT 2
COM='WATER ROD CELL - BETWEEN DISKS'
CYLINDER 3 1 0.5715 2P2.4892
CYLINDER 2 1 0.6121 2P2.4892
CUBOID 3 1 4P0.6299 2P2.4892
UNIT 3
COM='FUEL PIN CELL - FOR DISK SLICE OF CASK'
CYLINDER 1 1 0.3922 2P0.6350
CYLINDER 0 1 0.4001 2P0.6350
CYLINDER 2 1 0.4572 2P0.6350
CUBOID 3 1 4P0.6299 2P0.6350
UNIT 4
COM='WATER ROD CELL - FOR DISK SLICE OF CASK'
CYLINDER 3 1 0.5715 2P0.6350
CYLINDER 2 1 0.6121 2P0.6350
CUBOID 3 1 4P0.6299 2P0.6350
UNIT 5
COM='X-X BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P2.4892
CUBOID 4 1 2P10.4140 2P0.0951 2P2.4892
UNIT 6
COM='Y-Y BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P2.4892
CUBOID 4 1 2P0.0951 2P10.4140 2P2.4892
UNIT 7
COM='X-X BORAL SHEET WITH DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P0.6350
CUBOID 4 1 2P10.4140 2P0.0951 2P0.6350
UNIT 8
COM='Y-Y BORAL SHEET WITH DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P0.6350
CUBOID 4 1 2P0.0951 2P10.4140 2P0.6350
UNIT 10
COM='TUBE CELL IN H2O BETWEEN DISKS (A)'
ARRAY 1 -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE 5 0.0 +11.4308 0.0
HOLE 5 0.0 -11.4308 0.0
HOLE 6 +11.4308 0.0 0.0
HOLE 6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P2.4892
UNIT 11
COM='TUBE CELL IN H2O BETWEEN DISKS (B)'
```

Figure 6.6.2-1

CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
ARRAY 1 -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE 5 0.0 +11.4308 0.0
HOLE 5 0.0 -11.4308 0.0
HOLE 6 +11.4308 0.0 0.0
HOLE 6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P2.4892
UNIT 12
COM='TUBE CELL IN H2O BETWEEN DISKS (C)'
ARRAY 1 -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE 5 0.0 +11.4308 0.0
HOLE 5 0.0 -11.4308 0.0
HOLE 6 +11.4308 0.0 0.0
HOLE 6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P2.4892
UNIT 13
COM='TUBE CELL IN H2O BETWEEN DISKS (D)'
ARRAY 1 -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE 5 0.0 +11.4308 0.0
HOLE 5 0.0 -11.4308 0.0
HOLE 6 +11.4308 0.0 0.0
HOLE 6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P2.4892
UNIT 14
COM='WEB UNIT (1.5" WEB) - BETWEEN DISKS'
CUBOID 3 1 2P11.7946 2P1.8725 2P2.4892
UNIT 15
COM='WEB UNIT (1.0" WEB) - BETWEEN DISKS'
CUBOID 3 1 2P11.7946 2P1.2510 2P2.4892
UNIT 16
COM='WEB UNIT (0.875" WEB) - BETWEEN DISKS'
CUBOID 3 1 2P11.7946 2P1.0923 2P2.4892
UNIT 17
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (-X)'
ARRAY 10 -11.7946 -77.3262 -2.4892
UNIT 18
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (+X)'
ARRAY 11 -11.7946 -77.3262 -2.4892
UNIT 19
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (-X)'
ARRAY 12 -11.7946 -25.4616 -2.4892
UNIT 20
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (+X)'
ARRAY 13 -11.7946 -25.4616 -2.4892
UNIT 30
COM='TUBE CELL IN ST DISK (A)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 31
COM='TUBE CELL IN ST DISK (B)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 32
COM='TUBE CELL IN ST DISK (C)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
```

Figure 6.6.2-1

CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 33
COM='TUBE CELL IN ST DISK (D)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 34
COM='WEB UNIT (1.5" WEB) - ST DISKS'
CUBOID 5 1 2P11.7946 2P1.8725 2P0.6350
UNIT 35
COM='WEB UNIT (1.0" WEB) - ST DISKS'
CUBOID 5 1 2P11.7946 2P1.2510 2P0.6350
UNIT 36
COM='WEB UNIT (0.875" WEB) - ST DISKS'
CUBOID 5 1 2P11.7946 2P1.0923 2P0.6350
UNIT 37
COM='6x1 FUEL TUBE STACK ST DISK (-X)'
ARRAY 20 -11.7946 -77.3262 -0.6350
UNIT 38
COM='6x1 FUEL TUBE STACK ST DISK (+X)'
ARRAY 21 -11.7946 -77.3262 -0.6350
UNIT 39
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (-X)'
ARRAY 22 -11.7946 -25.4616 -0.6350
UNIT 40
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (+X)'
ARRAY 23 -11.7946 -25.4616 -0.6350
UNIT 50
COM='TUBE CELL IN AL DISK (A)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 51
COM='TUBE CELL IN AL DISK (B)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 52
COM='TUBE CELL IN AL DISK (C)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 53
COM='TUBE CELL IN AL DISK (D)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
```

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 54
COM='WEB UNIT (1.5" WEB) - AL DISKS'
CUBOID 4 1 2P11.7946 2P1.8725 2P0.6350
UNIT 55
COM='WEB UNIT (1.0" WEB) - AL DISKS'
CUBOID 4 1 2P11.7946 2P1.2510 2P0.6350
UNIT 56
COM='WEB UNIT (0.875" WEB) - AL DISKS'
CUBOID 4 1 2P11.7946 2P1.0923 2P0.6350
UNIT 57
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 30 -11.7946 -77.3262 -0.6350
UNIT 58
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 31 -11.7946 -77.3262 -0.6350
UNIT 59
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 32 -11.7946 -25.4616 -0.6350
UNIT 60
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 33 -11.7946 -25.4616 -0.6350
UNIT 70
COM='BASKET STRUCTURE IN TRANSPORT CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P2.4892
HOLE 17 -13.6669 0.0 0.0
HOLE 18 +13.6669 0.0 0.0
HOLE 19 -39.7578 0.0 0.0
HOLE 20 +39.7578 0.0 0.0
HOLE 19 -65.5312 0.0 0.0
HOLE 20 +65.5312 0.0 0.0
HOLE 10 +40.8048 +40.8048 0.0
HOLE 11 -40.8048 +40.8048 0.0
HOLE 12 -40.8048 -40.8048 0.0
HOLE 13 +40.8048 -40.8048 0.0
CYLINDER 5 1 +85.1662 2P2.4892
CYLINDER 9 1 +85.8647 2P2.4892
CYLINDER 5 1 +90.9447 2P2.4892
CYLINDER 7 1 +97.9297 2P2.4892
CYLINDER 5 1 +104.9147 2P2.4892
CYLINDER 8 1 +116.3604 2P2.4892
CYLINDER 0 1 +116.6788 2P2.4892
CYLINDER 5 1 +117.3156 2P2.4892
CUBOID 9 1 4P135.0 2P2.4892
UNIT 71
COM='BASKET STRUCTURE IN TRANSPORT CASK - ST DISK'
CYLINDER 5 1 +83.1850 2P0.6350
HOLE 37 -13.6669 0.0 0.0
HOLE 38 +13.6669 0.0 0.0
HOLE 39 -39.7578 0.0 0.0
HOLE 40 +39.7578 0.0 0.0
HOLE 39 -65.5312 0.0 0.0
HOLE 40 +65.5312 0.0 0.0
HOLE 30 +40.8048 +40.8048 0.0
HOLE 31 -40.8048 +40.8048 0.0
HOLE 32 -40.8048 -40.8048 0.0
HOLE 33 +40.8048 -40.8048 0.0
CYLINDER 3 1 +83.5787 2P0.6350
CYLINDER 5 1 +85.1662 2P0.6350
CYLINDER 9 1 +85.8647 2P0.6350
CYLINDER 5 1 +90.9447 2P0.6350
CYLINDER 7 1 +97.9297 2P0.6350
CYLINDER 5 1 +104.9147 2P0.6350
CYLINDER 8 1 +116.3604 2P0.6350
CYLINDER 0 1 +116.6788 2P0.6350
CYLINDER 5 1 +117.3156 2P0.6350
CUBOID 9 1 4P135.0 2P0.6350
UNIT 72
COM='BASKET STRUCTURE IN TRANSPORT CASK - AL DISK'
CYLINDER 4 1 +82.8675 2P0.6350
HOLE 57 -13.6669 0.0 0.0
HOLE 58 +13.6669 0.0 0.0
HOLE 59 -39.7578 0.0 0.0
HOLE 60 +39.7578 0.0 0.0
HOLE 59 -65.5312 0.0 0.0
HOLE 60 +65.5312 0.0 0.0
HOLE 50 +40.8048 +40.8048 0.0
HOLE 51 -40.8048 +40.8048 0.0
HOLE 52 -40.8048 -40.8048 0.0
HOLE 53 +40.8048 -40.8048 0.0
CYLINDER 3 1 +83.5787 2P0.6350
CYLINDER 5 1 +85.1662 2P0.6350
```

Figure 6.6.2-1

CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
CYLINDER 9 1 +85.8647 2P0.6350
CYLINDER 5 1 +90.9447 2P0.6350
CYLINDER 7 1 +97.9297 2P0.6350
CYLINDER 5 1 +104.9147 2P0.6350
CYLINDER 8 1 +116.3604 2P0.6350
CYLINDER 0 1 +116.6788 2P0.6350
CYLINDER 5 1 +117.3156 2P0.6350
CUBOID 9 1 4P135.0 2P0.6350
GLOBAL UNIT 73
COM='DISK SLICE STACK'
ARRAY 40 -135.0 -135.0 0.0
END GEOM
READ ARRAY
ARA=1 NUX=17 NUY=17 NUZ=1 FILL
      34R1
      5R1 2 2R1 2 2R1 2 5R1
      3R1 2 9R1 2 3R1
      17R1
2R1 2 2R1 2 2R1 2 2R1 2 2R1 2 2R1
      34R1
2R1 2 2R1 2 2R1 2 2R1 2 2R1 2 2R1
      34R1
2R1 2 2R1 2 2R1 2 2R1 2 2R1 2 2R1
      17R1
      3R1 2 9R1 2 3R1
      5R1 2 2R1 2 2R1 2 5R1
      34R1
END FILL
ARA=2 NUX=17 NUY=17 NUZ=1 FILL
      34R3
      5R3 4 2R3 4 2R3 4 5R3
      3R3 4 9R3 4 3R3
      17R3
2R3 4 2R3 4 2R3 4 2R3 4 2R3 4 2R3
      34R3
2R3 4 2R3 4 2R3 4 2R3 4 2R3 4 2R3
      34R3
2R3 4 2R3 4 2R3 4 2R3 4 2R3 4 2R3
      17R3
      3R3 4 9R3 4 3R3
      5R3 4 2R3 4 2R3 4 5R3
      34R3
END FILL
ARA=10 NUX=1 NUY=11 NUZ=1 FILL 12 16 12 15 12 14 11 15 11 16 11 END FILL
ARA=11 NUX=1 NUY=11 NUZ=1 FILL 13 16 13 15 13 14 10 15 10 16 10 END FILL
ARA=12 NUX=1 NUY=3 NUZ=1 FILL 12 14 11 END FILL
ARA=13 NUX=1 NUY=3 NUZ=1 FILL 13 14 10 END FILL
ARA=20 NUX=1 NUY=11 NUZ=1 FILL 32 36 32 35 32 34 31 35 31 36 31 END FILL
ARA=21 NUX=1 NUY=11 NUZ=1 FILL 33 36 33 35 33 34 30 35 30 36 30 END FILL
ARA=22 NUX=1 NUY=3 NUZ=1 FILL 32 34 31 END FILL
ARA=23 NUX=1 NUY=3 NUZ=1 FILL 33 34 30 END FILL
ARA=30 NUX=1 NUY=11 NUZ=1 FILL 52 56 52 55 52 54 51 55 51 56 51 END FILL
ARA=31 NUX=1 NUY=11 NUZ=1 FILL 53 56 53 55 53 54 50 55 50 56 50 END FILL
ARA=32 NUX=1 NUY=3 NUZ=1 FILL 52 54 51 END FILL
ARA=33 NUX=1 NUY=3 NUZ=1 FILL 53 54 50 END FILL
ARA=40 NUX=1 NUY=1 NUZ=4 FILL 70 71 70 72 END FILL
END ARRAY
READ BOUNDS 2FC=PER YXF=MIRROR END BOUNDS
END DATA

SECONDARY MODULE 000008 HAS BEEN CALLED.

MODULE 000008 IS FINISHED. COMPLETION CODE 0. CPU TIME USED 1.21 (SECONDS).

SECONDARY MODULE 000002 HAS BEEN CALLED.

MODULE 000002 IS FINISHED. COMPLETION CODE 0. CPU TIME USED 11.42 (SECONDS).

SECONDARY MODULE 000009 HAS BEEN CALLED.

MODULE 000009 IS FINISHED. COMPLETION CODE 0. CPU TIME USED 3681.88 (SECONDS).

MODULE CSAS25 IS FINISHED. COMPLETION CODE 0. CPU TIME USED 3696.43 (SECONDS).
```

Figure 6.6.2-1

CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
CCCCCCCCCCCC SSSSSSSSSS AAAAAAAAAA SSSSSSSSSS 2222222222 555555555555
CCCCCCCCCCCC SSSSSSSSSSSS AAAAAAAAAAAA SSSSSSSSSSSS 222222222222 555555555555
CC          CC SS      SS AA      AA SS      SS 22      22 55
CC          SS      AA      AA SS      SS 22      22 55
CC          SS      AA      AA SS      SS 22      22 55
CC          SSSSSSSSSS AAAAAAAAAAAA SSSSSSSSSSSS 22      555555555555
CC          SSSSSSSSSSSS AAAAAAAAAAAA SSSSSSSSSSSS 22      555555555555
CC          SS      AA      AA SS      SS 22      55
CC          SS      AA      AA SS      SS 22      55
CC          CC SS      SS AA      AA SS      SS 22      55 55
CCCCCCCCCCCC SSSSSSSSSSSS AA      AA SSSSSSSSSSSS 222222222222 555555555555
CCCCCCCCCCCC SSSSSSSSSSSS AA      AA SSSSSSSSSSSS 222222222222 555555555555
```

```
SSSSSSSSSSS CCCCCCCCCC AAAAAAAAAA LL      EEEEEEEEEEE PFFFFFFFFPPP CCCCCCCCCC
SSSSSSSSSSS CCCCCCCCCC AAAAAAAAAAAA LL      EEEEEEEEEEE PFFFFFFFFPPP CCCCCCCCCC
SS      SS CC      CC AA      AA LL      EE      EE      PP      PP CC      CC
SS      CC      AA      AA LL      EE      EE      PP      PP CC      CC
SS      CC      AA      AA LL      EE      EE      PP      PP CC      CC
SSSSSSSSSSS CC      AAAAAAAAAAAA LL      EEEEEEEEE PFFFFFFFFPPP CC
SSSSSSSSSSS CC      AAAAAAAAAAAA LL      EEEEEEEEE PFFFFFFFFPPP CC
SS      SS CC      AA      AA LL      EE      EE      PP      PP CC      CC
SS      SS CC      AA      AA LL      EE      EE      PP      PP CC      CC
SS      SS CC      AA      AA LL      EE      EE      PP      PP CC      CC
SSSSSSSSSSS CCCCCCCCCC AA      AA LLLLLLLLLLLL EEEEEEEEEEE PP      CCCCCCCCCC
SSSSSSSSSSS CCCCCCCCCC AA      AA LLLLLLLLLLLL EEEEEEEEEEE PP      CCCCCCCCCC
```

```
00000000 8888888888 // 2222222222 3333333333 // 9999999999 6666666666
000000000 888888888888 // 222222222222 333333333333 // 999999999999 666666666666
00      00 88      88 // 22      22 33      33 // 99      99 66
00      00 88      88 // 22      22 33      33 // 99      99 66
00      00 8888888888 // 22      22 333      333 // 999999999999 666666666666
00      00 888888888888 // 22      22 333      333 // 9999999999999 6666666666666
00      00 88      88 // 22      22 33      33 // 99      99 66
00      00 88      88 // 22      22 33      33 // 99      99 66
00      00 88      88 // 22      22 33      33 // 99      99 66
000000000 888888888888 // 222222222222 333333333333 // 9999999999999 6666666666666
00000000 888888888888 // 222222222222 333333333333 // 9999999999999 666666666666
```

```
00000000 666666666666 44      666666666666 2222222222 666666666666
000000000 66666666666666 444      66666666666666 222222222222 66666666666666
00      00 66      66 ::: 4444      66      22      66
00      00 66      66 ::: 44 44      66      22      66
00      00 66      66 ::: 44 44      66      22      66
00      00 666666666666 44 44      666666666666 22      666666666666
00      00 66666666666666 44 44      66666666666666 22      66666666666666
00      00 66      66 ::: 444444444444 66      66      22      66
00      00 66      66 ::: 444444444444 66      66      22      66
00      00 66      66 ::: 44      66      22      66
000000000 66666666666666 44      66666666666666 222222222222 66666666666666
00000000 666666666666 44      666666666666 222222222222 666666666666
```

```
SSSSSSSSSSS CCCCCCCCCC AAAAAAAAAA LL      EEEEEEEEEEE PFFFFFFFFPPP CCCCCCCCCC
SSSSSSSSSSS CCCCCCCCCC AAAAAAAAAAAA LL      EEEEEEEEEEE PFFFFFFFFPPP CCCCCCCCCC
SS      SS CC      CC AA      AA LL      EE      EE      PP      PP CC      CC
SS      CC      AA      AA LL      EE      EE      PP      PP CC      CC
SS      CC      AA      AA LL      EE      EE      PP      PP CC      CC
SSSSSSSSSSS CC      AAAAAAAAAAAA LL      EEEEEEEEE PFFFFFFFFPPP CC
SSSSSSSSSSS CC      AAAAAAAAAAAA LL      EEEEEEEEE PFFFFFFFFPPP CC
SS      SS CC      AA      AA LL      EE      EE      PP      PP CC      CC
SS      SS CC      AA      AA LL      EE      EE      PP      PP CC      CC
SS      SS CC      AA      AA LL      EE      EE      PP      PP CC      CC
SSSSSSSSSSS CCCCCCCCCC AA      AA LLLLLLLLLLLL EEEEEEEEEEE PP      CCCCCCCCCC
SSSSSSSSSSS CCCCCCCCCC AA      AA LLLLLLLLLLLL EEEEEEEEEEE PP      CCCCCCCCCC
```



**Figure 6.6.2-1**

## CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
*****  
*****  
*****      PROGRAM VERIFICATION INFORMATION      *****  
*****  
***** CODE SYSTEM:   SCALE-PC VERSION:   4.3     *****  
*****  
*****  
*****  
*****  
*****  
*****      PROGRAM:    CSAS                      *****  
*****  
***** CREATION DATE:   03-08-96                  *****  
*****  
***** VOLUME:         ENG                        *****  
*****  
***** LIBRARY:        G:\scale43\exe              *****  
*****  
*****  
***** PRODUCTION CODE: CSAS                       *****  
*****  
***** VERSION:       3.1                          *****  
*****  
***** JOBNAME:       SCALE-PC                     *****  
*****  
***** DATE OF EXECUTION: 08/23/96                 *****  
*****  
***** TIME OF EXECUTION: 06:46:26                *****  
*****  
*****
```

Figure 6.6.2-1

CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PICH

\*\*\*\* PROBLEM PARAMETERS \*\*\*\*

LIB 27GROUPNDF4 LIBRARY  
MX 10 MIXTURES  
MSC 19 COMPOSITION SPECIFICATIONS  
IZM 4 MATERIAL ZONES  
GE LATTICECELL GEOMETRY  
MORE 0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA  
MSLN 0 FUEL SOLUTIONS

\*\*\*\* PROBLEM COMPOSITION DESCRIPTION \*\*\*\*

SC UO2 STANDARD COMPOSITION  
MX 1 MIXTURE NO.  
VF 0.9500 VOLUME FRACTION  
ROTH 10.9600 THEORETICAL DENSITY  
NEL 2 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
92000 1.00 ATOM/MOLECULE  
92235 4.200 WT%  
92238 95.800 WT%  
8016 2.00 ATOMS/MOLECULE

END

SC ZIRCALLOY STANDARD COMPOSITION  
MX 2 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 6.5600 THEORETICAL DENSITY  
NEL 1 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
40302 1.00 ATOM/MOLECULE

END

SC H2O STANDARD COMPOSITION  
MX 3 MIXTURE NO.  
VF 0.0001 VOLUME FRACTION  
ROTH 0.9982 THEORETICAL DENSITY  
NEL 2 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
1001 2.00 ATOMS/MOLECULE  
8016 1.00 ATOM/MOLECULE

END

SC AL STANDARD COMPOSITION  
MX 4 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 2.7020 THEORETICAL DENSITY  
NEL 1 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
13027 1.00 ATOM/MOLECULE

END

SC SS304 STANDARD COMPOSITION  
MX 5 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 7.9200 THEORETICAL DENSITY  
NEL 4 NO. ELEMENTS  
ICP 0 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
24304 19.000 WT%  
25055 2.000 WT%  
26304 69.500 WT%  
28304 9.500 WT%

END

SC AL STANDARD COMPOSITION  
MX 6 MIXTURE NO.  
VF 0.4635 VOLUME FRACTION  
ROTH 2.6041 SPECIFIED DENSITY  
NEL 1 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
13027 1.00 ATOM/MOLECULE

END

SC B-10 STANDARD COMPOSITION  
MX 6 MIXTURE NO.

Figure 6.6.2-1

CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```

VF      0.0567 VOLUME FRACTION
ROTH    2.6041 SPECIFIED DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
          5010      1.00 ATOM/MOLECULE
END

SC B-11      STANDARD COMPOSITION
MX          6 MIXTURE NO.
VF      0.3444 VOLUME FRACTION
ROTH    2.6041 SPECIFIED DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
          5011      1.00 ATOM/MOLECULE
END

SC C          STANDARD COMPOSITION
MX          6 MIXTURE NO.
VF      0.1165 VOLUME FRACTION
ROTH    2.6041 SPECIFIED DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
          6012      1.00 ATOM/MOLECULE
END

SC PB        STANDARD COMPOSITION
MX          7 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH    11.3440 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
          82000     1.00 ATOM/MOLECULE
END

SC B-10      STANDARD COMPOSITION
MX          8 MIXTURE NO.
DEN      8.5530E-05 ATOMIC DENSITY
ROTH    1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
          5010      1.00 ATOM/MOLECULE
END

SC B-11      STANDARD COMPOSITION
MX          8 MIXTURE NO.
DEN      3.4220E-04 ATOMIC DENSITY
ROTH    1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
          5011      1.00 ATOM/MOLECULE
END

SC AL        STANDARD COMPOSITION
MX          8 MIXTURE NO.
DEN      7.7630E-03 ATOMIC DENSITY
ROTH    2.7020 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
          13027     1.00 ATOM/MOLECULE
END

SC H          STANDARD COMPOSITION
MX          8 MIXTURE NO.
DEN      5.8540E-02 ATOMIC DENSITY
ROTH    1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
          1001      1.00 ATOM/MOLECULE
END

SC O          STANDARD COMPOSITION
MX          8 MIXTURE NO.
DEN      2.6090E-02 ATOMIC DENSITY
ROTH    1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN

```

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
      8016      1.00 ATOM/MOLECULE
END

SC C          STANDARD COMPOSITION
MX            8 MIXTURE NO.
DEN  2.2640E-02 ATOMIC DENSITY
ROTH  2.1000 THEORETICAL DENSITY
NEL    1 NO. ELEMENTS
ICP    1 0/1 MIXTURE/COMPOUND
TEMP   293.0 DEG KELVIN
      6012      1.00 ATOM/MOLECULE
END

SC N          STANDARD COMPOSITION
MX            8 MIXTURE NO.
DEN  1.3940E-03 ATOMIC DENSITY
ROTH  1.0000 THEORETICAL DENSITY
NEL    1 NO. ELEMENTS
ICP    1 0/1 MIXTURE/COMPOUND
TEMP   293.0 DEG KELVIN
      7014      1.00 ATOM/MOLECULE
END

SC H2O        STANDARD COMPOSITION
MX            9 MIXTURE NO.
VF      0.1000 VOLUME FRACTION
ROTH  0.9982 THEORETICAL DENSITY
NEL     2 NO. ELEMENTS
ICP     1 0/1 MIXTURE/COMPOUND
TEMP   293.0 DEG KELVIN
      1001      2.00 ATOMS/MOLECULE
      8016      1.00 ATOM/MOLECULE
END

SC H2O        STANDARD COMPOSITION
MX           10 MIXTURE NO.
VF      0.0001 VOLUME FRACTION
ROTH  0.9982 THEORETICAL DENSITY
NEL     2 NO. ELEMENTS
ICP     1 0/1 MIXTURE/COMPOUND
TEMP   293.0 DEG KELVIN
      1001      2.00 ATOMS/MOLECULE
      8016      1.00 ATOM/MOLECULE
END

**** PROBLEM GEOMETRY ****

CTP SQUAREPITCH CELL TYPE
PITCH  1.2598 CM CENTER TO CENTER SPACING
FUELOD 0.7844 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL   1 MIXTURE NO. OF FUEL
MMOD    3 MIXTURE NO. OF MODERATOR
CLADCD  0.9144 CM CLAD OUTER DIAMETER
MCLAD   2 MIXTURE NO. OF CLAD
GAPCD   0.8001 CM GAP OUTER DIAMETER
MGAP    0 MIXTURE NO. OF GAP
```

ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY

```
ZONE  1 IS FUEL
ZONE  2 IS GAP
ZONE  3 IS CLAD
ZONE  4 IS MOD
```

Figure 6.6.2-1

CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
.....
***
***                               UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PICH
***
.....
***
***          ***** DATA LIBRARY INFORMATION *****
***
***          UNIT          DATA SET NAME          VOLUME          UNIT FUNCTION
***          NUMBER          NAME          NAME
***          -----          -
***
***          89          G:\scale43\DATALIB\FT89F001          STANDARD COMPOSITION LIBRARY
***
***          82          G:\scale43\DATALIB\FT82F001          CROSS SECTION LIBRARY
***
***          11          C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARNO-          SHORT CROSS SECTION LIBRARY
***
***          90          C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARNO-          INPUT DATA DIRECT ACCESS
***
.....
***
***          STANDARD COMPOSITION LIBRARY DATA
***          -----
***
***          UNIT NUMBER : 89
***
***          DATASET NAME : G:\scale43\DATALIB\FT89F001
***
***          LIBRARY TITLE: SCALE-4 STANDARD COMPOSITION LIBRARY
***          637 STANDARD COMPOSITIONS, 490 NUCLIDES
***          90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.
***
***          CREATION DATE: 6/30/95
***
.....
***
***          CROSS SECTION LIBRARY DATA
***          -----
***
***          UNIT NUMBER : 82
***
***          DATASET NAME : G:\scale43\DATALIB\FT82F001
***
***          LIBRARY TITLE: SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
***          BASED ON ENDF-B VERSION 4 DATA
***          COMPILED FOR NRC          1/27/89
***          LAST UPDATED
***          L.M.PETRIE - ORNL
***
***          08/12/94
***
.....
***
.....
```

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```

KK      KK      EEEEEEEEEEE NN      NN      0000000000      VV      VV
KK      KK      EEEEEEEEEEE NNN      NN      00000000000000      VV      VV
KK      KK      EE      NNNN      NN      00      00      VV      VV
KK      KK      EE      NN NN      NN      00      00      VV      VV
KK      KK      EE      NN NN      NN      00      00      VV      VV
KKKKKKKK      EEEEEEEEE     NN      NN      NN      00      00      ----- VV      VV
KKKKKKKK      EEEEEEEEE     NN      NN      NN      00      00      ----- VV      VV
KK      KK      EE      NN      NN      NN      00      00      VV      VV
KK      KK      EE      NN      NN      NN      00      00      VV      VV
KK      KK      EE      NN      NNNN      00      00      VV      VV
KK      KK      EEEEEEEEEEE NN      NNN      00000000000000      VVV
KK      KK      EEEEEEEEEEE NN      NN      00000000000      V

SSSSSSSSSS      CCCCCCCCCC      AAAAAAAAAA      LL      EEEEEEEEEEE      PPPPPPPPPPP      CCCCCCCCCC
SSSSSSSSSSSS      CCCCCCCCCCCC      AAAAAAAAAAAA      LL      EEEEEEEEEEE      PPPPPPPPPPPPP      CCCCCCCCCCCC
SS      SS      CC      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SS      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SS      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SSSSSSSSSSSS      CC      AAAAAAAAAAAAAA      LL      EEEEEEEEE     ----- PPPPPPPPPPPPP      CC
SSSSSSSSSSSS      CC      AAAAAAAAAAAAAA      LL      EEEEEEEEE     ----- PPPPPPPPPPPPP      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SSSSSSSSSSSS      CCCCCCCCCCCC      AA      AA      LLLLLLLLLLLLLL      EEEEEEEEEEE      PP      CCCCCCCCCCCC
SSSSSSSSSSSS      CCCCCCCCCCCC      AA      AA      LLLLLLLLLLLLLL      EEEEEEEEEEE      PP      CCCCCCCCCC

00000000      888888888888      //      22222222222      33333333333      //      99999999999      66666666666
0000000000      8888888888888      //      2222222222222      3333333333333      //      9999999999999      6666666666666
00      00      88      88      //      22      22      33      33      //      99      99      66      66
00      00      88      88      //      22      22      33      33      //      99      99      66      66
00      00      88      88      //      22      22      33      33      //      99      99      66      66
00      00      88888888888      //      22      333      //      9999999999999      6666666666666
00      00      888888888888      //      22      333      //      9999999999999      6666666666666
00      00      88      88      //      22      33      //      99      99      66      66
00      00      88      88      //      22      33      //      99      99      66      66
00      00      88      88      //      22      33      //      99      99      66      66
0000000000      8888888888888      //      2222222222222      3333333333333      //      9999999999999      6666666666666
00000000      888888888888      //      2222222222222      3333333333333      //      9999999999999      6666666666666

00000000      6666666666666      44      6666666666666      44      00000000
0000000000      66666666666666      444      66666666666666      444      0000000000
00      00      66      66      4444      66      4444      00      00
00      00      66      66      44 44      66      44 44      00      00
00      00      66      66      44 44      66      44 44      00      00
00      00      66666666666666      44 44      66666666666666      44 44      00      00
00      00      66666666666666      44 44      66666666666666      44 44      00      00
00      00      66      66      4444444444444      66      66      4444444444444      00      00
00      00      66      66      44444444444444      66      66      44444444444444      00      00
00      00      66      66      44      66      66      44      00      00
0000000000      6666666666666666      44      6666666666666666      44      000000000
00000000      66666666666666      44      6666666666666666      44      00000000

SSSSSSSSSSSS      CCCCCCCCCC      AAAAAAAAAA      LL      EEEEEEEEEEE      PPPPPPPPPPP      CCCCCCCCCC
SSSSSSSSSSSSSS      CCCCCCCCCCCC      AAAAAAAAAAAA      LL      EEEEEEEEEEE      PPPPPPPPPPPPP      CCCCCCCCCCCC
SS      SS      CC      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SS      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SS      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SSSSSSSSSSSS      CC      AAAAAAAAAAAAAA      LL      EEEEEEEEE     ----- PPPPPPPPPPPPP      CC
SSSSSSSSSSSS      CC      AAAAAAAAAAAAAA      LL      EEEEEEEEE     ----- PPPPPPPPPPPPP      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SSSSSSSSSSSSSS      CCCCCCCCCCCC      AA      AA      LLLLLLLLLLLLLL      EEEEEEEEEEE      PP      CCCCCCCCCCCC
SSSSSSSSSSSS      CCCCCCCCCCCC      AA      AA      LLLLLLLLLLLLLL      EEEEEEEEEEE      PP      CCCCCCCCCC
```

**Figure 6.6.2-1**

## CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
*****  
*** PROGRAM VERIFICATION INFORMATION ***  
*** CODE SYSTEM: SCALE-PC VERSION: 4.3 ***  
*****  
  
PROGRAM: O0O009  
CREATION DATE: 03-08-96  
VOLUME: ENG  
LIBRARY: G:\scale43\exe  
  
PRODUCTION CODE: KENOVA  
VERSION: 3.1  
JOBNAME: SCALE-PC  
DATE OF EXECUTION: 08/23/96  
TIME OF EXECUTION: 06:46:40
```

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH		
***** NUMERIC PARAMETERS *****		
TME	MAXIMUM PROBLEM TIME (MIN)	*****
TBA	TIME PER GENERATION (MIN)	0.50
GEN	NUMBER OF GENERATIONS	203
NPG	NUMBER PER GENERATION	1000
NSK	NUMBER OF GENERATIONS TO BE SKIPPED	3
BEG	BEGINNING GENERATION NUMBER	1
RES	GENERATIONS BETWEEN CHECKPOINTS	0
X1D	NUMBER OF EXTRA 1-D CROSS SECTIONS	1
NBK	NEUTRON BANK SIZE	1025
XNB	EXTRA POSITIONS IN NEUTRON BANK	0
NFB	FISSION BANK SIZE	1000
XFB	EXTRA POSITIONS IN FISSION BANK	0
WTA	DEFAULT VALUE OF WEIGHT AVERAGE	0.5000
WTH	WEIGHT HIGH FOR SPLITTING	3.0000
WTL	WEIGHT LOW FOR RUSSIAN ROULETTE	0.3333
RND	STARTING RANDOM NUMBER	BB827100001
NBS	NUMBER OF D.A. BLOCKS ON UNIT 8	200
NLS	LENGTH OF D.A. BLOCKS ON UNIT 8	512
ADJ	MODE OF CALCULATION	FORWARD
	INPUT DATA WRITTEN ON RESTART UNIT	NO
	BINARY DATA INTERFACE	YES



Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```
*****
***                                     ***
***               UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH ***
***                                     ***
***** LOGICAL PARAMETERS *****
***                                     ***
*** RUN  EXECUTE PROBLEM AFTER CHECKING DATA  YES          PLT  PLOT PICTURE MAP(S)          NO ***
*** FLX  COMPUTE FLUX                          NO          FDN  COMPUTE FISSION DENSITIES      NO ***
*** SMU  COMPUTE AVG UNIT SELF-MULTIPLICATION  NO          NUB  COMPUTE NU-BAR & AVG FISSION GROUP  YES ***
*** MKU  COMPUTE MATRIX K-EFF BY UNIT NUMBER   NO          MKP  COMPUTE MATRIX K-EFF BY UNIT LOCATION NO ***
*** CKU  COMPUTE COFACTOR K-EFF BY UNIT NUMBER NO          CKP  COMPUTE COFACTOR K-EFF BY UNIT LOCATION NO ***
*** FMU  PRINT FISSION PROD MATRIX BY UNIT NUMBER NO        FMP  PRINT FISSION PROD MATRIX BY UNIT LOCATION NO ***
*** MKH  COMPUTE MATRIX K-EFF BY HOLE NUMBER   NO          MKA  COMPUTE MATRIX K-EFF BY ARRAY NUMBER  NO ***
*** CKH  COMPUTE COFACTOR K-EFF BY HOLE NUMBER NO          CKA  COMPUTE COFACTOR K-EFF BY ARRAY NUMBER  NO ***
*** FMH  PRINT FISSION PROD MATRIX BY HOLE NUMBER NO        FMA  PRINT FISSION PROD MATRIX BY ARRAY NUMBER  NO ***
*** HHL  COLLECT MATRIX BY HIGHEST HOLE LEVEL  NO          HAL  COLLECT MATRIX BY HIGHEST ARRAY LEVEL  NO ***
*** AMX  PRINT ALL MIXED CROSS SECTIONS        NO          FAR  PRINT FIS. AND ABS. BY REGION      NO ***
*** XS1  PRINT 1-D MIXTURE X-SECTIONS          NO          GAS  PRINT FAR BY GROUP          NO ***
*** XS2  PRINT 2-D MIXTURE X-SECTIONS          NO          PAX  PRINT XSEC-ALBEDO CORRELATION TABLES NO ***
*** XAP  PRINT MIXTURE ANGLES & PROBABILITIES  NO          PWT  PRINT WEIGHT AVERAGE ARRAY      NO ***
*** PKI  PRINT FISSION SPECTRUM               NO          PGM  PRINT INPUT GEOMETRY          NO ***
*** P1D  PRINT EXTRA 1-D CROSS SECTIONS        NO          BUG  PRINT DEBUG INFORMATION      NO ***
***                                     ***
***                                     TRK  PRINT TRACKING INFORMATION      NO ***
***                                     ***
*****
***
PARAMETER INPUT COMPLETED
*****
..... 0 IO'S WERE USED READING THE PARAMETER DATA .....
***** DATA READING COMPLETED *****
```

```

***
***                UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH
***
*****
***
***          UNIT              VOLUME             UNIT FUNCTION
***      NUMBER              NAME                 -----
***      -----
***
***      XSC   14    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARNO-        MIXED CROSS SECTIONS
***
***      ALB   79    G:\scale43\DATALIB\FT79F001                        INPUT ALBEDOS
***
***      WTS   80    G:\scale43\DATALIB\FT80F001                        INPUT WEIGHTS
***
***      SKT   16     UNKNOWN                                           WRITE SCRATCH DATA
***
***      BIN   95    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARNO-        BINARY INPUT DATA
***
***      RST   95    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARNO-        READ RESTART DATA
***
***      LIB    4    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARNO-        INPUT AMPX WORKING LIBRARY
***
***               8    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARNO-        INPUT DATA DIRECT ACCESS
***
***               9     UNKNOWN                                           SUPER GROUPED DIRECT ACCESS
***
***            10     UNKNOWN                                           XSEC MIXING DIRECT ACCESS
***
*****
***
***      .....      0 IO'S WERE USED PREPARING INPUT DATA      .....
***

```

Figure 6.6.2-1

CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH									
MIXING TABLE									
NUMBER OF SCATTERING ANGLES = 2 CROSS SECTION MESSAGE THRESHOLD =3.0E-05									
MIXTURE =	1	DENSITY(G/CC) =	10.412						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
1008016	4.64627E-02	1.18489E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276			
08/12/94									UPDATED
1092235	9.87669E-04	3.70234E-02	92235	235.0441	URANIUM-235	ENDF/B-IV MAT 1261			
08/12/94									UPDATED
1092238	2.22437E-02	8.44487E-01	92238	238.0510	URANIUM-238	ENDF/B-IV MAT 1262			
08/12/94									UPDATED
MIXTURE =	2	DENSITY(G/CC) =	6.5600						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
2040302	4.33078E-02	1.00000E+00	40000	91.2196	ZIRCALLOY	ENDF/B-IV MAT 1284			
08/12/94									UPDATED
MIXTURE =	3	DENSITY(G/CC) =	0.99817E-04						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
3001001	6.67692E-06	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002			
08/12/94									UPDATED
3008016	3.33846E-06	8.88074E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276			
08/12/94									UPDATED
MIXTURE =	4	DENSITY(G/CC) =	2.7020						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
4013027	6.03066E-02	1.00000E+00	13027	26.9818	AL-27 1193 218 GP 040375(5)				
08/12/94									UPDATED
MIXTURE =	5	DENSITY(G/CC) =	7.9200						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
5024304	1.74286E-02	1.90000E-01	24000	51.9957	CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'				
08/12/94									UPDATED
5025055	1.73633E-03	1.99999E-02	25055	54.9379	MANGANESE-55	ENDF/B-IV MAT 1197			
08/12/94									UPDATED
5026304	5.93579E-02	6.95000E-01	26000	55.8447	FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'				
08/12/94									UPDATED
5028304	7.72070E-03	9.50001E-02	28000	58.6872	NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'				
08/12/94									UPDATED
MIXTURE =	6	DENSITY(G/CC) =	2.5549						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
6005010	8.88038E-03	5.77924E-02	5010	10.0130	B-10 1273 218NGP 042375 P-3 293K				
08/12/94									UPDATED
6005011	4.90582E-02	3.51040E-01	5011	11.0096	BORON-11	ENDF/B-IV MAT 1160			
08/12/94									UPDATED
6006012	1.52248E-02	1.18744E-01	6000	12.0001	CARBON-12	ENDF/B-IV MAT 1274/THRM1065			
08/12/94									UPDATED
6013027	2.69393E-02	4.72424E-01	13027	26.9818	AL-27 1193 218 GP 040375(5)				
08/12/94									UPDATED
MIXTURE =	7	DENSITY(G/CC) =	11.344						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
7082000	3.29690E-02	1.00000E+00	82000	207.2100	PB 1288 218NGP 042375 P-3 293K				
08/12/94									UPDATED
MIXTURE =	8	DENSITY(G/CC) =	1.6298						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
8001001	5.85400E-02	6.01023E-02	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002			
08/12/94									UPDATED
8005010	8.55300E-05	8.72589E-04	5010	10.0130	B-10 1273 218NGP 042375 P-3 293K				
08/12/94									UPDATED
8005011	3.42200E-04	3.83863E-03	5011	11.0096	BORON-11	ENDF/B-IV MAT 1160			
08/12/94									UPDATED
8006012	2.26400E-02	2.76813E-01	6000	12.0001	CARBON-12	ENDF/B-IV MAT 1274/THRM1065			
08/12/94									UPDATED
8007014	1.39400E-03	1.98893E-02	7014	14.0033	NITROGEN-14	ENDF/B-IV MAT 1275			
08/12/94									UPDATED
8008016	2.60900E-02	4.25068E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276			
08/12/94									UPDATED
8013027	7.76300E-03	2.13416E-01	13027	26.9818	AL-27 1193 218 GP 040375(5)				
08/12/94									UPDATED
MIXTURE =	9	DENSITY(G/CC) =	0.99817E-01						
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
9001001	6.67692E-03	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002			
08/12/94									UPDATED
9008016	3.33846E-03	8.88074E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276			
08/12/94									UPDATED
MIXTURE =	10	DENSITY(G/CC) =	0.99817E-04						

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
10001001	6.67692E-06	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002
08/12/94						UPDATED
10008016	3.33846E-06	8.88074E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276
08/12/94						UPDATED
3001001					HYDROGEN	ENDF/B-IV MAT 1269/THRM1002
8001001					HYDROGEN	ENDF/B-IV MAT 1269/THRM1002
9001001					HYDROGEN	ENDF/B-IV MAT 1269/THRM1002
10001001					HYDROGEN	ENDF/B-IV MAT 1269/THRM1002
6005010			B-10	1273	218NGP 042375 P-3 293K	UPDATED 08/12/94
8005010			B-10	1273	218NGP 042375 P-3 293K	UPDATED 08/12/94
6005011			BORON-11		ENDF/B-IV MAT 1160	UPDATED 08/12/94
8005011			BORON-11		ENDF/B-IV MAT 1160	UPDATED 08/12/94
6006012			CARBON-12		ENDF/B-IV MAT 1274/THRM1065	UPDATED 08/12/94
8006012			CARBON-12		ENDF/B-IV MAT 1274/THRM1065	UPDATED 08/12/94
8007014			NITROGEN-14		ENDF/B-IV MAT 1275	UPDATED 08/12/94
1008016			OXYGEN-16		ENDF/B-IV MAT 1276	UPDATED 08/12/94
3008016			OXYGEN-16		ENDF/B-IV MAT 1276	UPDATED 08/12/94
8008016			OXYGEN-16		ENDF/B-IV MAT 1276	UPDATED 08/12/94
9008016			OXYGEN-16		ENDF/B-IV MAT 1276	UPDATED 08/12/94
10008016			OXYGEN-16		ENDF/B-IV MAT 1276	UPDATED 08/12/94
4013027			AL-27	1193	218 GP 040375(5)	UPDATED 08/12/94
6013027			AL-27	1193	218 GP 040375(5)	UPDATED 08/12/94
8013027			AL-27	1193	218 GP 040375(5)	UPDATED 08/12/94
5024304			CR 1191	WT SS-304(1/EST)	P-3 293K SP=5+4(42375)'	UPDATED 08/12/94
5025055			MANGANESE-55		ENDF/B-IV MAT 1197	UPDATED 08/12/94
5026304			FE 1192	WT SS-304(1/EST)	P-3 293K SP=5+4(42375)'	UPDATED 08/12/94
5028304			NI 1190	WT SS-304(1/EST)	P-3 293K SP=5+4(42375)'	UPDATED 08/12/94
2040302			ZIRCALLOY		ENDF/B-IV MAT 1284	UPDATED 08/12/94
7082000			PB 1288	218NGP 042375 P-3 293K		UPDATED 08/12/94
1092235			URANIUM-235		ENDF/B-IV MAT 1261	UPDATED 08/12/94
1092238			URANIUM-238		ENDF/B-IV MAT 1262	UPDATED 08/12/94
KENO MESSAGE NUMBER K5-222      2 TRANSFERS FOR MIXTURE      3 WERE CORRECTED FOR BAD MOMENTS.						
KENO MESSAGE NUMBER K5-222      1 TRANSFERS FOR MIXTURE      9 WERE CORRECTED FOR BAD MOMENTS.						
KENO MESSAGE NUMBER K5-222      2 TRANSFERS FOR MIXTURE      10 WERE CORRECTED FOR BAD MOMENTS.						
..... 0 IO'S WERE USED MIXING CROSS-SECTIONS .....						
1-D CROSS SECTION ARRAY ID NUMBERS						
1 2002 1452 27 18 1018						
..... 0 IO'S WERE USED PREPARING THE CROSS SECTIONS .....						

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

```

*****
***      UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH      ***
***                                                                                       ***
*****
***                               ***** ADDITIONAL INFORMATION *****                               ***
***                                                                                       ***
***  NUMBER OF ENERGY GROUPS          27      USE LATTICE GEOMETRY          YES ***
***                                                                                       ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP 1      GLOBAL ARRAY NUMBER          40 ***
***                                                                                       ***
***  NO. OF SCATTERING ANGLES IN XSECS    2      NUMBER OF UNITS IN THE GLOBAL X DIR.  1 ***
***                                                                                       ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK  28      NUMBER OF UNITS IN THE GLOBAL Y DIR.  1 ***
***                                                                                       ***
***  ENTRIES/NEUTRON IN THE FISSION BANK  21      NUMBER OF UNITS IN THE GLOBAL Z DIR.  4 ***
***                                                                                       ***
***  NUMBER OF MIXTURES USED             9      USE A GLOBAL REFLECTOR          YES ***
***                                                                                       ***
***  NUMBER OF BIAS ID'S USED             1      USE NESTED HOLES              YES ***
***                                                                                       ***
***  NUMBER OF DIFFERENTIAL ALBEDOS USED   0      NUMBER OF HOLES              78 ***
***                                                                                       ***
***  TOTAL INPUT GEOMETRY REGIONS         148     MAXIMUM HOLE NESTING LEVEL        2 ***
***                                                                                       ***
***  NUMBER OF GEOMETRY REGIONS USED       148     USE NESTED ARRAYS              YES ***
***                                                                                       ***
***  LARGEST GEOMETRY UNIT NUMBER          73      NUMBER OF ARRAYS USED              15 ***
***                                                                                       ***
***  LARGEST ARRAY NUMBER                 40      MAXIMUM ARRAY NESTING LEVEL        3 ***
***                                                                                       ***
***  +X BOUNDARY CONDITION      MIRROR      -X BOUNDARY CONDITION      MIRROR ***
***                                                                                       ***
***  +Y BOUNDARY CONDITION      MIRROR      -Y BOUNDARY CONDITION      MIRROR ***
***                                                                                       ***
***  +Z BOUNDARY CONDITION      PER          -Z BOUNDARY CONDITION      PER ***
***                                                                                       ***
*****

```

**Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)**

VOLUME FRACTION OF FISSILE MATERIAL IN THE CORE= 4.20003E-02

START TYPE 0 WAS USED.

THE NEUTRONS WERE STARTED WITH A FLAT DISTRIBUTION IN A CUBOID DEFINED BY:

+X= 1.35000E+02 -X=-1.35000E+02 +Y= 1.35000E+02 -Y=-1.35000E+02 +Z= 1.24968E+01 -Z= 0.00000E+00  
THE FLAG TO START NEUTRONS IN THE REFLECTOR WAS TURNED OFF

0.04183 MINUTES WERE REQUIRED FOR STARTING. TOTAL ELAPSED TIME IS 0.06400 MINUTES.

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH

GENERATION	K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING... ONLY	445 INDEPENDENT	FISSION POINTS WERE	GENERATED	
1	3.91864E-01	3.63333E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING... ONLY	414 INDEPENDENT	FISSION POINTS WERE	GENERATED	
2	3.90933E-01	6.69167E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING... ONLY	429 INDEPENDENT	FISSION POINTS WERE	GENERATED	
3	3.92909E-01	9.67500E-01	3.92909E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	3.83835E-01	1.26683E+00	3.88372E-01	4.53733E-03	0.00000E+00	0.00000E+00
5	4.08764E-01	1.57533E+00	3.95169E-01	7.28475E-03	0.00000E+00	0.00000E+00
6	4.05077E-01	1.87933E+00	3.97646E-01	5.71570E-03	0.00000E+00	0.00000E+00
7	4.18995E-01	2.19233E+00	4.01916E-01	6.15074E-03	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING... ONLY	986 INDEPENDENT	FISSION POINTS WERE	GENERATED	
8	3.74551E-01	2.48617E+00	3.97355E-01	6.78394E-03	0.00000E+00	0.00000E+00
9	3.91704E-01	2.78833E+00	3.96548E-01	5.79003E-03	0.00000E+00	0.00000E+00
10	3.87236E-01	3.09583E+00	3.95384E-01	5.14765E-03	0.00000E+00	0.00000E+00
11	3.99307E-01	3.40250E+00	3.95820E-01	4.56068E-03	0.00000E+00	0.00000E+00
12	4.03168E-01	3.71283E+00	3.96555E-01	4.14485E-03	0.00000E+00	0.00000E+00
13	3.95329E-01	4.01133E+00	3.96443E-01	3.75081E-03	0.00000E+00	0.00000E+00
14	3.99014E-01	4.30800E+00	3.96657E-01	3.43071E-03	0.00000E+00	0.00000E+00
15	3.82535E-01	4.60733E+00	3.95571E-01	3.33754E-03	0.00000E+00	0.00000E+00
16	4.21574E-01	4.90933E+00	3.97428E-01	3.60522E-03	0.00000E+00	0.00000E+00
17	3.84784E-01	5.20867E+00	3.96585E-01	3.46051E-03	0.00000E+00	0.00000E+00
18	3.91699E-01	5.49983E+00	3.96280E-01	3.25139E-03	0.00000E+00	0.00000E+00
19	3.92056E-01	5.79733E+00	3.96032E-01	3.06424E-03	0.00000E+00	0.00000E+00
20	4.04790E-01	6.09567E+00	3.96518E-01	2.92969E-03	0.00000E+00	0.00000E+00
21	3.96272E-01	6.39700E+00	3.96505E-01	2.77123E-03	0.00000E+00	0.00000E+00
22	3.96804E-01	6.70817E+00	3.96520E-01	2.62907E-03	0.00000E+00	0.00000E+00
23	4.00698E-01	7.00933E+00	3.96719E-01	2.50864E-03	0.00000E+00	0.00000E+00
195	3.84032E-01	5.89588E+01	3.96453E-01	6.86523E-04	0.00000E+00	0.00000E+00
196	3.87751E-01	5.92627E+01	3.96408E-01	6.84446E-04	0.00000E+00	0.00000E+00
197	3.88469E-01	5.95547E+01	3.96368E-01	6.82144E-04	0.00000E+00	0.00000E+00
198	3.96927E-01	5.98623E+01	3.96370E-01	6.78660E-04	0.00000E+00	0.00000E+00
199	3.97955E-01	6.01543E+01	3.96378E-01	6.75254E-04	0.00000E+00	0.00000E+00
200	3.93562E-01	6.04537E+01	3.96364E-01	6.71986E-04	0.00000E+00	0.00000E+00
201	3.97456E-01	6.07585E+01	3.96370E-01	6.68623E-04	0.00000E+00	0.00000E+00
202	3.90767E-01	6.10570E+01	3.96342E-01	6.65861E-04	0.00000E+00	0.00000E+00
203	3.89955E-01	6.13600E+01	3.96310E-01	6.63302E-04	0.00000E+00	0.00000E+00

KENO MESSAGE NUMBER K5-123

EXECUTION TERMINATED DUE TO COMPLETION OF THE SPECIFIED NUMBER OF GENERATIONS.

Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)

UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH

LIFETIME = 1.88203E-05 + OR - 3.58429E-07      GENERATION TIME = 1.70782E-06 + OR - 1.09764E-08  
 NU BAR = 2.55492E+00 + OR - 4.43799E-04      AVERAGE FISSION GROUP = 6.62068E+00 + OR - 6.12800E-03  
 ENERGY (EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 8.29856E+04 + OR - 5.54268E+02

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.39633	+ OR - 0.00067	0.39566 TO 0.39699	0.39499 TO 0.39766	0.39433 TO 0.39833	200000
4	0.39639	+ OR - 0.00067	0.39572 TO 0.39706	0.39506 TO 0.39772	0.39439 TO 0.39839	199000
5	0.39633	+ OR - 0.00067	0.39566 TO 0.39699	0.39499 TO 0.39766	0.39433 TO 0.39833	198000
6	0.39628	+ OR - 0.00067	0.39561 TO 0.39695	0.39494 TO 0.39762	0.39428 TO 0.39829	197000
7	0.39617	+ OR - 0.00066	0.39550 TO 0.39683	0.39484 TO 0.39749	0.39418 TO 0.39815	196000
8	0.39628	+ OR - 0.00066	0.39562 TO 0.39693	0.39496 TO 0.39759	0.39431 TO 0.39825	195000
9	0.39630	+ OR - 0.00066	0.39564 TO 0.39696	0.39498 TO 0.39762	0.39432 TO 0.39828	194000
10	0.39635	+ OR - 0.00066	0.39569 TO 0.39701	0.39503 TO 0.39767	0.39437 TO 0.39833	193000
11	0.39633	+ OR - 0.00066	0.39567 TO 0.39700	0.39500 TO 0.39766	0.39434 TO 0.39833	192000
12	0.39630	+ OR - 0.00067	0.39563 TO 0.39696	0.39496 TO 0.39763	0.39430 TO 0.39830	191000
17	0.39629	+ OR - 0.00066	0.39562 TO 0.39695	0.39496 TO 0.39762	0.39430 TO 0.39828	186000
22	0.39629	+ OR - 0.00068	0.39561 TO 0.39697	0.39493 TO 0.39765	0.39425 TO 0.39833	181000
27	0.39635	+ OR - 0.00069	0.39566 TO 0.39704	0.39497 TO 0.39773	0.39427 TO 0.39842	176000
32	0.39638	+ OR - 0.00070	0.39568 TO 0.39708	0.39498 TO 0.39777	0.39428 TO 0.39847	171000
37	0.39633	+ OR - 0.00072	0.39561 TO 0.39704	0.39490 TO 0.39776	0.39418 TO 0.39847	166000
42	0.39622	+ OR - 0.00073	0.39548 TO 0.39695	0.39475 TO 0.39768	0.39402 TO 0.39841	161000
47	0.39634	+ OR - 0.00073	0.39561 TO 0.39706	0.39489 TO 0.39779	0.39416 TO 0.39852	156000
52	0.39625	+ OR - 0.00074	0.39551 TO 0.39699	0.39477 TO 0.39773	0.39403 TO 0.39847	151000
57	0.39614	+ OR - 0.00076	0.39538 TO 0.39690	0.39462 TO 0.39766	0.39386 TO 0.39842	146000
62	0.39589	+ OR - 0.00077	0.39512 TO 0.39666	0.39435 TO 0.39743	0.39357 TO 0.39820	141000
67	0.39604	+ OR - 0.00079	0.39525 TO 0.39684	0.39446 TO 0.39763	0.39366 TO 0.39842	136000
72	0.39634	+ OR - 0.00080	0.39554 TO 0.39713	0.39474 TO 0.39793	0.39395 TO 0.39872	131000
.						
.						
.						
167	0.39464	+ OR - 0.00127	0.39337 TO 0.39591	0.39210 TO 0.39717	0.39083 TO 0.39844	36000
172	0.39476	+ OR - 0.00136	0.39339 TO 0.39612	0.39203 TO 0.39749	0.39067 TO 0.39885	31000
177	0.39567	+ OR - 0.00151	0.39416 TO 0.39719	0.39265 TO 0.39870	0.39114 TO 0.40021	26000
182	0.39496	+ OR - 0.00167	0.39329 TO 0.39663	0.39162 TO 0.39830	0.38995 TO 0.39997	21000
187	0.39369	+ OR - 0.00195	0.39174 TO 0.39563	0.38980 TO 0.39758	0.38785 TO 0.39952	16000
192	0.39183	+ OR - 0.00133	0.39050 TO 0.39315	0.38918 TO 0.39448	0.38785 TO 0.39580	11000
197	0.39444	+ OR - 0.00144	0.39300 TO 0.39587	0.39156 TO 0.39731	0.39012 TO 0.39875	6000



**Figure 6.6.2-1 CSAS Input & Output for Normal Conditions Criticality Analysis: PWR Fuel (continued)**

UMS PWR TC; NORMAL OP; ARRAY; 0.0001 GM/CC IN - 0.1 GM/CC EX; 270CM PITCH

FREQUENCY FOR GENERATIONS 4 TO 203  
\*\*\*\*\*  
0.3714 TO 0.3840 \*\*\*\*\*  
0.3840 TO 0.3967 \*\*\*\*\*  
0.3967 TO 0.4093 \*\*\*\*\*  
0.4093 TO 0.4220 \*\*\*\*\*  
0.4220 TO 0.4346 \*

FREQUENCY FOR GENERATIONS 54 TO 203  
\*\*\*\*\*  
0.3714 TO 0.3840 \*\*\*\*\*  
0.3840 TO 0.3967 \*\*\*\*\*  
0.3967 TO 0.4093 \*\*\*\*\*  
0.4093 TO 0.4220 \*\*\*\*\*  
0.4220 TO 0.4346 \*

FREQUENCY FOR GENERATIONS 104 TO 203  
\*\*\*\*\*  
0.3714 TO 0.3840 \*\*\*\*\*  
0.3840 TO 0.3967 \*\*\*\*\*  
0.3967 TO 0.4093 \*\*\*\*\*  
0.4093 TO 0.4220 \*\*\*\*\*  
0.4220 TO 0.4346 \*

FREQUENCY FOR GENERATIONS 154 TO 203  
\*\*\*\*\*  
0.3714 TO 0.3840 \*\*\*\*\*  
0.3840 TO 0.3967 \*\*\*\*\*  
0.3967 TO 0.4093 \*\*\*\*\*  
0.4093 TO 0.4220 \*\*\*\*\*  
0.4220 TO 0.4346 \*\*\*\*\*

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel

```
PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25 WILL BE CALLED
UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PICH
27GROUPNDF4 LATTICECELL
UO2 1 0.95 293.0 92235 4.20 92238 95.80 END
ZIRCALLOY 2 1.0 293.0 END
H2O 3 1.0 293.0 END
AL 4 1.0 293.0 END
SS304 5 1.0 293.0 END
AL 6 DEN=2.6041 0.4635 293.0 END
B-10 6 DEN=2.6041 0.0567 293.0 END
B-11 6 DEN=2.6041 0.3444 293.0 END
C 6 DEN=2.6041 0.1165 293.0 END
PB 7 1.0 293.0 END
B-10 8 0.0 8.553-5 293.0 END
B-11 8 0.0 3.422-4 293.0 END
AL 8 0.0 7.763-3 293.0 END
H 8 0.0 5.854-2 293.0 END
O 8 0.0 2.609-2 293.0 END
C 8 0.0 2.264-2 293.0 END
N 8 0.0 1.394-3 293.0 END
H2O 9 1.0 293.0 END
H2O 10 1.0 293.0 END
END COMP
SQUAREPITCH 1.2598 0.7844 1 3 0.9144 2 0.8001 10 END
UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH
READ PARAM RUN=YES PLT=NO TME=5000 GEN=803 NPG=1000 END PARAM
READ GEOM
UNIT 1
COM='FUEL PIN CELL - BETWEEN DISKS'
CYLINDER 1 1 0.3922 2P2.4892
CYLINDER 10 1 0.4001 2P2.4892
CYLINDER 2 1 0.4572 2P2.4892
CUBOID 3 1 4P0.6299 2P2.4892
UNIT 2
COM='WATER ROD CELL - BETWEEN DISKS'
CYLINDER 3 1 0.5715 2P2.4892
CYLINDER 2 1 0.6121 2P2.4892
CUBOID 3 1 4P0.6299 2P2.4892
UNIT 3
COM='FUEL PIN CELL - FOR DISK SLICE OF CASK'
CYLINDER 1 1 0.3922 2P0.6350
CYLINDER 10 1 0.4001 2P0.6350
CYLINDER 2 1 0.4572 2P0.6350
CUBOID 3 1 4P0.6299 2P0.6350
UNIT 4
COM='WATER ROD CELL - FOR DISK SLICE OF CASK'
CYLINDER 3 1 0.5715 2P0.6350
CYLINDER 2 1 0.6121 2P0.6350
CUBOID 3 1 4P0.6299 2P0.6350
UNIT 5
COM='X-X BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P2.4892
CUBOID 4 1 2P10.4140 2P0.0951 2P2.4892
UNIT 6
COM='Y-Y BORAL SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P2.4892
CUBOID 4 1 2P0.0951 2P10.4140 2P2.4892
UNIT 7
COM='X-X BORAL SHEET WITH DISKS'
CUBOID 6 1 2P10.4140 2P0.0635 2P0.6350
CUBOID 4 1 2P10.4140 2P0.0951 2P0.6350
UNIT 8
COM='Y-Y BORAL SHEET WITH DISKS'
CUBOID 6 1 2P0.0635 2P10.4140 2P0.6350
CUBOID 4 1 2P0.0951 2P10.4140 2P0.6350
UNIT 10
COM='TUBE CELL IN H2O BETWEEN DISKS (A)'
ARRAY 1 -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE 5 0.0 +11.4308 0.0
HOLE 5 0.0 -11.4308 0.0
HOLE 6 +11.4308 0.0 0.0
HOLE 6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P2.4892
```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```
UNIT 11
COM='TUBE CELL IN H2O BETWEEN DISKS (B)'
ARRAY 1 -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE 5 0.0 +11.4308 0.0
HOLE 5 0.0 -11.4308 0.0
HOLE 6 +11.4308 0.0 0.0
HOLE 6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P2.4892
UNIT 12
COM='TUBE CELL IN H2O BETWEEN DISKS (C)'
ARRAY 1 -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE 5 0.0 +11.4308 0.0
HOLE 5 0.0 -11.4308 0.0
HOLE 6 +11.4308 0.0 0.0
HOLE 6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P2.4892
UNIT 13
COM='TUBE CELL IN H2O BETWEEN DISKS (D)'
ARRAY 1 -10.7083 -10.7083 -2.4892
CUBOID 3 1 4P11.2141 2P2.4892
CUBOID 5 1 4P11.3355 2P2.4892
CUBOID 3 1 4P11.5260 2P2.4892
HOLE 5 0.0 +11.4308 0.0
HOLE 5 0.0 -11.4308 0.0
HOLE 6 +11.4308 0.0 0.0
HOLE 6 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P2.4892
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P2.4892
UNIT 14
COM='WEB UNIT (1.5" WEB) - BETWEEN DISKS'
CUBOID 3 1 2P11.7946 2P1.8725 2P2.4892
UNIT 15
COM='WEB UNIT (1.0" WEB) - BETWEEN DISKS'
CUBOID 3 1 2P11.7946 2P1.2510 2P2.4892
UNIT 16
COM='WEB UNIT (0.875" WEB) - BETWEEN DISKS'
CUBOID 3 1 2P11.7946 2P1.0923 2P2.4892
UNIT 17
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (-X)'
ARRAY 10 -11.7946 -77.3262 -2.4892
UNIT 18
COM='6X1 FUEL TUBE STACK BETWEEN DISKS (+X)'
ARRAY 11 -11.7946 -77.3262 -2.4892
UNIT 19
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (-X)'
ARRAY 12 -11.7946 -25.4616 -2.4892
UNIT 20
COM='2X1 FUEL TUBE STACK OF TUBES BETWEEN DISKS (+X)'
ARRAY 13 -11.7946 -25.4616 -2.4892
UNIT 30
COM='TUBE CELL IN ST DISK (A)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 31
COM='TUBE CELL IN ST DISK (B)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 32
COM='TUBE CELL IN ST DISK (C)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 33
COM='TUBE CELL IN ST DISK (D)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 34
COM='WEB UNIT (1.5" WEB) - ST DISKS'
CUBOID 5 1 2P11.7946 2P1.8725 2P0.6350
UNIT 35
COM='WEB UNIT (1.0" WEB) - ST DISKS'
CUBOID 5 1 2P11.7946 2P1.2510 2P0.6350
UNIT 36
COM='WEB UNIT (0.875" WEB) - ST DISKS'
CUBOID 5 1 2P11.7946 2P1.0923 2P0.6350
UNIT 37
COM='6x1 FUEL TUBE STACK ST DISK (-X)'
ARRAY 20 -11.7946 -77.3262 -0.6350
UNIT 38
COM='6x1 FUEL TUBE STACK ST DISK (+X)'
ARRAY 21 -11.7946 -77.3262 -0.6350
UNIT 39
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (-X)'
ARRAY 22 -11.7946 -25.4616 -0.6350
UNIT 40
COM='2X1 FUEL TUB STACK OF TUBES ST DISK (+X)'
ARRAY 23 -11.7946 -25.4616 -0.6350
UNIT 50
COM='TUBE CELL IN AL DISK (A)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +12.0176 -11.5715 2P0.6350
UNIT 51
COM='TUBE CELL IN AL DISK (B)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +12.0176 -11.5715 2P0.6350
UNIT 52
COM='TUBE CELL IN AL DISK (C)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +11.5715 -12.0176 +11.5715 -12.0176 2P0.6350
UNIT 53
COM='TUBE CELL IN AL DISK (D)'
ARRAY 2 -10.7083 -10.7083 -0.6350
CUBOID 3 1 4P11.2141 2P0.6350
CUBOID 5 1 4P11.3355 2P0.6350
CUBOID 3 1 4P11.5260 2P0.6350
HOLE 7 0.0 +11.4308 0.0
HOLE 7 0.0 -11.4308 0.0
```

**Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)**

```
HOLE 8 +11.4308 0.0 0.0
HOLE 8 -11.4308 0.0 0.0
CUBOID 5 1 4P11.5715 2P0.6350
CUBOID 3 1 +12.0176 -11.5715 +11.5715 -12.0176 2P0.6350
UNIT 54
COM='WEB UNIT (1.5" WEB) - AL DISKS'
CUBOID 4 1 2P11.7946 2P1.8725 2P0.6350
UNIT 55
COM='WEB UNIT (1.0" WEB) - AL DISKS'
CUBOID 4 1 2P11.7946 2P1.2510 2P0.6350
UNIT 56
COM='WEB UNIT (0.875" WEB) - AL DISKS'
CUBOID 4 1 2P11.7946 2P1.0923 2P0.6350
UNIT 57
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 30 -11.7946 -77.3262 -0.6350
UNIT 58
COM='6X1 FUEL TUBE STACK AL DISK'
ARRAY 31 -11.7946 -77.3262 -0.6350
UNIT 59
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 32 -11.7946 -25.4616 -0.6350
UNIT 60
COM='2X1 FUEL TUBE STACK OF TUBES AL DISK'
ARRAY 33 -11.7946 -25.4616 -0.6350
UNIT 70
COM='BASKET STRUCTURE IN TRANSPORT CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P2.4892
HOLE 17 -13.6669 0.0 0.0
HOLE 18 +13.6669 0.0 0.0
HOLE 19 -39.7578 0.0 0.0
HOLE 20 +39.7578 0.0 0.0
HOLE 19 -65.5312 0.0 0.0
HOLE 20 +65.5312 0.0 0.0
HOLE 10 +40.8048 +40.8048 0.0
HOLE 11 -40.8048 +40.8048 0.0
HOLE 12 -40.8048 -40.8048 0.0
HOLE 13 +40.8048 -40.8048 0.0
CYLINDER 5 1 +85.1662 2P2.4892
CYLINDER 9 1 +85.8647 2P2.4892
CYLINDER 5 1 +90.9447 2P2.4892
CYLINDER 7 1 +97.9297 2P2.4892
CYLINDER 5 1 +104.9147 2P2.4892
CYLINDER 9 1 +116.3604 2P2.4892
CYLINDER 9 1 +116.6788 2P2.4892
CYLINDER 5 1 +117.3156 2P2.4892
CUBOID 9 1 4P135.0 2P2.4892
UNIT 71
COM='BASKET STRUCTURE IN TRANSPORT CASK - ST DISK'
CYLINDER 5 1 +83.1850 2P0.6350
HOLE 37 -13.6669 0.0 0.0
HOLE 38 +13.6669 0.0 0.0
HOLE 39 -39.7578 0.0 0.0
HOLE 40 +39.7578 0.0 0.0
HOLE 39 -65.5312 0.0 0.0
HOLE 40 +65.5312 0.0 0.0
HOLE 30 +40.8048 +40.8048 0.0
HOLE 31 -40.8048 +40.8048 0.0
HOLE 32 -40.8048 -40.8048 0.0
HOLE 33 +40.8048 -40.8048 0.0
CYLINDER 3 1 +83.5787 2P0.6350
CYLINDER 5 1 +85.1662 2P0.6350
CYLINDER 9 1 +85.8647 2P0.6350
CYLINDER 5 1 +90.9447 2P0.6350
CYLINDER 7 1 +97.9297 2P0.6350
CYLINDER 5 1 +104.9147 2P0.6350
CYLINDER 9 1 +116.3604 2P0.6350
CYLINDER 9 1 +116.6788 2P0.6350
CYLINDER 5 1 +117.3156 2P0.6350
CUBOID 9 1 4P135.0 2P0.6350
UNIT 72
COM='BASKET STRUCTURE IN TRANSPORT CASK - AL DISK'
CYLINDER 4 1 +82.8675 2P0.6350
HOLE 57 -13.6669 0.0 0.0
HOLE 58 +13.6669 0.0 0.0
HOLE 59 -39.7578 0.0 0.0
HOLE 60 +39.7578 0.0 0.0
HOLE 59 -65.5312 0.0 0.0
HOLE 60 +65.5312 0.0 0.0
HOLE 50 +40.8048 +40.8048 0.0
HOLE 51 -40.8048 +40.8048 0.0
HOLE 52 -40.8048 -40.8048 0.0
HOLE 53 +40.8048 -40.8048 0.0
CYLINDER 3 1 +83.5787 2P0.6350
CYLINDER 5 1 +85.1662 2P0.6350
```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```
CYLINDER 9 1 +85.8647 2P0.6350
CYLINDER 5 1 +90.9447 2P0.6350
CYLINDER 7 1 +97.9297 2P0.6350
CYLINDER 5 1 +104.9147 2P0.6350
CYLINDER 9 1 +116.3604 2P0.6350
CYLINDER 9 1 +116.6788 2P0.6350
CYLINDER 5 1 +117.3156 2P0.6350
CUBOID 9 1 4P135.0 2P0.6350
GLOBAL UNIT 73
COM='DISK SLICE STACK'
ARRAY 40 -135.0 -135.0 0.0
END GEOM
READ ARRAY
ARA=1 NUX=17 NUY=17 NUZ=1 FILL
      34R1
      5R1 2 2R1 2 2R1 2 5R1
      3R1 2 9R1 2 3R1
      17R1
2R1 2 2R1 2 2R1 2 2R1 2 2R1
      34R1
2R1 2 2R1 2 2R1 2 2R1 2 2R1
      34R1
2R1 2 2R1 2 2R1 2 2R1 2 2R1
      17R1
      3R1 2 9R1 2 3R1
      5R1 2 2R1 2 2R1 2 5R1
      34R1
END FILL
ARA=2 NUX=17 NUY=17 NUZ=1 FILL
      34R3
      5R3 4 2R3 4 2R3 4 5R3
      3R3 4 9R3 4 3R3
      17R3
2R3 4 2R3 4 2R3 4 2R3 4 2R3
      34R3
2R3 4 2R3 4 2R3 4 2R3 4 2R3
      34R3
2R3 4 2R3 4 2R3 4 2R3 4 2R3
      17R3
      3R3 4 9R3 4 3R3
      5R3 4 2R3 4 2R3 4 5R3
      34R3
END FILL
ARA=10 NUX=1 NUY=11 NUZ=1 FILL 12 16 12 15 12 14 11 15 11 16 11 END FILL
ARA=11 NUX=1 NUY=11 NUZ=1 FILL 13 16 13 15 13 14 10 15 10 16 10 END FILL
ARA=12 NUX=1 NUY=3 NUZ=1 FILL 12 14 11 END FILL
ARA=13 NUX=1 NUY=3 NUZ=1 FILL 13 14 10 END FILL
ARA=20 NUX=1 NUY=11 NUZ=1 FILL 32 36 32 35 32 34 31 35 31 36 31 END FILL
ARA=21 NUX=1 NUY=11 NUZ=1 FILL 33 36 33 35 33 34 30 35 30 36 30 END FILL
ARA=22 NUX=1 NUY=3 NUZ=1 FILL 32 34 31 END FILL
ARA=23 NUX=1 NUY=3 NUZ=1 FILL 33 34 30 END FILL
ARA=30 NUX=1 NUY=11 NUZ=1 FILL 52 56 52 55 52 54 51 55 51 56 51 END FILL
ARA=31 NUX=1 NUY=11 NUZ=1 FILL 53 56 53 55 53 54 50 55 50 56 50 END FILL
ARA=32 NUX=1 NUY=3 NUZ=1 FILL 52 54 51 END FILL
ARA=33 NUX=1 NUY=3 NUZ=1 FILL 53 54 50 END FILL
ARA=40 NUX=1 NUY=1 NUZ=4 FILL 70 71 70 72 END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=MIRROR END BOUNDS
END DATA

SECONDARY MODULE 000008 HAS BEEN CALLED.

MODULE 000008 IS FINISHED. COMPLETION CODE 0. CPU TIME USED 1.65 (SECONDS).

SECONDARY MODULE 000002 HAS BEEN CALLED.

MODULE 000002 IS FINISHED. COMPLETION CODE 0. CPU TIME USED 15.43 (SECONDS).

SECONDARY MODULE 000009 HAS BEEN CALLED.

MODULE 000009 IS FINISHED. COMPLETION CODE 0. CPU TIME USED 2047.19 (SECONDS).

MODULE CSAS25 IS FINISHED. COMPLETION CODE 0. CPU TIME USED 2066.19 (SECONDS).
```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```

CCCCCCCCCCCC SSSSSSSSSS AAAAAAAAAA SSSSSSSSSS 2222222222 555555555555
CCCCCCCCCCCC SSSSSSSSSSSS AAAAAAAAAAAA SSSSSSSSSSSS 222222222222 555555555555
CC          CC SS          SS AA          AA SS          SS 22          22 55
CC          SS AA          AA SS          SS 22          22 55
CC          SS AA          AA SS          SS 22          22 55
CC          SSSSSSSSSS AAAAAAAAAAAA SSSSSSSSSS 22          22 555555555555
CC          SSSSSSSSSS AAAAAAAAAAAA SSSSSSSSSS 22          22 555555555555
CC          SS AA          AA SS          SS 22          22 55
CC          SS AA          AA SS          SS 22          22 55
CC          CC SS          SS AA          AA SS          SS 22          55 55
CCCCCCCCCCCC SSSSSSSSSS AA          AA SSSSSSSSSS 222222222222 555555555555
CCCCCCCCCCCC SSSSSSSSSS AA          AA SSSSSSSSSS 222222222222 555555555555

SSSSSSSSSSS CCCCCCCCCC AAAAAAAAAA LL          EEEEEEEEEEE PPPPPPPPPPP CCCCCCCCCC
SSSSSSSSSSS CCCCCCCCCC AAAAAAAAAAAA LL          EEEEEEEEEEE PPPPPPPPPPP CCCCCCCCCC
SS          SS CC          CC AA          AA LL          EE          EE PP          PF CC          CC
SS          CC AA          AA LL          EE          EE PP          PF CC          CC
SS          CC AA          AA LL          EE          EE PP          PF CC          CC
SSSSSSSSSSS CC          AAAAAAAAAAAA LL          EEEEEEEEEEE ----- PPPPPPPPPPP CC
SSSSSSSSSSS CC          AAAAAAAAAAAA LL          EEEEEEEEEEE ----- PPPPPPPPPPP CC
SS          SS CC          AA          AA LL          EE          EE PP          CC
SS          SS CC          AA          AA LL          EE          EE PP          CC
SS          SS CC          AA          AA LL          EE          EE PP          CC          CC
SSSSSSSSSSS CCCCCCCCCC AA          AA LLLLLLLLLLLL EEEEEEEEEEE PP          CCCCCCCCCC
SSSSSSSSSSS CCCCCCCCCC AA          AA LLLLLLLLLLLL EEEEEEEEEEE PP          CCCCCCCCCC

0000000 8888888888 // 2222222222 2222222222 // 9999999999 66666666666
00000000 888888888888 // 222222222222 222222222222 // 999999999999 666666666666
00          00 88          88 // 22          22 22          22 // 99          99 66
00          00 88          88 // 22          22 22          22 // 99          99 66
00          00 88          88 // 22          22 22          22 // 99          99 66
00          00 8888888888 // 22          22 22          22 // 999999999999 666666666666
00          00 8888888888 // 22          22 22          22 // 999999999999 666666666666
00          00 88          88 // 22          22 22          22 // 99          99 66
00          00 88          88 // 22          22 22          22 // 99          99 66
00          00 88          88 // 22          22 22          22 // 99          99 66
00          00 88          88 // 22          22 22          22 // 99          99 66
00000000 888888888888 // 222222222222 222222222222 // 999999999999 666666666666
0000000 8888888888 // 222222222222 222222222222 // 999999999999 666666666666

11          11 0000000 0000000 11          0000000
111         111 000000000 000000000 111         000000000
1111        1111 ::: 00          00 00          00 ::: 1111        00          00
11          11 ::: 00          00 00          00 ::: 11          00          00
11          11 ::: 00          00 00          00 ::: 11          00          00
11          11 00          00 00          00 00          00 11          00          00
11          11 00          00 00          00 00          00 11          00          00
11          11 00          00 00          00 00          00 11          00          00
11          11 00          00 00          00 00          00 11          00          00
11          11 00          00 00          00 00          00 11          00          00
11111111 11111111 00000000 00000000 11111111 00000000
11111111 11111111 0000000 0000000 11111111 0000000

```

SSSSSSSSSS	CCCCCCCCCC	AAAAAAAA	LL	EEEEEEEEEEEE		PPPPPPPPPP	CCCCCCCCCC			
SSSSSSSSSSSS	CCCCCCCCCCCC	AAAAAAAAAA	LL	EEEEEEEEEEEE		PPPPPPPPPPPP	CCCCCCCCCCCC			
SS	SS	CC	AA	AA	LL	EE	PP	PP	CC	CC
SS		CC	AA	AA	LL	EE		PP	PP	CC
SS		CC	AA	AA	LL	EE		PP	PP	CC
SSSSSSSSSSS	CC		AAAAAAAAAAAA	LL	EEEEEEEE	-----	PPPPPPPPPPPP		CC	
SSSSSSSSSSS	CC		AAAAAAAAAAAA	LL	EEEEEEEE	-----	PPPPPPPPPPPP		CC	
	SS	CC	AA	AA	LL	EE		PP		CC
	SS	CC	AA	AA	LL	EE		PP		CC
SS	SS	CC	AA	AA	LL	EE		PP		CC
SSSSSSSSSSSS	CCCCCCCCCCCC	AA	AA	LLLLLLLLLLLL	EEEEEEEEEEEE		PP		CCCCCCCCCCCC	
SSSSSSSSSSS	CCCCCCCCCCCC	AA	AA	LLLLLLLLLLLL	EEEEEEEEEEEE		PP		CCCCCCCCCCCC	

```
*****  
*****  
***** PROGRAM VERIFICATION INFORMATION *****  
*****  
***** CODE SYSTEM: SCALE-PC VERSION: 4.3 *****  
*****  
*****  
*****  
***** PROGRAM: CSAS *****  
*****  
***** CREATION DATE: 03-08-96 *****  
*****  
***** VOLUME: ENG *****  
*****  
***** LIBRARY: G:\scale43\exe *****  
*****  
*****  
***** PRODUCTION CODE: CSAS *****  
*****  
***** VERSION: 3.1 *****  
*****  
***** JOBNAME: SCALE-PC *****  
*****  
***** DATE OF EXECUTION: 08/22/96 *****  
*****  
***** TIME OF EXECUTION: 11:00:10 *****  
*****
```



**Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)**

UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PICH

\*\*\*\* PROBLEM PARAMETERS \*\*\*\*

LIB 27GROUPNDF4 LIBRARY  
MXK 10 MIXTURES  
MSC 19 COMPOSITION SPECIFICATIONS  
IZM 4 MATERIAL ZONES  
GE LATTICECELL GEOMETRY  
MORE 0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA  
MSLN 0 FUEL SOLUTIONS

\*\*\*\* PROBLEM COMPOSITION DESCRIPTION \*\*\*\*

SC UO2 STANDARD COMPOSITION  
MX 1 MIXTURE NO.  
VF 0.9500 VOLUME FRACTION  
ROTH 10.9600 THEORETICAL DENSITY  
NEL 2 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
92000 1.00 ATOM/MOLECULE  
92235 4.200 WT%  
92238 95.800 WT%  
8016 2.00 ATOMS/MOLECULE

END

SC ZIRCALLOY STANDARD COMPOSITION  
MX 2 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 6.5600 THEORETICAL DENSITY  
NEL 1 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
40302 1.00 ATOM/MOLECULE

END

SC H2O STANDARD COMPOSITION  
MX 3 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 0.9982 THEORETICAL DENSITY  
NEL 2 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
1001 2.00 ATOMS/MOLECULE  
8016 1.00 ATOM/MOLECULE

END

SC AL STANDARD COMPOSITION  
MX 4 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 2.7020 THEORETICAL DENSITY  
NEL 1 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
13027 1.00 ATOM/MOLECULE

END

SC SS304 STANDARD COMPOSITION  
MX 5 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 7.9200 THEORETICAL DENSITY  
NEL 4 NO. ELEMENTS  
ICP 0 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
24304 19.000 WT%  
25055 2.000 WT%  
26304 69.500 WT%  
28304 9.500 WT%

END

SC AL STANDARD COMPOSITION  
MX 6 MIXTURE NO.  
VF 0.4635 VOLUME FRACTION  
ROTH 2.6041 SPECIFIED DENSITY  
NEL 1 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
13027 1.00 ATOM/MOLECULE

END

SC B-10 STANDARD COMPOSITION  
MX 6 MIXTURE NO.

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```
VF      0.0567 VOLUME FRACTION
ROTH    2.6041 SPECIFIED DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        5010      1.00 ATOM/MOLECULE
END
```

```
SC B-11      STANDARD COMPOSITION
MX           6 MIXTURE NO.
VF      0.3444 VOLUME FRACTION
ROTH    2.6041 SPECIFIED DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        5011      1.00 ATOM/MOLECULE
END
```

```
SC C         STANDARD COMPOSITION
MX           6 MIXTURE NO.
VF      0.1165 VOLUME FRACTION
ROTH    2.6041 SPECIFIED DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        6012      1.00 ATOM/MOLECULE
END
```

```
SC PB        STANDARD COMPOSITION
MX           7 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH    11.3440 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        82000     1.00 ATOM/MOLECULE
END
```

```
SC B-10      STANDARD COMPOSITION
MX           8 MIXTURE NO.
DEN     8.5530E-05 ATOMIC DENSITY
ROTH    1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        5010      1.00 ATOM/MOLECULE
END
```

```
SC B-11      STANDARD COMPOSITION
MX           8 MIXTURE NO.
DEN     3.4220E-04 ATOMIC DENSITY
ROTH    1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        5011      1.00 ATOM/MOLECULE
END
```

```
SC AL        STANDARD COMPOSITION
MX           8 MIXTURE NO.
DEN     7.7630E-03 ATOMIC DENSITY
ROTH    2.7020 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        13027     1.00 ATOM/MOLECULE
END
```

```
SC H         STANDARD COMPOSITION
MX           8 MIXTURE NO.
DEN     5.8540E-02 ATOMIC DENSITY
ROTH    1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        1001      1.00 ATOM/MOLECULE
END
```

```
SC O         STANDARD COMPOSITION
MX           8 MIXTURE NO.
DEN     2.6090E-02 ATOMIC DENSITY
ROTH    1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

8016 1.00 ATOM/MOLECULE  
END

SC C STANDARD COMPOSITION  
MX 8 MIXTURE NO.  
DEN 2.2640E-02 ATOMIC DENSITY  
ROTH 2.1000 THEORETICAL DENSITY  
NEL 1 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
6012 1.00 ATOM/MOLECULE  
END

SC N STANDARD COMPOSITION  
MX 8 MIXTURE NO.  
DEN 1.3940E-03 ATOMIC DENSITY  
ROTH 1.0000 THEORETICAL DENSITY  
NEL 1 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
7014 1.00 ATOM/MOLECULE  
END

SC H2O STANDARD COMPOSITION  
MX 9 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 0.9982 THEORETICAL DENSITY  
NEL 2 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
1001 2.00 ATOMS/MOLECULE  
8016 1.00 ATOM/MOLECULE  
END

SC H2O STANDARD COMPOSITION  
MX 10 MIXTURE NO.  
VF 1.0000 VOLUME FRACTION  
ROTH 0.9982 THEORETICAL DENSITY  
NEL 2 NO. ELEMENTS  
ICP 1 0/1 MIXTURE/COMPOUND  
TEMP 293.0 DEG KELVIN  
1001 2.00 ATOMS/MOLECULE  
8016 1.00 ATOM/MOLECULE  
END

\*\*\*\* PROBLEM GEOMETRY \*\*\*\*

CTP SQUAREPITCH CELL TYPE  
PITCH 1.2598 CM CENTER TO CENTER SPACING  
FUELOD 0.7844 CM FUEL DIAMETER OR SLAB THICKNESS  
MFUEL 1 MIXTURE NO. OF FUEL  
MMOD 3 MIXTURE NO. OF MODERATOR  
CLADOD 0.9144 CM CLAD OUTER DIAMETER  
MCLAD 2 MIXTURE NO. OF CLAD  
GAPOD 0.8001 CM GAP OUTER DIAMETER  
MGAP 10 MIXTURE NO. OF GAP

ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY

ZONE 1 IS FUEL  
ZONE 2 IS GAP  
ZONE 3 IS CLAD  
ZONE 4 IS MOD

[illegible]

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```

KK      KK      EEEEEEEEEEE      NN      NN      0000000000      VV      VV
KK      KK      EEEEEEEEEEE      NNN      NN      0000000000000      VV      VV
KK      KK      EE      NNNN      NN      00      00      VV      VV
KK      KK      EE      NN      NN      NN      00      00      VV      VV
KK      KK      EE      NN      NN      NN      00      00      VV      VV
KKKKKKKK      EEEEEEEEE      NN      NN      NN      00      00      VV      VV
KKKKKKKK      EEEEEEEEE      NN      NN      NN      00      00      VV      VV
KK      KK      EE      NN      NN      NN      00      00      VV      VV
KK      KK      EE      NN      NN      NN      00      00      VV      VV
KK      KK      EE      NN      NNN      00      00      VV      VV
KK      KK      EEEEEEEEEEE      NN      NNN      0000000000000      VVV
KK      KK      EEEEEEEEEEE      NN      NN      00000000000      V

SSSSSSSSSS      CCCCCCCCCC      AAAAAAAAA      LL      EEEEEEEEEEE      PPPPPPPPPPP      CCCCCCCCCC
SSSSSSSSSSSS      CCCCCCCCCC      AAAAAAAAA      LL      EEEEEEEEEEE      PPPPPPPPPPPPP      CCCCCCCCCC
SS      SS      CC      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SS      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SS      CC      AA      AA      LL      EE      EE      PP      PP      CC      CC
SSSSSSSSSS      CC      AAAAAAAAA      LL      EEEEEEEEE      PFFFFFFFFFFFF      CC
SSSSSSSSSS      CC      AAAAAAAAA      LL      EEEEEEEEE      PFFFFFFFFFFFF      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SS      SS      CC      AA      AA      LL      EE      EE      PP      CC      CC
SSSSSSSSSSSS      CCCCCCCCCC      AA      AA      LLLLLLLLLLLL      EEEEEEEEEEE      PP      CCCCCCCCCC
SSSSSSSSSS      CCCCCCCCCC      AA      AA      LLLLLLLLLLLL      EEEEEEEEEEE      PP      CCCCCCCCCC

0000000      88888888888      //      2222222222      2222222222      //      9999999999      66666666666
000000000      8888888888888      //      22222222222      22222222222      //      9999999999999      6666666666666
00      00      88      88      //      22      22      22      22      //      99      99      66
00      00      88      88      //      22      22      22      22      //      99      99      66
00      00      88      88      //      22      22      22      22      //      99      99      66
00      00      88888888888      //      22      22      22      22      //      9999999999999      6666666666666
00      00      88888888888      //      22      22      22      22      //      9999999999999      6666666666666
00      00      88      88      //      22      22      22      22      //      99      99      66
00      00      88      88      //      22      22      22      22      //      99      99      66
00      00      88      88      //      22      22      22      22      //      99      99      66
00      00      8888888888888      //      22222222222      22222222222      //      9999999999999      6666666666666
000000000      8888888888888      //      22222222222      22222222222      //      9999999999999      6666666666666
0000000      8888888888888      //      22222222222      22222222222      //      9999999999999      6666666666666

11      11      0000000      0000000      2222222222      9999999999
111      111      0000000000      0000000000      2222222222222      9999999999999
1111      1111      :::      00      00      00      00      :::      22      22      99      99
11      11      :::      00      00      00      00      :::      22      22      99      99
11      11      :::      00      00      00      00      :::      22      22      99      99
11      11      :::      00      00      00      00      :::      22      22      99      99
11      11      :::      00      00      00      00      :::      22      22      99      99
11      11      :::      00      00      00      00      :::      22      22      99      99
11      11      :::      00      00      00      00      :::      22      22      99      99
11      11      :::      00      00      00      00      :::      22      22      99      99
11111111      11111111      000000000      000000000      2222222222222      9999999999999
11111111      11111111      00000000      00000000      2222222222222      9999999999999

```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```

SSSSSSSSSS  CCCCCCCCCC  AAAAAAAAAA  LL  EEEEEEEEEEEE  PFFFFFFFFPPP  CCCCCCCCCC
SSSSSSSSSS  CCCCCCCCCC  AAAAAAAAAA  LL  EEEEEEEEEEEE  PFFFFFFFFPPP  CCCCCCCCCC
SS      SS  CC      CC  AA      AA  LL  EE  EEEEEEEEEEEE  PP      PP  CC      CC
SS      CC  CC      CC  AA      AA  LL  EE  EEEEEEEEEEEE  PP      PP  CC      CC
SS      CC  CC      CC  AA      AA  LL  EE  EEEEEEEEEEEE  PP      PP  CC      CC
SSSSSSSSSS  CC  AAAAAAAAAA  LL  EEEEEEEEE  -----  PFFFFFFFFPPP  CC
SSSSSSSSSS  CC  AAAAAAAAAA  LL  EEEEEEEEE  -----  PFFFFFFFFPPP  CC
SS      SS  CC  AA      AA  LL  EE  EEEEEEEEE  PP      CC
SS      SS  CC  AA      AA  LL  EE  EEEEEEEEE  PP      CC
SS      SS  CC  AA      AA  LL  EE  EEEEEEEEE  PP      CC
SSSSSSSSSS  CCCCCCCCCC  AA      AA  LLLLLLLLLLLL  EEEEEEEEEEEE  PP      CC
SSSSSSSSSS  CCCCCCCCCC  AA      AA  LLLLLLLLLLLL  EEEEEEEEEEEE  PP      CCCCCCCCCC

```

```

*****
*****
*****  PROGRAM VERIFICATION INFORMATION  *****
*****  CODE SYSTEM:  SCALE-PC VERSION:  4.3  *****
*****
*****
*****  PROGRAM:  000009  *****
*****  CREATION DATE:  03-08-96  *****
*****  VOLUME:  ENG  *****
*****  LIBRARY:  G:\scale43\exe  *****
*****  PRODUCTION CODE:  KENOVA  *****
*****  VERSION:  3.1  *****
*****  JOBNAM:  SCALE-PC  *****
*****  DATE OF EXECUTION:  08/22/96  *****
*****  TIME OF EXECUTION:  11:00:29  *****
*****
*****
*****

```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis; PWR Fuel (continued)

```

***
***                                UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH
***
*****      NUMERIC PARAMETERS      *****
***
***      TME      MAXIMUM PROBLEM TIME (MIN)      *****
***
***      TBA      TIME PER GENERATION (MIN)      0.50
***
***      GEN      NUMBER OF GENERATIONS      803
***
***      NPG      NUMBER PER GENERATION      1000
***
***      NSK      NUMBER OF GENERATIONS TO BE SKIPPED      3
***
***      BEG      BEGINNING GENERATION NUMBER      1
***
***      RES      GENERATIONS BETWEEN CHECKPOINTS      0
***
***      X1D      NUMBER OF EXTRA 1-D CROSS SECTIONS      1
***
***      NBK      NEUTRON BANK SIZE      1025
***
***      XNB      EXTRA POSITIONS IN NEUTRON BANK      0
***
***      NFB      FISSION BANK SIZE      1000
***
***      XFB      EXTRA POSITIONS IN FISSION BANK      0
***
***      WTA      DEFAULT VALUE OF WEIGHT AVERAGE      0.5000
***
***      WTH      WEIGHT HIGH FOR SPLITTING      3.0000
***
***      WTL      WEIGHT LOW FOR RUSSIAN ROULETTE      0.3333
***
***      RND      STARTING RANDOM NUMBER      BB827100001
***
***      NBS      NUMBER OF D.A. BLOCKS ON UNIT 8      200
***
***      NLS      LENGTH OF D.A. BLOCKS ON UNIT 8      512
***
***      ADJ      MODE OF CALCULATION      FORWARD
***
***      INPUT DATA WRITTEN ON RESTART UNIT      NO
***
***      BINARY DATA INTERFACE      YES
***

```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```

.....
***
***                               UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH
***
.....
***                               ***** LOGICAL PARAMETERS *****
***
*** RUN  EXECUTE PROBLEM AFTER CHECKING DATA  YES          PLT  PLOT PICTURE MAP(S)                NO ***
***
*** FLX  COMPUTE FLUX                          NO          FDN  COMPUTE FISSION DENSITIES             NO ***
***
*** SMU  COMPUTE AVG UNIT SELF-MULTIPLICATION  NO          NUB  COMPUTE NU-BAR & AVG FISSION GROUP        YES ***
***
*** MKU  COMPUTE MATRIX K-EFF BY UNIT NUMBER   NO          MKP  COMPUTE MATRIX K-EFF BY UNIT LOCATION    NO ***
***
*** CKU  COMPUTE COFACTOR K-EFF BY UNIT NUMBER NO          CKP  COMPUTE COFACTOR K-EFF BY UNIT LOCATION    NO ***
***
*** FMU  PRINT FISS PROD MATRIX BY UNIT NUMBER NO          FMP  PRINT FISS PROD MATRIX BY UNIT LOCATION    NO ***
***
*** MKH  COMPUTE MATRIX K-EFF BY HOLE NUMBER   NO          MKA  COMPUTE MATRIX K-EFF BY ARRAY NUMBER      NO ***
***
*** CKH  COMPUTE COFACTOR K-EFF BY HOLE NUMBER NO          CKA  COMPUTE COFACTOR K-EFF BY ARRAY NUMBER      NO ***
***
*** FMH  PRINT FISS PROD MATRIX BY HOLE NUMBER NO          FMA  PRINT FISS PROD MATRIX BY ARRAY NUMBER      NO ***
***
*** HHL  COLLECT MATRIX BY HIGHEST HOLE LEVEL  NO          HAL  COLLECT MATRIX BY HIGHEST ARRAY LEVEL    NO ***
***
*** AMX  PRINT ALL MIXED CROSS SECTIONS        NO          FAR  PRINT FIS. AND ABS. BY REGION              NO ***
***
*** XS1  PRINT 1-D MIXTURE X-SECTIONS          NO          GAS  PRINT FAR BY GROUP                          NO ***
***
*** XS2  PRINT 2-D MIXTURE X-SECTIONS          NO          PAX  PRINT XSEC-ALBEDO CORRELATION TABLES      NO ***
***
*** XAP  PRINT MIXTURE ANGLES & PROBABILITIES  NO          PWT  PRINT WEIGHT AVERAGE ARRAY                NO ***
***
*** PKI  PRINT FISSION SPECTRUM                NO          PGM  PRINT INPUT GEOMETRY                      NO ***
***
*** P1D  PRINT EXTRA 1-D CROSS SECTIONS        NO          BUG  PRINT DEBUG INFORMATION                   NO ***
***
***                                     TRK  PRINT TRACKING INFORMATION                   NO ***
***
.....
***
***                               PARAMETER INPUT COMPLETED
***
.....
***                               0 IO'S WERE USED READING THE PARAMETER DATA
***
***** DATA READING COMPLETED *****

```



Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```

***
***                               UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH
***
*****
***
***      UNIT      VOLUME
***      NUMBER    NAME      UNIT FUNCTION
***      -----
***      XSC  14    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARAC-  MIXED CROSS SECTIONS
***      ALB  79    G:\scale43\DATA\LIB\FT79F001                INPUT ALBEDOS
***      WTS  80    G:\scale43\DATA\LIB\FT80F001                INPUT WEIGHTS
***      SKT  16    UNKNOWN                                     WRITE SCRATCH DATA
***      BIN  95    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARAC-  BINARY INPUT DATA
***      RST  95    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARAC-  READ RESTART DATA
***      LIB   4    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARAC-  INPUT AMPX WORKING LIBRARY
***      8        C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARAC-  INPUT DATA DIRECT ACCESS
***      9        UNKNOWN                                     SUPER GROUPED DIRECT ACCESS
***      10       UNKNOWN                                     XSEC MIXING DIRECT ACCESS
***
*****
***
***      0 IO'S WERE USED PREPARING INPUT DATA
***
***
***      CROSS SECTIONS READ FROM THE AMPX WORKING LIBRARY ON UNIT 4

```

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH									
MIXING TABLE									
NUMBER OF SCATTERING ANGLES = 2									
CROSS SECTION MESSAGE THRESHOLD =3.0E-05									
MIXTURE =	1	DENSITY(G/CC) = 10.412							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
1008016	4.64627E-02	1.18489E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED		
08/12/94									
1092235	9.87669E-04	3.70234E-02	92235	235.0441	URANIUM-235	ENDF/B-IV MAT 1261	UPDATED		
08/12/94									
1092238	2.22437E-02	8.44487E-01	92238	238.0510	URANIUM-238	ENDF/B-IV MAT 1262	UPDATED		
08/12/94									
MIXTURE =	2	DENSITY(G/CC) = 6.5600							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
2040302	4.33078E-02	1.00000E+00	40000	91.2196	ZIRCALLOY	ENDF/B-IV MAT 1284	UPDATED		
08/12/94									
MIXTURE =	3	DENSITY(G/CC) = 0.99817							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
3001001	6.67692E-02	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002	UPDATED		
08/12/94									
3008016	3.33846E-02	8.88074E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED		
08/12/94									
MIXTURE =	4	DENSITY(G/CC) = 2.7020							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
4013027	6.03066E-02	1.00000E+00	13027	26.9818	AL-27 1193 218 GP 040375(5)	UPDATED			
08/12/94									
MIXTURE =	5	DENSITY(G/CC) = 7.9200							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
5024304	1.74286E-02	1.90000E-01	24000	51.9957	CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'	UPDATED			
08/12/94									
5025055	1.73633E-03	1.99999E-02	25055	54.9379	MANGANESE-55	ENDF/B-IV MAT 1197	UPDATED		
08/12/94									
5026304	5.93579E-02	6.95000E-01	26000	55.8447	FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'	UPDATED			
08/12/94									
5028304	7.72070E-03	9.50001E-02	28000	58.6872	NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'	UPDATED			
08/12/94									
MIXTURE =	6	DENSITY(G/CC) = 2.5549							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
6005010	8.88038E-03	5.77924E-02	5010	10.0130	B-10 1273 218NGP 042375 P-3 293K	UPDATED			
08/12/94									
6005011	4.90582E-02	3.51040E-01	5011	11.0096	BORON-11	ENDF/B-IV MAT 1160	UPDATED		
08/12/94									
6006012	1.52248E-02	1.18744E-01	6000	12.0001	CARBON-12	ENDF/B-IV MAT 1274/THRM1065	UPDATED		
08/12/94									
6013027	2.69393E-02	4.72424E-01	13027	26.9818	AL-27 1193 218 GP 040375(5)	UPDATED			
08/12/94									
MIXTURE =	7	DENSITY(G/CC) = 11.344							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
7082000	3.29690E-02	1.00000E+00	82000	207.2100	PB 1288 218NGP 042375 P-3 293K	UPDATED			
08/12/94									
MIXTURE =	8	DENSITY(G/CC) = 1.6298							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
8001001	5.85400E-02	6.01023E-02	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002	UPDATED		
08/12/94									
8005010	8.55300E-05	8.72589E-04	5010	10.0130	B-10 1273 218NGP 042375 P-3 293K	UPDATED			
08/12/94									
8005011	3.42200E-04	3.83863E-03	5011	11.0096	BORON-11	ENDF/B-IV MAT 1160	UPDATED		
08/12/94									
8006012	2.26400E-02	2.76813E-01	6000	12.0001	CARBON-12	ENDF/B-IV MAT 1274/THRM1065	UPDATED		
08/12/94									
8007014	1.39400E-03	1.98893E-02	7014	14.0033	NITROGEN-14	ENDF/B-IV MAT 1275	UPDATED		
08/12/94									
8008016	2.60900E-02	4.25068E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED		
08/12/94									
8013027	7.76300E-03	2.13416E-01	13027	26.9818	AL-27 1193 218 GP 040375(5)	UPDATED			
08/12/94									
MIXTURE =	9	DENSITY(G/CC) = 0.99817							
NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE				
9001001	6.67692E-02	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002	UPDATED		
08/12/94									
9008016	3.33846E-02	8.88074E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED		
08/12/94									
MIXTURE =	10	DENSITY(G/CC) = 0.99817							

**Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)**

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE		
10001001	6.67692E-02	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002	UPDATED
08/12/94							
10008016	3.33846E-02	8.88074E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED
08/12/94							
			3001001		HYDROGEN	ENDF/B-IV MAT 1269/THRM1002	UPDATED 08/12/94
			8001001		HYDROGEN	ENDF/B-IV MAT 1269/THRM1002	UPDATED 08/12/94
			9001001		HYDROGEN	ENDF/B-IV MAT 1269/THRM1002	UPDATED 08/12/94
			10001001		HYDROGEN	ENDF/B-IV MAT 1269/THRM1002	UPDATED 08/12/94
			6005010		B-10 1273 218NGP 042375 P-3 293K		UPDATED 08/12/94
			8005010		B-10 1273 218NGP 042375 P-3 293K		UPDATED 08/12/94
			6005011		BORON-11	ENDF/B-IV MAT 1160	UPDATED 08/12/94
			8005011		BORON-11	ENDF/B-IV MAT 1160	UPDATED 08/12/94
			6006012		CARBON-12	ENDF/B-IV MAT 1274/THRM1065	UPDATED 08/12/94
			8006012		CARBON-12	ENDF/B-IV MAT 1274/THRM1065	UPDATED 08/12/94
			8007014		NITROGEN-14	ENDF/B-IV MAT 1275	UPDATED 08/12/94
			1008016		OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED 08/12/94
			3008016		OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED 08/12/94
			8008016		OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED 08/12/94
			9008016		OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED 08/12/94
			10008016		OXYGEN-16	ENDF/B-IV MAT 1276	UPDATED 08/12/94
			4013027		AL-27 1193 218 GP 040375(5)		UPDATED 08/12/94
			6013027		AL-27 1193 218 GP 040375(5)		UPDATED 08/12/94
			8013027		AL-27 1193 218 GP 040375(5)		UPDATED 08/12/94
			5024304		CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'		UPDATED 08/12/94
			5025055		MANGANESE-55	ENDF/B-IV MAT 1197	UPDATED 08/12/94
			5026304		FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'		UPDATED 08/12/94
			5028304		NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'		UPDATED 08/12/94
			2040302		ZIRCALLOY	ENDF/B-IV MAT 1284	UPDATED 08/12/94
			7082000		PB 1288 218NGP 042375 P-3 293K		UPDATED 08/12/94
			1092235		URANIUM-235	ENDF/B-IV MAT 1261	UPDATED 08/12/94
			1092238		URANIUM-238	ENDF/B-IV MAT 1262	UPDATED 08/12/94
KENO MESSAGE NUMBER K5-222      1 TRANSFERS FOR MIXTURE      3 WERE CORRECTED FOR BAD MOMENTS.							
KENO MESSAGE NUMBER K5-222      1 TRANSFERS FOR MIXTURE      9 WERE CORRECTED FOR BAD MOMENTS.							
KENO MESSAGE NUMBER K5-222      1 TRANSFERS FOR MIXTURE      10 WERE CORRECTED FOR BAD MOMENTS.							
..... 0 IO'S WERE USED MIXING CROSS-SECTIONS .....							
1-D CROSS SECTION ARRAY ID NUMBERS							
1    2002    1452    27    18    1018							
..... 0 IO'S WERE USED PREPARING THE CROSS SECTIONS .....							

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```

*****
***          UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH          ***
***                                                                                          ***
*****
***          ***** ADDITIONAL INFORMATION *****          ***
***                                                                                          ***
*** NUMBER OF ENERGY GROUPS          27          USE LATTICE GEOMETRY          YES          ***
*** NO. OF FISSION SPECTRUM SOURCE GROUP 1          GLOBAL ARRAY NUMBER          40          ***
*** NO. OF SCATTERING ANGLES IN XSECS  2          NUMBER OF UNITS IN THE GLOBAL X DIR.  1          ***
*** ENTRIES/NEUTRON IN THE NEUTRON BANK 28          NUMBER OF UNITS IN THE GLOBAL Y DIR.  1          ***
*** ENTRIES/NEUTRON IN THE FISSION BANK 21          NUMBER OF UNITS IN THE GLOBAL Z DIR.  4          ***
*** NUMBER OF MIXTURES USED          9          USE A GLOBAL REFLECTOR          YES          ***
*** NUMBER OF BIAS ID'S USED          1          USE NESTED HOLES          YES          ***
*** NUMBER OF DIFFERENTIAL ALBEDOS USED  0          NUMBER OF HOLES          78          ***
*** TOTAL INPUT GEOMETRY REGIONS          148          MAXIMUM HOLE NESTING LEVEL          2          ***
*** NUMBER OF GEOMETRY REGIONS USED          148          USE NESTED ARRAYS          YES          ***
*** LARGEST GEOMETRY UNIT NUMBER          73          NUMBER OF ARRAYS USED          15          ***
*** LARGEST ARRAY NUMBER          40          MAXIMUM ARRAY NESTING LEVEL          3          ***
***                                                                                          ***
*** +X BOUNDARY CONDITION          MIRROR          -X BOUNDARY CONDITION          MIRROR          ***
*** +Y BOUNDARY CONDITION          MIRROR          -Y BOUNDARY CONDITION          MIRROR          ***
*** +Z BOUNDARY CONDITION          PER          -Z BOUNDARY CONDITION          PER          ***
***                                                                                          ***

```

VOLUME FRACTION OF FISSILE MATERIAL IN THE CORE= 4.20003E-02

START TYPE 0 WAS USED.

THE NEUTRONS WERE STARTED WITH A FLAT DISTRIBUTION IN A CUBOID DEFINED BY:

+X= 1.35000E+02 -X=-1.35000E+02 +Y= 1.35000E+02 -Y=-1.35000E+02 +Z= 1.24968E+01 -Z= 0.00000E+00  
THE FLAG TO START NEUTRONS IN THE REFLECTOR WAS TURNED OFF

0.04917 MINUTES WERE REQUIRED FOR STARTING. TOTAL ELAPSED TIME IS 0.07467 MINUTES.

**Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)**

UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH

GENERATION	GENERATION	ELAPSED TIME	AVERAGE	AVG K-EFF	MATRIX	MATRIX K-EFF
KENO MESSAGE NUMBER K5-132	K-EFFECTIVE	MINUTES	K-EFFECTIVE	DEVIATION	K-EFFECTIVE	DEVIATION
1	8.41911E-01	WARNING... ONLY	916 INDEPENDENT	FISSION POINTS WERE	GENERATED	0.00000E+00
2	8.91415E-01	WARNING... ONLY	976 INDEPENDENT	FISSION POINTS WERE	GENERATED	0.00000E+00
3	9.04504E-01	WARNING... ONLY	989 INDEPENDENT	FISSION POINTS WERE	GENERATED	0.00000E+00
4	9.06173E-01	2.00500E-01	9.04504E-01	0.00000E+00	0.00000E+00	0.00000E+00
5	9.10171E-01	2.39833E-01	9.05338E-01	8.34495E-04	0.00000E+00	0.00000E+00
6	9.50256E-01	2.78167E-01	9.06949E-01	1.68147E-03	0.00000E+00	0.00000E+00
7	9.04911E-01	3.17667E-01	9.17776E-01	1.08918E-02	0.00000E+00	0.00000E+00
8	9.29772E-01	3.57000E-01	9.15203E-01	8.82042E-03	0.00000E+00	0.00000E+00
9	9.16157E-01	3.96333E-01	9.17631E-01	7.60014E-03	0.00000E+00	0.00000E+00
10	9.84707E-01	4.34833E-01	9.17421E-01	6.42674E-03	0.00000E+00	0.00000E+00
11	8.95141E-01	4.74167E-01	9.25831E-01	1.00856E-02	0.00000E+00	0.00000E+00
12	9.25400E-01	5.15333E-01	9.22421E-01	9.52588E-03	0.00000E+00	0.00000E+00
13	9.19387E-01	5.53833E-01	9.22719E-01	8.52541E-03	0.00000E+00	0.00000E+00
14	8.94697E-01	5.93167E-01	9.22416E-01	7.71747E-03	0.00000E+00	0.00000E+00
15	9.36445E-01	6.32500E-01	9.20106E-01	7.41408E-03	0.00000E+00	0.00000E+00
16	9.48605E-01	6.72833E-01	9.21363E-01	6.93480E-03	0.00000E+00	0.00000E+00
17	9.35131E-01	7.12167E-01	9.23309E-01	6.70878E-03	0.00000E+00	0.00000E+00
18	9.22992E-01	7.51500E-01	9.24097E-01	6.29506E-03	0.00000E+00	0.00000E+00
19	9.29173E-01	7.90000E-01	9.24028E-01	5.88890E-03	0.00000E+00	0.00000E+00
20	9.35483E-01	8.29333E-01	9.24331E-01	5.53993E-03	0.00000E+00	0.00000E+00
21	9.34083E-01	8.67833E-01	9.24950E-01	5.25971E-03	0.00000E+00	0.00000E+00
22	9.30179E-01	9.06167E-01	9.25431E-01	4.99836E-03	0.00000E+00	0.00000E+00
23	9.11446E-01	9.44667E-01	9.25668E-01	4.74780E-03	0.00000E+00	0.00000E+00
24	8.80720E-01	9.85000E-01	9.24991E-01	4.56655E-03	0.00000E+00	0.00000E+00
25	9.52190E-01	1.02333E+00	9.22979E-01	4.79658E-03	0.00000E+00	0.00000E+00
26	9.21261E-01	1.06183E+00	9.24249E-01	4.75600E-03	0.00000E+00	0.00000E+00
27	9.33612E-01	1.10117E+00	9.24124E-01	4.55522E-03	0.00000E+00	0.00000E+00
28	9.13231E-01	1.14050E+00	9.24504E-01	4.38567E-03	0.00000E+00	0.00000E+00
29	9.27053E-01	1.17817E+00	9.24070E-01	4.23586E-03	0.00000E+00	0.00000E+00
30	9.66969E-01	1.21750E+00	9.24181E-01	4.07746E-03	0.00000E+00	0.00000E+00
31	9.47153E-01	1.25583E+00	9.25709E-01	4.21584E-03	0.00000E+00	0.00000E+00
32	9.63032E-01	1.29533E+00	9.26448E-01	4.13453E-03	0.00000E+00	0.00000E+00
33	9.64676E-01	1.33367E+00	9.27668E-01	4.17634E-03	0.00000E+00	0.00000E+00
34	9.50496E-01	1.37217E+00	9.28862E-01	4.21209E-03	0.00000E+00	0.00000E+00
35	9.33633E-01	1.40967E+00	9.29538E-01	4.13400E-03	0.00000E+00	0.00000E+00
36	9.20850E-01	1.44900E+00	9.29662E-01	4.00869E-03	0.00000E+00	0.00000E+00
37	9.30132E-01	1.48850E+00	9.29403E-01	3.89762E-03	0.00000E+00	0.00000E+00
38	9.28127E-01	1.52867E+00	9.29423E-01	3.78468E-03	0.00000E+00	0.00000E+00
39	9.08762E-01	1.56617E+00	9.29387E-01	3.67823E-03	0.00000E+00	0.00000E+00
40	9.28885E-01	1.60650E+00	9.28830E-01	3.62061E-03	0.00000E+00	0.00000E+00
41	9.33467E-01	1.64583E+00	9.28831E-01	3.52404E-03	0.00000E+00	0.00000E+00
42	9.12224E-01	1.68333E+00	9.28950E-01	3.43455E-03	0.00000E+00	0.00000E+00
43	9.09205E-01	1.72100E+00	9.28532E-01	3.37360E-03	0.00000E+00	0.00000E+00
44	9.35166E-01	1.76033E+00	9.28061E-01	3.32388E-03	0.00000E+00	0.00000E+00
45	9.14761E-01	1.79883E+00	9.28230E-01	3.24819E-03	0.00000E+00	0.00000E+00
46	9.44628E-01	1.83633E+00	9.27917E-01	3.18718E-03	0.00000E+00	0.00000E+00
47	9.10068E-01	1.87283E+00	9.28297E-01	3.13698E-03	0.00000E+00	0.00000E+00
48	9.01385E-01	1.91233E+00	9.27891E-01	3.09311E-03	0.00000E+00	0.00000E+00
49	9.02785E-01	1.95067E+00	9.27315E-01	3.07951E-03	0.00000E+00	0.00000E+00
50	9.02785E-01	1.99100E+00	9.26793E-01	3.05815E-03	0.00000E+00	0.00000E+00
51	9.24339E-01	2.03033E+00	9.26742E-01	2.99419E-03	0.00000E+00	0.00000E+00
52	9.38424E-01	2.06967E+00	9.26981E-01	2.94212E-03	0.00000E+00	0.00000E+00
53	9.32145E-01	2.10633E+00	9.27084E-01	2.88453E-03	0.00000E+00	0.00000E+00
54	8.98183E-01	2.14483E+00	9.26517E-01	2.88363E-03	0.00000E+00	0.00000E+00
55	9.37065E-01	2.18317E+00	9.26720E-01	2.83490E-03	0.00000E+00	0.00000E+00
56	9.45753E-01	2.22267E+00	9.27079E-01	2.80399E-03	0.00000E+00	0.00000E+00
57	9.40239E-01	2.26017E+00	9.27323E-01	2.76235E-03	0.00000E+00	0.00000E+00
58	9.21737E-01	2.29767E+00	9.27221E-01	2.71356E-03	0.00000E+00	0.00000E+00
59	9.39034E-01	2.33617E+00	9.27432E-01	2.67300E-03	0.00000E+00	0.00000E+00
60	9.17091E-01	2.37550E+00	9.27251E-01	2.63194E-03	0.00000E+00	0.00000E+00
61	9.37030E-01	2.41400E+00	9.27419E-01	2.59166E-03	0.00000E+00	0.00000E+00
62	9.21403E-01	2.45333E+00	9.27317E-01	2.54939E-03	0.00000E+00	0.00000E+00
63	9.05006E-01	2.49350E+00	9.26946E-01	2.53398E-03	0.00000E+00	0.00000E+00
64	9.55974E-01	2.53300E+00	9.27421E-01	2.53712E-03	0.00000E+00	0.00000E+00
65	9.06396E-01	2.57133E+00	9.27082E-01	2.51879E-03	0.00000E+00	0.00000E+00
66	9.29975E-01	2.61067E+00	9.27128E-01	2.47892E-03	0.00000E+00	0.00000E+00
67	8.89966E-01	2.64917E+00	9.26548E-01	2.50802E-03	0.00000E+00	0.00000E+00
68	9.14582E-01	2.68767E+00	9.26364E-01	2.47599E-03	0.00000E+00	0.00000E+00
69	8.74626E-01	2.72700E+00	9.25580E-01	2.56110E-03	0.00000E+00	0.00000E+00
70	9.04011E-01	2.76550E+00	9.25258E-01	2.54304E-03	0.00000E+00	0.00000E+00
71	9.21942E-01	2.80383E+00	9.25209E-01	2.50584E-03	0.00000E+00	0.00000E+00
72	9.31927E-01	2.84233E+00	9.25306E-01	2.47118E-03	0.00000E+00	0.00000E+00
73	9.06844E-01	2.88083E+00	9.25043E-01	2.44986E-03	0.00000E+00	0.00000E+00
74	9.36779E-01	2.91917E+00	9.25208E-01	2.42075E-03	0.00000E+00	0.00000E+00
75	9.25122E-01	2.95683E+00	9.25207E-01	2.38690E-03	0.00000E+00	0.00000E+00
76	8.87717E-01	2.99617E+00	9.24693E-01	2.40934E-03	0.00000E+00	0.00000E+00
77	9.34421E-01	3.03467E+00	9.24825E-01	2.38019E-03	0.00000E+00	0.00000E+00
78	9.24711E-01	3.07300E+00	9.24823E-01	2.34824E-03	0.00000E+00	0.00000E+00
79	9.85591E-01	3.11050E+00	9.25623E-01	2.45121E-03	0.00000E+00	0.00000E+00
80	9.10257E-01	3.14900E+00	9.25423E-01	2.42739E-03	0.00000E+00	0.00000E+00

**Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)**

80	9.58537E-01	3.18750E+00	9.25848E-01	2.43338E-03	0.00000E+00	0.00000E+00
81	9.33016E-01	3.22583E+00	9.25938E-01	2.40410E-03	0.00000E+00	0.00000E+00
82	9.26576E-01	3.26533E+00	9.25946E-01	2.37387E-03	0.00000E+00	0.00000E+00
83	9.16535E-01	3.30283E+00	9.25830E-01	2.34726E-03	0.00000E+00	0.00000E+00
84	9.45884E-01	3.34033E+00	9.26075E-01	2.33132E-03	0.00000E+00	0.00000E+00
785	9.54140E-01	3.34010E+01	9.30689E-01	8.53588E-04	0.00000E+00	0.00000E+00
786	8.80900E-01	3.34405E+01	9.30625E-01	8.54861E-04	0.00000E+00	0.00000E+00
787	9.50545E-01	3.34780E+01	9.30651E-01	8.54148E-04	0.00000E+00	0.00000E+00
788	9.21978E-01	3.35265E+01	9.30639E-01	8.53132E-04	0.00000E+00	0.00000E+00
789	9.38711E-01	3.35685E+01	9.30650E-01	8.52109E-04	0.00000E+00	0.00000E+00
790	9.68809E-01	3.36080E+01	9.30698E-01	8.52403E-04	0.00000E+00	0.00000E+00
791	9.45933E-01	3.36510E+01	9.30717E-01	8.51541E-04	0.00000E+00	0.00000E+00
792	9.40492E-01	3.36903E+01	9.30730E-01	8.50553E-04	0.00000E+00	0.00000E+00
793	8.71320E-01	3.37278E+01	9.30655E-01	8.52791E-04	0.00000E+00	0.00000E+00
794	9.28630E-01	3.37663E+01	9.30652E-01	8.51717E-04	0.00000E+00	0.00000E+00
795	9.39924E-01	3.38057E+01	9.30664E-01	8.50723E-04	0.00000E+00	0.00000E+00
796	9.20043E-01	3.38432E+01	9.30650E-01	8.49756E-04	0.00000E+00	0.00000E+00
797	9.37450E-01	3.38825E+01	9.30659E-01	8.48729E-04	0.00000E+00	0.00000E+00
798	9.46410E-01	3.39202E+01	9.30679E-01	8.47893E-04	0.00000E+00	0.00000E+00
799	9.18939E-01	3.39595E+01	9.30664E-01	8.46957E-04	0.00000E+00	0.00000E+00
800	9.24313E-01	3.39970E+01	9.30656E-01	8.45932E-04	0.00000E+00	0.00000E+00
801	9.36265E-01	3.40363E+01	9.30663E-01	8.44902E-04	0.00000E+00	0.00000E+00
802	9.78485E-01	3.40748E+01	9.30723E-01	8.45960E-04	0.00000E+00	0.00000E+00
803	9.41388E-01	3.41115E+01	9.30736E-01	8.45008E-04	0.00000E+00	0.00000E+00

KENO MESSAGE NUMBER K5-123

EXECUTION TERMINATED DUE TO COMPLETION OF THE SPECIFIED NUMBER OF GENERATIONS.

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH						
LIFETIME = 3.65041E-05 + OR - 7.13855E-08		GENERATION TIME = 2.99769E-05 + OR - 4.37968E-08				
NU BAR = 2.43809E+00 + OR - 6.63659E-05		AVERAGE FISSION GROUP = 2.22802E+01 + OR - 3.88385E-03				
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 1.85977E-01 + OR - 5.91369E-04						
NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.93077	+ OR - 0.00085	0.92992 TO 0.93161	0.92908 TO 0.93246	0.92823 TO 0.93331	800000
4	0.93080	+ OR - 0.00085	0.92995 TO 0.93165	0.92911 TO 0.93249	0.92826 TO 0.93334	799000
5	0.93083	+ OR - 0.00085	0.92998 TO 0.93167	0.92913 TO 0.93252	0.92829 TO 0.93337	798000
6	0.93080	+ OR - 0.00085	0.92995 TO 0.93165	0.92911 TO 0.93250	0.92826 TO 0.93334	797000
7	0.93083	+ OR - 0.00085	0.92999 TO 0.93168	0.92914 TO 0.93253	0.92829 TO 0.93338	796000
8	0.93084	+ OR - 0.00085	0.92999 TO 0.93168	0.92914 TO 0.93253	0.92829 TO 0.93338	795000
9	0.93085	+ OR - 0.00085	0.93000 TO 0.93170	0.92915 TO 0.93255	0.92830 TO 0.93340	794000
10	0.93079	+ OR - 0.00085	0.92994 TO 0.93163	0.92909 TO 0.93248	0.92824 TO 0.93333	793000
11	0.93083	+ OR - 0.00085	0.92998 TO 0.93168	0.92913 TO 0.93253	0.92829 TO 0.93337	792000
12	0.93084	+ OR - 0.00085	0.92999 TO 0.93169	0.92914 TO 0.93254	0.92829 TO 0.93338	791000
17	0.93086	+ OR - 0.00085	0.93001 TO 0.93172	0.92916 TO 0.93257	0.92831 TO 0.93342	786000
22	0.93087	+ OR - 0.00086	0.93001 TO 0.93172	0.92915 TO 0.93258	0.92829 TO 0.93344	781000
27	0.93094	+ OR - 0.00086	0.93008 TO 0.93180	0.92922 TO 0.93266	0.92836 TO 0.93352	776000
.						
.						
772	0.93281	+ OR - 0.00533	0.92748 TO 0.93814	0.92214 TO 0.94348	0.91681 TO 0.94881	31000
777	0.93481	+ OR - 0.00591	0.92889 TO 0.94072	0.92298 TO 0.94664	0.91706 TO 0.95255	26000
782	0.93990	+ OR - 0.00675	0.93315 TO 0.94665	0.92640 TO 0.95340	0.91965 TO 0.96015	21000
787	0.93494	+ OR - 0.00587	0.92908 TO 0.94081	0.92321 TO 0.94668	0.91734 TO 0.95254	16000
792	0.93120	+ OR - 0.00776	0.92344 TO 0.93896	0.91567 TO 0.94672	0.90791 TO 0.95448	11000
797	0.94097	+ OR - 0.00861	0.93236 TO 0.94957	0.92375 TO 0.95818	0.91515 TO 0.96679	6000

Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH

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                                FREQUENCY FOR GENERATIONS      4 TO 803

0.8620 TO 0.8679      **
0.8679 TO 0.8739      ****
0.8739 TO 0.8798      ****
0.8798 TO 0.8857      *****
0.8857 TO 0.8917      *****
0.8917 TO 0.8976      *****
0.8976 TO 0.9035      *****
0.9035 TO 0.9095      *****
0.9095 TO 0.9154      *****
0.9154 TO 0.9214      *****
0.9214 TO 0.9273      *****
0.9273 TO 0.9332      *****
0.9332 TO 0.9392      *****
0.9392 TO 0.9451      *****
0.9451 TO 0.9510      *****
0.9510 TO 0.9570      *****
0.9570 TO 0.9629      *****
0.9629 TO 0.9688      *****
0.9688 TO 0.9748      *****
0.9748 TO 0.9807      *****
0.9807 TO 0.9866      *****
0.9866 TO 0.9926      *****
0.9926 TO 0.9985      *
0.9985 TO 1.0045      **
1.0045 TO 1.0104      **
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                                FREQUENCY FOR GENERATIONS    204 TO 803

0.8620 TO 0.8679      **
0.8679 TO 0.8739      ****
0.8739 TO 0.8798      ****
0.8798 TO 0.8857      *****
0.8857 TO 0.8917      *****
0.8917 TO 0.8976      *****
0.8976 TO 0.9035      *****
0.9035 TO 0.9095      *****
0.9095 TO 0.9154      *****
0.9154 TO 0.9214      *****
0.9214 TO 0.9273      *****
0.9273 TO 0.9332      *****
0.9332 TO 0.9392      *****
0.9392 TO 0.9451      *****
0.9451 TO 0.9510      *****
0.9510 TO 0.9570      *****
0.9570 TO 0.9629      *****
0.9629 TO 0.9688      *****
0.9688 TO 0.9748      *****
0.9748 TO 0.9807      *****
0.9807 TO 0.9866      *****
0.9866 TO 0.9926      *****
0.9926 TO 0.9985      *
0.9985 TO 1.0045      *
1.0045 TO 1.0104      **
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**Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)**

UMS PWR TC; ACCIDENT; ARRAY; 1.0 GM/CC IN - 1.0 GM/CC EX; 270CM PITCH

FREQUENCY FOR GENERATIONS 404 TO 803

0.8620 TO 0.8679	*
0.8679 TO 0.8739	***
0.8739 TO 0.8798	**
0.8798 TO 0.8857	*****
0.8857 TO 0.8917	*****
0.8917 TO 0.8976	*****
0.8976 TO 0.9035	*****
0.9035 TO 0.9095	*****
0.9095 TO 0.9154	*****
0.9154 TO 0.9214	*****
0.9214 TO 0.9273	*****
0.9273 TO 0.9332	*****
0.9332 TO 0.9392	*****
0.9392 TO 0.9451	*****
0.9451 TO 0.9510	*****
0.9510 TO 0.9570	*****
0.9570 TO 0.9629	*****
0.9629 TO 0.9688	*****
0.9688 TO 0.9748	*****
0.9748 TO 0.9807	*****
0.9807 TO 0.9866	*****
0.9866 TO 0.9926	**
0.9926 TO 0.9985	*
0.9985 TO 1.0045	*
1.0045 TO 1.0104	**

FREQUENCY FOR GENERATIONS 604 TO 803

0.8620 TO 0.8679	*
0.8679 TO 0.8739	*
0.8739 TO 0.8798	**
0.8798 TO 0.8857	***
0.8857 TO 0.8917	*
0.8917 TO 0.8976	*****
0.8976 TO 0.9035	*****
0.9035 TO 0.9095	*****
0.9095 TO 0.9154	*****
0.9154 TO 0.9214	*****
0.9214 TO 0.9273	*****
0.9273 TO 0.9332	*****
0.9332 TO 0.9392	*****
0.9392 TO 0.9451	*****
0.9451 TO 0.9510	*****
0.9510 TO 0.9570	*****
0.9570 TO 0.9629	*****
0.9629 TO 0.9688	***
0.9688 TO 0.9748	*****
0.9748 TO 0.9807	****
0.9807 TO 0.9866	****
0.9866 TO 0.9926	*
0.9926 TO 0.9985	*
0.9985 TO 1.0045	*
1.0045 TO 1.0104	*

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel

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PRIMARY MODULE ACCESS AND INPUT RECORD SCALE DRIVER 95/03/29 09:06:37
MODULE CSAS25 WILL BE CALLED
UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH
27GROUNDF4 LATTICECELL
UO2 1 0.95 293.0 92235 4.00 92238 96.00 END
ZIRCALLOY 2 1.0 293.0 END
H2O 3 1.0 293.0 END
AL 4 1.0 293.0 END
SS304 5 1.0 293.0 END
AL 6 DEN=2.6849 0.8706 293.0 END
B-10 6 DEN=2.6849 0.0137 293.0 END
B-11 6 DEN=2.6849 0.0830 293.0 END
C 6 DEN=2.6849 0.0281 293.0 END
CARBONSTEEL 7 1.0 293.0 END
PB 8 1.0 293.0 END
B-10 9 0.0 8.553-5 END
B-11 9 0.0 3.422-4 END
AL 9 0.0 7.763-3 END
H 9 0.0 5.854-2 END
O 9 0.0 2.609-2 END
C 9 0.0 2.264-2 END
N 9 0.0 1.394-3 END
H2O 10 0.6 293.0 END
H2O 11 1.0 293.0 END
END COMP
SQUAREPITCH 1.4529 0.9055 1 3 1.0770 2 0.9246 11 END
UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH
READ PARAM TBA=5 RUN=YES FLT=NO TME=5000 GEN=803 NPG=1000 END PARAM
READ GEOM
UNIT 1
COM='FUEL PIN CELL - WITH H2O'
CYLINDER 1 1 0.4528 2P1.7145
CYLINDER 11 1 0.4623 2P1.7145
CYLINDER 2 1 0.5385 2P1.7145
CUBOID 3 1 4P0.7264 2P1.7145
UNIT 2
COM='WATER ROD CELL - WITH H2O'
CYLINDER 3 1 0.4623 2P1.7145
CYLINDER 2 1 0.5385 2P1.7145
CUBOID 3 1 4P0.7264 2P1.7145
UNIT 3
COM='FUEL PIN CELL - WITH ST DISK'
CYLINDER 1 1 0.4528 2P0.7938
CYLINDER 11 1 0.4623 2P0.7938
CYLINDER 2 1 0.5385 2P0.7938
CUBOID 3 1 4P0.7264 2P0.7938
UNIT 4
COM='WATER ROD CELL - WITH ST DISK'
CYLINDER 3 1 0.4623 2P0.7938
CYLINDER 2 1 0.5385 2P0.7938
CUBOID 3 1 4P0.7264 2P0.7938
UNIT 5
COM='FUEL PIN CELL - WITH AL DISK'
CYLINDER 1 1 0.4528 2P0.6350
CYLINDER 11 1 0.4623 2P0.6350
CYLINDER 2 1 0.5385 2P0.6350
CUBOID 3 1 4P0.7264 2P0.6350
UNIT 6
COM='WATER ROD CELL - WITH AL DISK'
CYLINDER 3 1 0.4623 2P0.6350
CYLINDER 2 1 0.5385 2P0.6350
CUBOID 3 1 4P0.7264 2P0.6350
UNIT 7
COM='FUEL PIN ARRAY + CHANNEL - BETWEEN DISKS'
ARRAY 1 -6.5376 -6.5376 -1.7145
CUBOID 3 1 4P6.7031 2P1.7145
CUBOID 2 1 4P6.9063 2P1.7145
UNIT 8
COM='FUEL PIN ARRAY + CHANNEL - ST DISKS'
ARRAY 2 -6.5376 -6.5376 -0.7938
CUBOID 3 1 4P6.7031 2P0.7938
CUBOID 2 1 4P6.9063 2P0.7938
UNIT 9
COM='FUEL PIN ARRAY + CHANNEL - AL DISKS'
ARRAY 3 -6.5376 -6.5376 -0.6350
CUBOID 3 1 4P6.7031 2P0.6350
CUBOID 2 1 4P6.9063 2P0.6350
UNIT 10
COM='X-X BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P1.7145
CUBOID 4 1 2P6.7310 2P0.1714 2P1.7145
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P1.7145
UNIT 11
COM='Y-Y BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P1.7145
CUBOID 4 1 2P0.1714 2P6.7310 2P1.7145
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P1.7145
UNIT 12
COM='X-X BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.7938
CUBOID 4 1 2P6.7310 2P0.1714 2P0.7938
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.7938
UNIT 13
COM='Y-Y BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.7938
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Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
CUBOID 4 1 2P0.1714 2P6.7310 2P0.7938
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.7938
UNIT 14
COM='X-X BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.6350
CUBOID 4 1 2P6.7310 2P0.1714 2P0.6350
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.6350
UNIT 15
COM='Y-Y BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.6350
CUBOID 4 1 2P0.1714 2P6.7310 2P0.6350
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.6350
UNIT 20
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 21
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 22
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 23
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 24
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 25
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 26
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
UNIT 27
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
UNIT 28
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE 11 +7.7859 0.0 0.0
UNIT 29
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE 11 +7.7859 0.0 0.0
UNIT 30
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE 11 +7.7859 0.0 0.0
UNIT 31
```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
COM='FUEL TUBE CELL NO BORAL SHEETS - BETWEEN DISKS (BL)'  
CUBOID 3 1 4P7.4930 2P1.7145  
HOLE 7 -0.5867 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P1.7145  
UNIT 40  
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TR)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 +0.5867 +0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938  
HOLE 12 0.0 +7.7859 0.0  
HOLE 13 +7.7859 0.0 0.0  
UNIT 41  
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TL)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 -0.5867 +0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938  
HOLE 12 0.0 +7.7859 0.0  
HOLE 13 +7.7859 0.0 0.0  
UNIT 42  
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BL)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 -0.5867 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938  
HOLE 12 0.0 +7.7859 0.0  
HOLE 13 +7.7859 0.0 0.0  
UNIT 43  
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BR)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 +0.5867 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938  
HOLE 12 0.0 +7.7859 0.0  
HOLE 13 +7.7859 0.0 0.0  
UNIT 44  
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (T)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 0.0 +0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938  
HOLE 12 0.0 +7.7859 0.0  
HOLE 13 +7.7859 0.0 0.0  
UNIT 45  
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (B)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 0.0 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938  
HOLE 12 0.0 +7.7859 0.0  
HOLE 13 +7.7859 0.0 0.0  
UNIT 46  
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (TL)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 -0.5867 +0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938  
HOLE 12 0.0 +7.7859 0.0  
UNIT 47  
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (BL)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 -0.5867 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938  
HOLE 12 0.0 +7.7859 0.0  
UNIT 48  
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BL)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 -0.5867 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938  
HOLE 13 +7.7859 0.0 0.0  
UNIT 49  
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (B)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 0.0 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938  
HOLE 13 +7.7859 0.0 0.0  
UNIT 50  
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BR)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 +0.5867 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938  
HOLE 13 +7.7859 0.0 0.0  
UNIT 51  
COM='FUEL TUBE CELL NO BORAL SHEETS - STEEL DISKS (BL)'  
CUBOID 3 1 4P7.4930 2P0.7938  
HOLE 8 -0.5867 -0.5867 0.0  
CUBOID 5 1 4P7.6144 2P0.7938  
UNIT 60  
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TR)'  
CUBOID 3 1 4P7.4930 2P0.6350  
HOLE 9 +0.5867 +0.5867 0.0
```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0
UNIT 61
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0
UNIT 62
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0
UNIT 63
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0
UNIT 64
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0
UNIT 65
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0
UNIT 66
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
UNIT 67
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
UNIT 68
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE 15 +7.7859 0.0 0.0
UNIT 69
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE 15 +7.7859 0.0 0.0
UNIT 70
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE 15 +7.7859 0.0 0.0
UNIT 71
COM='FUEL TUBE CELL NO BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
UNIT 80
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 20 -0.0297 -0.0297 0.0
UNIT 81
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 21 -0.3586 -0.0297 0.0
UNIT 82
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 22 -0.3586 -0.3586 0.0
```

**Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)**

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UNIT 83
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 23 -0.0297 -0.3586 0.0
UNIT 84
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 24 -0.1942 -0.0297 0.0
UNIT 85
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 25 -0.1942 -0.3586 0.0
UNIT 86
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 26 -0.3586 -0.0297 0.0
UNIT 87
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 27 -0.3586 -0.3586 0.0
UNIT 88
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 28 -0.3586 -0.3586 0.0
UNIT 89
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 29 -0.1942 -0.3586 0.0
UNIT 90
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 30 -0.0297 -0.3586 0.0
UNIT 91
COM='DISK OPENING NO BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 31 -0.3586 -0.3586 0.0
UNIT 100
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 40 -0.0297 -0.0297 0.0
UNIT 101
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 41 -0.3586 -0.0297 0.0
UNIT 102
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 42 -0.3586 -0.3586 0.0
UNIT 103
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 43 -0.0297 -0.3586 0.0
UNIT 104
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 44 -0.1942 -0.0297 0.0
UNIT 105
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 45 -0.1942 -0.3586 0.0
UNIT 106
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 46 -0.3586 -0.0297 0.0
UNIT 107
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 47 -0.3586 -0.3586 0.0
UNIT 108
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 48 -0.3586 -0.3586 0.0
UNIT 109
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 49 -0.1942 -0.3586 0.0
UNIT 110
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 50 -0.0297 -0.3586 0.0
UNIT 111
COM='DISK OPENING NO BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 51 -0.3586 -0.3586 0.0
UNIT 120
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 60 -0.0297 -0.0297 0.0
UNIT 121
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 61 -0.3586 -0.0297 0.0
UNIT 122
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 62 -0.3586 -0.3586 0.0
```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
UNIT 123
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 63 -0.0297 -0.3586 0.0
UNIT 124
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 64 -0.1942 -0.0297 0.0
UNIT 125
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 65 -0.1942 -0.3586 0.0
UNIT 126
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 66 -0.3586 -0.0297 0.0
UNIT 127
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 67 -0.3586 -0.3586 0.0
UNIT 128
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 68 -0.3586 -0.3586 0.0
UNIT 129
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 69 -0.1942 -0.3586 0.0
UNIT 130
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 70 -0.0297 -0.3586 0.0
UNIT 131
COM='DISK OPENING NO BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 71 -0.3586 -0.3586 0.0
UNIT 140
COM='BASKET STRUCTURE IN TRANSPORT CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P1.7145
HOLE 90 -70.3885 +8.7986 0.0
HOLE 83 -52.7914 +8.7986 0.0
HOLE 83 -52.7914 +26.3957 0.0
HOLE 90 -52.7914 +43.9928 0.0
HOLE 83 -35.1942 +8.7986 0.0
HOLE 83 -35.1942 +26.3957 0.0
HOLE 83 -35.1942 +43.9928 0.0
HOLE 90 -35.1942 +61.5899 0.0
HOLE 83 -17.5971 +8.7986 0.0
HOLE 83 -17.5971 +26.3957 0.0
HOLE 83 -17.5971 +43.9928 0.0
HOLE 90 -17.5971 +61.5899 0.0
HOLE 85 0.0 +8.7986 0.0
HOLE 85 0.0 +26.3957 0.0
HOLE 85 0.0 +43.9928 0.0
HOLE 89 0.0 +61.5899 0.0
HOLE 82 +17.5971 +8.7986 0.0
HOLE 82 +17.5971 +26.3957 0.0
HOLE 82 +17.5971 +43.9928 0.0
HOLE 88 +17.5971 +61.5899 0.0
HOLE 82 +35.1942 +8.7986 0.0
HOLE 82 +35.1942 +26.3957 0.0
HOLE 82 +35.1942 +43.9928 0.0
HOLE 91 +35.1942 +61.5899 0.0
HOLE 82 +52.7914 +8.7986 0.0
HOLE 87 +52.7914 +26.3957 0.0
HOLE 91 +52.7914 +43.9928 0.0
HOLE 91 +70.3885 +8.7986 0.0
HOLE 80 -70.3885 -8.7986 0.0
HOLE 80 -52.7914 -8.7986 0.0
HOLE 80 -52.7914 -26.3957 0.0
HOLE 80 -52.7914 -43.9928 0.0
HOLE 80 -35.1942 -8.7986 0.0
HOLE 80 -35.1942 -26.3957 0.0
HOLE 80 -35.1942 -43.9928 0.0
HOLE 80 -35.1942 -61.5899 0.0
HOLE 80 -17.5971 -8.7986 0.0
HOLE 80 -17.5971 -26.3957 0.0
HOLE 80 -17.5971 -43.9928 0.0
HOLE 80 -17.5971 -61.5899 0.0
HOLE 84 0.0 -8.7986 0.0
HOLE 84 0.0 -26.3957 0.0
HOLE 84 0.0 -43.9928 0.0
HOLE 84 0.0 -61.5899 0.0
HOLE 81 +17.5971 -8.7986 0.0
HOLE 81 +17.5971 -26.3957 0.0
HOLE 81 +17.5971 -43.9928 0.0
HOLE 81 +17.5971 -61.5899 0.0
HOLE 81 +35.1942 -8.7986 0.0
HOLE 81 +35.1942 -26.3957 0.0
HOLE 81 +35.1942 -43.9928 0.0
HOLE 86 +35.1942 -61.5899 0.0
HOLE 81 +52.7914 -8.7986 0.0
HOLE 86 +52.7914 -26.3957 0.0
HOLE 86 +52.7914 -43.9928 0.0
HOLE 86 +70.3885 -8.7986 0.0
CYLINDER 5 1 +85.1662 2P1.7145
```



Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
CYLINDER 10 1 +85.8647 2P1.7145
CYLINDER 5 1 +90.9447 2P1.7145
CYLINDER 8 1 +97.9297 2P1.7145
CYLINDER 5 1 +104.9147 2P1.7145
CYLINDER 10 1 +116.3604 2P1.7145
CYLINDER 10 1 +116.6788 2P1.7145
CYLINDER 5 1 +117.3156 2P1.7145
CUBOID 10 1 4P150.0 2P1.7145
UNIT 141
COM=BASKET STRUCTURE IN TRANSPORT CASK - CARBON STEEL DISK
CYLINDER 7 1 +83.1850 2P0.7938
HOLE 110 -70.3885 +8.7986 0.0
HOLE 103 -52.7914 +8.7986 0.0
HOLE 103 -52.7914 +26.3957 0.0
HOLE 110 -52.7914 +43.9928 0.0
HOLE 103 -35.1942 +8.7986 0.0
HOLE 103 -35.1942 +26.3957 0.0
HOLE 103 -35.1942 +43.9928 0.0
HOLE 110 -35.1942 +61.5899 0.0
HOLE 103 -17.5971 +8.7986 0.0
HOLE 103 -17.5971 +26.3957 0.0
HOLE 103 -17.5971 +43.9928 0.0
HOLE 110 -17.5971 +61.5899 0.0
HOLE 105 0.0 +8.7986 0.0
HOLE 105 0.0 +26.3957 0.0
HOLE 105 0.0 +43.9928 0.0
HOLE 109 0.0 +61.5899 0.0
HOLE 102 +17.5971 +8.7986 0.0
HOLE 102 +17.5971 +26.3957 0.0
HOLE 102 +17.5971 +43.9928 0.0
HOLE 108 +17.5971 +61.5899 0.0
HOLE 102 +35.1942 +8.7986 0.0
HOLE 102 +35.1942 +26.3957 0.0
HOLE 102 +35.1942 +43.9928 0.0
HOLE 111 +35.1942 +61.5899 0.0
HOLE 102 +52.7914 +8.7986 0.0
HOLE 107 +52.7914 +26.3957 0.0
HOLE 111 +52.7914 +43.9928 0.0
HOLE 111 +70.3885 +8.7986 0.0
HOLE 100 -70.3885 -8.7986 0.0
HOLE 100 -52.7914 -8.7986 0.0
HOLE 100 -52.7914 -26.3957 0.0
HOLE 100 -52.7914 -43.9928 0.0
HOLE 100 -35.1942 -8.7986 0.0
HOLE 100 -35.1942 -26.3957 0.0
HOLE 100 -35.1942 -43.9928 0.0
HOLE 100 -35.1942 -61.5899 0.0
HOLE 100 -17.5971 -8.7986 0.0
HOLE 100 -17.5971 -26.3957 0.0
HOLE 100 -17.5971 -43.9928 0.0
HOLE 100 -17.5971 -61.5899 0.0
HOLE 104 0.0 -8.7986 0.0
HOLE 104 0.0 -26.3957 0.0
HOLE 104 0.0 -43.9928 0.0
HOLE 104 0.0 -61.5899 0.0
HOLE 101 +17.5971 -8.7986 0.0
HOLE 101 +17.5971 -26.3957 0.0
HOLE 101 +17.5971 -43.9928 0.0
HOLE 101 +17.5971 -61.5899 0.0
HOLE 101 +35.1942 -8.7986 0.0
HOLE 101 +35.1942 -26.3957 0.0
HOLE 101 +35.1942 -43.9928 0.0
HOLE 106 +35.1942 -61.5899 0.0
HOLE 101 +52.7914 -8.7986 0.0
HOLE 106 +52.7914 -26.3957 0.0
HOLE 106 +52.7914 -43.9928 0.0
HOLE 106 +70.3885 -8.7986 0.0
CYLINDER 3 1 +83.5787 2P0.7938
CYLINDER 5 1 +85.1662 2P0.7938
CYLINDER 10 1 +85.8647 2P0.7938
CYLINDER 5 1 +90.9447 2P0.7938
CYLINDER 8 1 +97.9297 2P0.7938
CYLINDER 5 1 +104.9147 2P0.7938
CYLINDER 10 1 +116.3604 2P0.7938
CYLINDER 10 1 +116.6788 2P0.7938
CYLINDER 5 1 +117.3156 2P0.7938
CUBOID 10 1 4P150.0 2P0.7938
UNIT 142
COM=BASKET STRUCTURE IN TRANSPORT CASK - AL DISK
CYLINDER 4 1 +82.8675 2P0.6350
HOLE 130 -70.3885 +8.7986 0.0
HOLE 123 -52.7914 +8.7986 0.0
HOLE 123 -52.7914 +26.3957 0.0
HOLE 130 -52.7914 +43.9928 0.0
HOLE 123 -35.1942 +8.7986 0.0
HOLE 123 -35.1942 +26.3957 0.0
HOLE 123 -35.1942 +43.9928 0.0
HOLE 130 -35.1942 +61.5899 0.0
HOLE 123 -17.5971 +8.7986 0.0
HOLE 123 -17.5971 +26.3957 0.0
HOLE 123 -17.5971 +43.9928 0.0
HOLE 130 -17.5971 +61.5899 0.0
HOLE 125 0.0 +8.7986 0.0
HOLE 125 0.0 +26.3957 0.0
HOLE 125 0.0 +43.9928 0.0
HOLE 129 0.0 +61.5899 0.0
```



Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```

HOLE 122 +17.5971 +8.7986 0.0
HOLE 122 +17.5971 +26.3957 0.0
HOLE 122 +17.5971 +43.9928 0.0
HOLE 128 +17.5971 +61.5899 0.0
HOLE 122 +35.1942 +8.7986 0.0
HOLE 122 +35.1942 +26.3957 0.0
HOLE 122 +35.1942 +43.9928 0.0
HOLE 131 +35.1942 +61.5899 0.0
HOLE 122 +52.7914 +8.7986 0.0
HOLE 127 +52.7914 +26.3957 0.0
HOLE 131 +52.7914 +43.9928 0.0
HOLE 131 +70.3885 +8.7986 0.0
HOLE 120 -70.3885 -8.7986 0.0
HOLE 120 -52.7914 -8.7986 0.0
HOLE 120 -52.7914 -26.3957 0.0
HOLE 120 -52.7914 -43.9928 0.0
HOLE 120 -35.1942 -8.7986 0.0
HOLE 120 -35.1942 -26.3957 0.0
HOLE 120 -35.1942 -43.9928 0.0
HOLE 120 -35.1942 -61.5899 0.0
HOLE 120 -17.5971 -8.7986 0.0
HOLE 120 -17.5971 -26.3957 0.0
HOLE 120 -17.5971 -43.9928 0.0
HOLE 120 -17.5971 -61.5899 0.0
HOLE 124 0.0 -8.7986 0.0
HOLE 124 0.0 -26.3957 0.0
HOLE 124 0.0 -43.9928 0.0
HOLE 124 0.0 -61.5899 0.0
HOLE 121 +17.5971 -8.7986 0.0
HOLE 121 +17.5971 -26.3957 0.0
HOLE 121 +17.5971 -43.9928 0.0
HOLE 121 +17.5971 -61.5899 0.0
HOLE 121 +35.1942 -8.7986 0.0
HOLE 121 +35.1942 -26.3957 0.0
HOLE 121 +35.1942 -43.9928 0.0
HOLE 126 +35.1942 -61.5899 0.0
HOLE 121 +52.7914 -8.7986 0.0
HOLE 126 +52.7914 -26.3957 0.0
HOLE 126 +52.7914 -43.9928 0.0
HOLE 126 +70.3885 -8.7986 0.0
CYLINDER 3 1 +83.5787 2P0.6350
CYLINDER 5 1 +85.1662 2P0.6350
CYLINDER 10 1 +85.8647 2P0.6350
CYLINDER 5 1 +90.9447 2P0.6350
CYLINDER 8 1 +97.9297 2P0.6350
CYLINDER 5 1 +104.9147 2P0.6350
CYLINDER 10 1 +116.3604 2P0.6350
CYLINDER 10 1 +116.6788 2P0.6350
CYLINDER 5 1 +117.3156 2P0.6350
CUBOID 10 1 4P150.0 2P0.6350
GLOBAL UNIT 143
COM='AXIAL STACK OF BASKET SLICES'
ARRAY 4 -150.0 -150.0 0.0
END GEOM
READ ARRAY
ARA=1 NUX=9 NUY=9 NUZ=1 FILL
36R1
4R1 2 4R1
5R1 2 3R1
27R1
END FILL
ARA=2 NUX=9 NUY=9 NUZ=1 FILL
36R3
4R3 4 4R3
5R3 4 3R3
27R3
END FILL
ARA=3 NUX=9 NUY=9 NUZ=1 FILL
36R5
4R5 6 4R5
5R5 6 3R5
27R5
END FILL
ARA=4 NUX=1 NUY=1 NUZ=4 FILL 140 141 140 142 END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=MIRROR END BOUNDS
END DATA

```

## BWR Fuel (continued)

CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAAAAA	SSSSSSSSSSSS	222222222222	SSSSSSSSSSSS
CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAAAAAAA	SSSSSSSSSSSS	222222222222	SSSSSSSSSSSS
CCCCCCCCCCCC	SS	AA	SS	22	SS
CCCCCCCCCCCC	SS	AA	SS	22	SS
CCCCCCCCCCCC	SS	AA	SS	22	SS
CCCCCCCCCCCC	SS	AA	SS	22	SS
CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAAAAAAA	SSSSSSSSSSSS	22	SSSSSSSSSSSS
CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAAAAAAA	SSSSSSSSSSSS	22	SSSSSSSSSSSS
CCCCCCCCCCCC	SS	AA	SS	22	SS
CCCCCCCCCCCC	SS	AA	SS	22	SS
CCCCCCCCCCCC	SS	AA	SS	22	SS
CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAAAAA	SSSSSSSSSSSS	222222222222	SSSSSSSSSSSS
CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAAAAA	SSSSSSSSSSSS	222222222222	SSSSSSSSSSSS
CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAAAAA	SSSSSSSSSSSS	222222222222	SSSSSSSSSSSS
CCCCCCCCCCCC	SSSSSSSSSSSS	AAAAAAAA	SSSSSSSSSSSS	222222222222	SSSSSSSSSSSS

[illegible]

00000000	44	888888888888	999999999999	999999999999
00000000	444	888888888888	999999999999	999999999999
00000000	4444	888888888888	999999999999	999999999999
00	4444	888888888888	999999999999	999999999999
00	44	88	99	99
00	44	88	99	99
00	44	88	99	99
00	44	88	99	99
00	44	88	99	99
00	44	88	99	99
00	44	88	99	99
00	44	88	99	99
00	4444444444	8888888888	9999999999	9999999999
00	444444444444	8888888888	9999999999	9999999999
00	444444444444	8888888888	9999999999	9999999999
00	444444444444	8888888888	9999999999	9999999999
00	44	88	99	99
00	44	88	99	99
00	44	88	99	99
00000000	44	888888888888	999999999999	999999999999
00000000	444	888888888888	999999999999	999999999999
00000000	4444	888888888888	999999999999	999999999999
00000000	44444	888888888888	999999999999	999999999999

[illegible]

SSSSSSSSSS	CCCCCCCCCC	AAAAAAAA	LL	EEEEEEEEEE	PPPPPPPPPP	CCCCCCCCCC
SSSSSSSSSSSS	CCCCCCCCCCCC	AAAAAAAAAA	LL	EEEEEEEEEE	PPPPPPPPPPPP	CCCCCCCCCCCC
SS SS	CC CC	AA AA	LL	EE	PP PP	CC CC
SS	CC	AA AA	LL	EE	PP PP	CC
SS	CC	AA AA	LL	EE	PP PP	CC
SSSSSSSSSS	CC	AAAAAAAAAAAA	LL	EEEEEEEE	PPPPPPPPPP	CC
SSSSSSSSSS	CC	AAAAAAAAAAAA	LL	EEEEEEEE	PPPPPPPPPP	CC
SS	CC	AA AA	LL	EE	PP	CC
SS	CC	AA AA	LL	EE	PP	CC
SS SS	CC CC	AA AA	LL	EE	PP	CC CC
SSSSSSSSSSSS	CCCCCCCCCCCC	AA AA	LLLLLLLLLLLL	EEEEEEEEEEEE	PP	CCCCCCCCCCCC
SSSSSSSSSS	CCCCCCCCCC	AA AA	LLLLLLLLLLLL	EEEEEEEEEEEE	PP	CCCCCCCCCC

```
*****  
*****  
***** PROGRAM VERIFICATION INFORMATION *****  
***** CODE SYSTEM: SCALE-PC VERSION: 4.3 *****  
*****  
*****  
***** PROGRAM: CSAS *****  
***** CREATION DATE: 03/08/96 *****  
***** VOLUME: ENG *****  
***** LIBRARY: G:\SCALE43\WIN_NT\EXE *****  
***** PRODUCTION CODE: CSAS *****  
***** VERSION: 3.1 *****  
***** JOBNAME: SCALE-PC *****  
***** DATE OF EXECUTION: 04/08/99 *****  
***** TIME OF EXECUTION: 10:36:57 *****  
*****
```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

UMS BWR ACCIDENT OF CASK ARRAY: 1.0 GM/CC IN 0.6 GM/CC EX, 300 CM PITCH

\*\*\*\* PROBLEM PARAMETERS \*\*\*\*

```
LIB 27GROUPNDF4 LIBRARY
MXK      11 MIXTURES
MSC      20 COMPOSITION SPECIFICATIONS
IZM      4 MATERIAL ZONES
GE LATTICECELL GEOMETRY
MORE     0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN     0 FUEL SOLUTIONS
```

\*\*\*\* PROBLEM COMPOSITION DESCRIPTION \*\*\*\*

```
SC UO2 STANDARD COMPOSITION
MX      1 MIXTURE NO.
VF      0.9500 VOLUME FRACTION
ROTH    10.9600 THEORETICAL DENSITY
NEL     2 NO. ELEMENTS
ICP     1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        92000 1.00 ATOM/MOLECULE
        92235 4.000 WT%
        92238 96.000 WT%
        8016 2.00 ATOMS/MOLECULE
END
```

```
SC ZIRCALLOY STANDARD COMPOSITION
MX      2 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH    6.5600 THEORETICAL DENSITY
NEL     1 NO. ELEMENTS
ICP     1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        40302 1.00 ATOM/MOLECULE
END
```

```
SC H2O STANDARD COMPOSITION
MX      3 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH    0.9982 THEORETICAL DENSITY
NEL     2 NO. ELEMENTS
ICP     1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        1001 2.00 ATOMS/MOLECULE
        8016 1.00 ATOM/MOLECULE
END
```

```
SC AL STANDARD COMPOSITION
MX      4 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH    2.7020 THEORETICAL DENSITY
NEL     1 NO. ELEMENTS
ICP     1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        13027 1.00 ATOM/MOLECULE
END
```

```
SC SS304 STANDARD COMPOSITION
MX      5 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH    7.9200 THEORETICAL DENSITY
NEL     4 NO. ELEMENTS
ICP     0 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        24304 19.000 WT%
        25055 2.000 WT%
        26304 69.500 WT%
        28304 9.500 WT%
END
```

```
SC AL STANDARD COMPOSITION
MX      6 MIXTURE NO.
VF      0.8706 VOLUME FRACTION
ROTH    2.6849 SPECIFIED DENSITY
NEL     1 NO. ELEMENTS
ICP     1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        13027 1.00 ATOM/MOLECULE
END
```

```
SC B-10 STANDARD COMPOSITION
MX      6 MIXTURE NO.
VF      0.0137 VOLUME FRACTION
ROTH    2.6849 SPECIFIED DENSITY
NEL     1 NO. ELEMENTS
ICP     1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
        5019 1.00 ATOM/MOLECULE
END
```

```
SC B-11 STANDARD COMPOSITION
MX      6 MIXTURE NO.
VF      0.0830 VOLUME FRACTION
```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
ROTH 2.6849 SPECIFIED DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
5011 1.00 ATOM/MOLECULE
END
```

```
SC C STANDARD COMPOSITION
MX 6 MIXTURE NO.
VF 0.0281 VOLUME FRACTION
ROTH 2.6849 SPECIFIED DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
6012 1.00 ATOM/MOLECULE
END
```

```
SC CARBONSTEEL STANDARD COMPOSITION
MX 7 MIXTURE NO.
VF 1.0000 VOLUME FRACTION
ROTH 7.8212 THEORETICAL DENSITY
NEL 2 NO. ELEMENTS
ICP 0 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
26000 99.000 WT%
6012 1.000 WT%
END
```

```
SC PB STANDARD COMPOSITION
MX 8 MIXTURE NO.
VF 1.0000 VOLUME FRACTION
ROTH 11.3440 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
82000 1.00 ATOM/MOLECULE
END
```

```
SC B-10 STANDARD COMPOSITION
MX 9 MIXTURE NO.
DEN 8.5530E-05 ATOMIC DENSITY
ROTH 1.0000 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
5010 1.00 ATOM/MOLECULE
END
```

```
SC B-11 STANDARD COMPOSITION
MX 9 MIXTURE NO.
DEN 3.4220E-04 ATOMIC DENSITY
ROTH 1.0000 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
5011 1.00 ATOM/MOLECULE
END
```

```
SC AL STANDARD COMPOSITION
MX 9 MIXTURE NO.
DEN 7.7630E-03 ATOMIC DENSITY
ROTH 2.7020 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
13027 1.00 ATOM/MOLECULE
END
```

```
SC H STANDARD COMPOSITION
MX 9 MIXTURE NO.
DEN 5.8540E-02 ATOMIC DENSITY
ROTH 1.0000 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
1001 1.00 ATOM/MOLECULE
END
```

```
SC O STANDARD COMPOSITION
MX 9 MIXTURE NO.
DEN 2.6090E-02 ATOMIC DENSITY
ROTH 1.0000 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
8015 1.00 ATOM/MOLECULE
END
```

```
SC C STANDARD COMPOSITION
MX 9 MIXTURE NO.
DEN 2.2640E-02 ATOMIC DENSITY
ROTH 2.1000 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
6012 1.00 ATOM/MOLECULE
END
```

```
SC N STANDARD COMPOSITION
MX 9 MIXTURE NO.
DEN 1.3940E-03 ATOMIC DENSITY
ROTH 1.0000 THEORETICAL DENSITY
```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
7014     1.00 ATOM/MOLECULE
END
```

```
SC H2O    STANDARD COMPOSITION
MX      10 MIXTURE NO.
VF      0.6000 VOLUME FRACTION
ROTH    0.9982 THEORETICAL DENSITY
NEL      2 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
1001     2.00 ATOMS/MOLECULE
8016     1.00 ATOM/MOLECULE
END
```

```
SC H2O    STANDARD COMPOSITION
MX      11 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH    0.9982 THEORETICAL DENSITY
NEL      2 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP    293.0 DEG KELVIN
1001     2.00 ATOMS/MOLECULE
8016     1.00 ATOM/MOLECULE
END
```

\*\*\* PROBLEM GEOMETRY \*\*\*

```
CTP SQUAREPITCH CELL TYPE
PITCH    1.4529 CM CENTER TO CENTER SPACING
FUELOD   0.9055 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL     1 MIXTURE NO. OF FUEL
MMOD      3 MIXTURE NO. OF MODERATOR
CLADOD   1.0770 CM CLAD OUTER DIAMETER
MCLAD     2 MIXTURE NO. OF CLAD
GAPOD    0.9246 CM GAP OUTER DIAMETER
MGAP      11 MIXTURE NO. OF GAP
```

ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY

```
ZONE 1 IS FUEL
ZONE 2 IS GAP
ZONE 3 IS CLAD
ZONE 4 IS MOD
```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```

***
***          UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH
***
***** DATA LIBRARY INFORMATION *****
***
***          UNIT          DATA SET NAME          VOLUME          UNIT FUNCTION
***          NUMBER          NAME          NAME
***          -----          -
***          89      G:\scale43\DATA LIB\FT89F001          STANDARD COMPOSITION LIBRARY
***          82      G:\scale43\DATA LIB\FT82F001          CROSS SECTION LIBRARY
***          11      D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Va          SHORT CROSS SECTION LIBRARY
***          90      D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Va          INPUT DATA DIRECT ACCESS
***
*****
***          STANDARD COMPOSITION LIBRARY DATA
***          -----
***          UNIT NUMBER : 89
***          DATASET NAME : G:\scale43\DATA LIB\FT89F001
***          LIBRARY TITLE: SCALE-4 STANDARD COMPOSITION LIBRARY
***                          637 STANDARD COMPOSITIONS, 490 NUCLIDES
***                          90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRIBUTIONS.
***          CREATION DATE: 6/30/95
***
***          CROSS SECTION LIBRARY DATA
***          -----
***          UNIT NUMBER : 82
***          DATASET NAME : G:\scale43\DATA LIB\FT82F001
***          LIBRARY TITLE: SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
***                          BASED ON ENDF-B VERSION 4 DATA
***                          COMPILED FOR NRC      1/27/89
***                          LAST UPDATED
***                          L.M.PETRIE - ORNL
***                          08/12/94
***
*****
KK  EEEEEEEEEEE NN NN OOOOOOOOOO VV VV

```

CSAS Input &amp; Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

[illegible][illegible][illegible][illegible]

6.6.2-63



CSAS Input &amp; Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

[illegible]

```
*****  
***** PROGRAM VERIFICATION INFORMATION *****  
***** CODE SYSTEM: SCALE-PC VERSION: 4.3 *****  
*****  
*****  
***** PROGRAM: 000009 *****  
***** CREATION DATE: 03/08/96 *****  
*****  
***** VOLUME: ENG *****  
***** LIBRARY: G:\SCALE43\WTR_NT\EXE *****  
*****  
***** PRODUCTION CODE: KENOVA *****  
***** VERSION: 3.1 *****  
***** JOBNAM: SCALE-PC *****  
***** DATE OF EXECUTION: 04/08/99 *****  
***** TIME OF EXECUTION: 10:37:18 *****
```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

*** UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH ***			
***** NUMERIC PARAMETERS *****			
TME	MAXIMUM PROBLEM TIME (MIN)	*****	
TBA	TIME PER GENERATION (MIN)	5.00	
GKN	NUMBER OF GENERATIONS	803	
NPG	NUMBER PER GENERATION	1000	
NSK	NUMBER OF GENERATIONS TO BE SKIPPED	3	
BEG	BEGINNING GENERATION NUMBER	1	
RES	GENERATIONS BETWEEN CHECKPOINTS	0	
XLD	NUMBER OF EXTRA 1-D CROSS SECTIONS	1	
NBK	NEUTRON BANK SIZE	1025	
XNB	EXTRA POSITIONS IN NEUTRON BANK	0	
NFB	FISSION BANK SIZE	1000	
XFB	EXTRA POSITIONS IN FISSION BANK	0	
WTA	DEFAULT VALUE OF WEIGHT AVERAGE	0.5000	
WTH	WEIGHT HIGH FOR SPLITTING	3.0000	
WTL	WEIGHT LOW FOR RUSSIAN ROULETTE	0.3333	
RND	STARTING RANDOM NUMBER	BB827100001	
NBS	NUMBER OF D.A. BLOCKS ON UNIT 8	200	
NLS	LENGTH OF D.A. BLOCKS ON UNIT 8	512	
ADJ	MODE OF CALCULATION	FORWARD	
	INPUT DATA WRITTEN ON RESTART UNIT	NO	
	BINARY DATA INTERFACE	YES	

```

*****
***                                     UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH ***
***
***** LOGICAL PARAMETERS *****
***
*** RUN EXECUTE PROBLEM AFTER CHECKING DATA YES          PLT PLOT PICTURE MAP(S) NO **
*** FLX COMPUTE FLUX NO                                PDN COMPUTE FISSION DENSITIES NO **
*** SMU COMPUTE AVG UNIT SELF-MULTIPLICATION NO          NUB COMPUTE NU-BAR & AVG FISSION GROUP YES **
*** MKU COMPUTE MATRIX K-EFF BY UNIT NUMBER NO          MKP COMPUTE MATRIX K-EFF BY UNIT LOCATION NO **
*** CKU COMPUTE COFACTOR K-EFF BY UNIT NUMBER NO        CKP COMPUTE COFACTOR K-EFF BY UNIT LOCATION NO **
*** FMU PRINT FISS PROD MATRIX BY UNIT NUMBER NO        FMP PRINT FISS PROD MATRIX BY UNIT LOCATION NO **
*** MKH COMPUTE MATRIX K-EFF BY HOLE NUMBER NO          MKA COMPUTE MATRIX K-EFF BY ARRAY NUMBER NO **
*** CRH COMPUTE COFACTOR K-EFF BY HOLE NUMBER NO        CKA COMPUTE COFACTOR K-EFF BY ARRAY NUMBER NO **
*** FMH PRINT FISS PROD MATRIX BY HOLE NUMBER NO        FMA PRINT FISS PROD MATRIX BY ARRAY NUMBER NO **
*** HHL COLLECT MATRIX BY HIGHEST HOLE LEVEL NO         HAL COLLECT MATRIX BY HIGHEST ARRAY LEVEL NO **
*** AMX PRINT ALL MIXED CROSS SECTIONS NO               FAR PRINT FIS. AND ABS. BY REGION NO **
*** XS1 PRINT 1-D MIXTURE X-SECTIONS NO                 GAS PRINT FAR BY GROUP NO **
*** XS2 PRINT 2-D MIXTURE X-SECTIONS NO                 PAX PRINT XSEC-ALBEDO CORRELATION TABLES NO **
*** XAP PRINT MIXTURE ANGLES & PROBABILITIES NO          PWT PRINT WEIGHT AVERAGE ARRAY NO **
*** PKI PRINT FISSION SPECTRUM NO                       PGM PRINT INPUT GEOMETRY NO **
*** FLD PRINT EXTRA 1-D CROSS SECTIONS NO              BUG PRINT DEBUG INFORMATION NO **
*** TRK PRINT TRACKING INFORMATION NO
***
*****
***** PARAMETER INPUT COMPLETED *****
*****
..... D_IO'S WERE USED READING THE PARAMETER DATA .....
***** DATA READING COMPLETED *****
*****
*****
***                                     UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH ***
***
UNIT      DATA SET NAME      VOLUME     UNIT FUNCTION
NUMBER
-----
***   XSC  14    D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Va    MIXED CROSS SECTIONS ***
***   ALB  79    G:\scale43\DATA LIB\FT79F001                INPUT ALBEDOS          ***
***   WTS  80    G:\scale43\DATA LIB\FT80F001                INPUT WEIGHTS          ***
***   SKT  16    UNKNOWN                                  WRITE SCRATCH DATA    ***
***   BIN  95    D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Va    BINARY INPUT DATA     ***
***   RST  95    D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Va    READ RESTART DATA     ***
***   LIB  4     D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Va    INPUT AMPX WORKING LIBRARY ***
***       8     D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Va    INPUT DATA DIRECT ACCESS ***
***       9     UNKNOWN                                  SUPER GROUPED DIRECT ACCESS ***
***      10    UNKNOWN                                  XSEC MIXING DIRECT ACCESS ***
*****
..... D_IO'S WERE USED PREPARING INPUT DATA .....
CROSS SECTIONS READ FROM THE AMPX WORKING LIBRARY ON UNIT 1

```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```

UMS_BWR_TOT ACCIDENT OP_CASK ARRAY 1.0 GM/CC IN 0.5 GM/CC EXP 300 CM PITCH
MIXING TABLE
NUMBER OF SCATTERING ANGLES = 2
CROSS SECTION MESSAGE THRESHOLD = 3.0E-05

MIXTURE = 1 DENSITY(G/CC) = 10.412
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
1008016 4.64617E-02 1.18487E-01 8016 15.9904 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED
08/12/94
1092235 9.40641E-04 3.52606E-02 92235 235.0441 URANIUM-235 ENDF/B-IV MAT 1261 UPDATED
08/12/94
1092238 2.22902E-02 8.46253E-01 92238 238.0510 URANIUM-238 ENDF/B-IV MAT 1262 UPDATED
08/12/94

MIXTURE = 2 DENSITY(G/CC) = 6.5600
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
2040302 4.33078E-02 1.00000E+00 40000 91.2196 ZIRCALLOY ENDF/B-IV MAT 1284 UPDATED
08/12/94

MIXTURE = 3 DENSITY(G/CC) = 0.99817
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
3001001 6.67692E-02 1.11927E-01 1001 1.0077 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED
08/12/94
3008016 3.33846E-02 8.88074E-01 8016 15.9904 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED
08/12/94

MIXTURE = 4 DENSITY(G/CC) = 2.7020
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
4013027 6.03066E-02 1.00000E+00 13027 26.9818 AL-27 1193 218 GP 040375(5) UPDATED
08/12/94

MIXTURE = 5 DENSITY(G/CC) = 7.9200
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
5024304 1.74286E-02 1.90000E-01 24000 51.9957 CR 1191 WT SS-304(1/EST) P-3 293K SP-5+4(42375) UPDATED
08/12/94
5025055 1.73633E-03 1.99999E-02 25055 54.9379 MANGANESE-55 ENDF/B-IV MAT 1197 UPDATED
08/12/94
5026304 5.93579E-02 6.95000E-01 26000 55.8447 PB 1192 WT SS-304(1/EST) P-3 293K SP-5+4(42375) UPDATED
08/12/94
5028304 7.72070E-03 9.50001E-02 28000 58.6872 NI 1190 WT SS-304(1/EST) P-3 293K SP-5+4(42375) UPDATED
08/12/94

MIXTURE = 6 DENSITY(G/CC) = 2.6726
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
6005010 2.21228E-03 1.37634E-02 5010 10.0130 B-10 1273 218NGP 042375 P-3 293K UPDATED
08/12/94
6005011 1.21898E-02 8.33855E-02 5011 11.0096 BORON-11 ENDF/B-IV MAT 1160 UPDATED
08/12/94
6006012 3.78620E-03 2.82300E-02 6000 12.0001 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED
08/12/94
6013027 5.21707E-02 8.74621E-01 13027 26.9818 AL-27 1193 218 GP 040375(5) UPDATED
08/12/94

MIXTURE = 7 DENSITY(G/CC) = 7.8212
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
7006012 3.92503E-03 1.00001E-02 6000 12.0001 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED
08/12/94
7026000 8.34982E-02 9.90000E-01 26000 55.8447 IRON ENDF/B-IV MAT 1192 UPDATED
08/12/94

MIXTURE = 8 DENSITY(G/CC) = 11.344
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
8082000 3.29690E-02 1.00000E+00 82000 207.2100 PB 1288 218NGP 042375 P-3 293K UPDATED
08/12/94

MIXTURE = 9 DENSITY(G/CC) = 1.6298
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
9001001 5.85400E-02 6.01023E-02 1001 1.0077 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED
08/12/94
9005010 8.55300E-05 8.72589E-04 5010 10.0130 B-10 1273 218NGP 042375 P-3 293K UPDATED
08/12/94
9005011 3.42200E-04 3.83863E-03 5011 11.0096 BORON-11 ENDF/B-IV MAT 1160 UPDATED
08/12/94
9006012 2.26400E-02 2.76813E-01 6000 12.0001 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED
08/12/94
9007014 1.39400E-03 1.98893E-02 7014 14.0033 NITROGEN-14 ENDF/B-IV MAT 1275 UPDATED
08/12/94
9008016 2.60900E-02 4.25068E-01 8016 15.9904 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED
08/12/94
9013027 7.76300E-03 2.13416E-01 13027 26.9818 AL-27 1193 218 GP 040375(5) UPDATED
08/12/94

MIXTURE = 10 DENSITY(G/CC) = 0.59890
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
10001001 4.00615E-02 1.11927E-01 1001 1.0077 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED
08/12/94
10008016 2.00308E-02 8.88074E-01 8016 15.9904 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED
08/12/94

MIXTURE = 11 DENSITY(G/CC) = 0.99817
NUCLIDE ATOM-DENS. WGT. FRAC. ZA AWT NUCLIDE TITLE
11001001 6.67692E-02 1.11927E-01 1001 1.0077 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED
08/12/94

```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

11008016 3.33846E-02 8.88074E-01 8016 15.9904 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94

```

3001001 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED 08/12/94
9001001 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED 08/12/94
10001001 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED 08/12/94
11001001 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED 08/12/94
6005010 B-10 1273 218NGP 042375 P-3 293K UPDATED 08/12/94
9005010 B-10 1273 218NGP 042375 P-3 293K UPDATED 08/12/94
6005011 BORON-11 ENDF/B-IV MAT 1160 UPDATED 08/12/94
9005011 BORON-11 ENDF/B-IV MAT 1160 UPDATED 08/12/94
6006012 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED 08/12/94
7006012 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED 08/12/94
9006012 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED 08/12/94
9007014 NITROGEN-14 ENDF/B-IV MAT 1275 UPDATED 08/12/94
1008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
3008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
9008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
10008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
11008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
4013027 AL-27 1193 218 GP 040375(5) UPDATED 08/12/94
6013027 AL-27 1193 218 GP 040375(5) UPDATED 08/12/94
9013027 AL-27 1193 218 GP 040375(5) UPDATED 08/12/94
5024304 CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375) UPDATED 08/12/94
5025055 MANGANESE-55 ENDF/B-IV MAT 1197 UPDATED 08/12/94
7026000 IRON ENDF/B-IV MAT 1192 UPDATED 08/12/94
5026304 FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375) UPDATED 08/12/94
5028304 NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375) UPDATED 08/12/94
2040302 ZIRCALLOY ENDF/B-IV MAT 1284 UPDATED 08/12/94
8082000 PB 1288 218NGP 042375 P-3 293K UPDATED 08/12/94
1092235 URANIUM-235 ENDF/B-IV MAT 1261 UPDATED 08/12/94
1092238 URANIUM-238 ENDF/B-IV MAT 1262 UPDATED 08/12/94

```

KENO MESSAGE NUMBER K5-222 1 TRANSFERS FOR MIXTURE 3 WERE CORRECTED FOR BAD MOMENTS

KENO MESSAGE NUMBER K5-222 1 TRANSFERS FOR MIXTURE 10 WERE CORRECTED FOR BAD MOMENTS

KENO MESSAGE NUMBER K5-222 1 TRANSFERS FOR MIXTURE 11 WERE CORRECTED FOR BAD MOMENTS

0.10'S WERE USED MIXING CROSS-SECTIONS

1-D CROSS SECTION ARRAY ID NUMBERS  
1 2002 1452 27 18 1018

0.10'S WERE USED PREPARING THE CROSS SECTIONS

```

*****
*** UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC BK; 300 CM PITCH ***
***
***** ADDITIONAL INFORMATION *****
***
*** NUMBER OF ENERGY GROUPS 27 USE LATTICE GEOMETRY YES ***
*** NO. OF FISSION SPECTRUM SOURCE GROUP 1 GLOBAL ARRAY NUMBER 4 ***
*** NO. OF SCATTERING ANGLES IN XSECS 2 NUMBER OF UNITS IN THE GLOBAL X DIR. 1 ***
*** ENTRIES/NEUTRON IN THE NEUTRON BANK 25 NUMBER OF UNITS IN THE GLOBAL Y DIR. 1 ***
*** ENTRIES/NEUTRON IN THE FISSION BANK 18 NUMBER OF UNITS IN THE GLOBAL Z DIR. 4 ***
*** NUMBER OF MIXTURES USED 10 USE A GLOBAL REFLECTOR YES ***
*** NUMBER OF BIAS ID'S USED 1 USE NESTED HOLES YES ***
*** NUMBER OF DIFFERENTIAL ALBEDOS USED 0 NUMBER OF HOLES 291 ***
*** TOTAL INPUT GEOMETRY REGIONS 222 MAXIMUM HOLE NESTING LEVEL 3 ***
*** NUMBER OF GEOMETRY REGIONS USED 222 USE NESTED ARRAYS YES ***
*** LARGEST GEOMETRY UNIT NUMBER 143 NUMBER OF ARRAYS USED 4 ***
*** LARGEST ARRAY NUMBER 4 MAXIMUM ARRAY NESTING LEVEL 2 ***
***
*** +X BOUNDARY CONDITION MIRROR -X BOUNDARY CONDITION MIRROR ***
*** +Y BOUNDARY CONDITION MIRROR -Y BOUNDARY CONDITION MIRROR ***
*** +Z BOUNDARY CONDITION PER -Z BOUNDARY CONDITION PER ***
***

```

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

VOLUME FRACTION OF FISSIONABLE MATERIAL IN THE CORE=0.16618E+02

START TYPE 0 WAS USED

THE NEUTRONS WERE STARTED WITH A FLAT DISTRIBUTION IN A CUBOID DEFINED BY:

+X= 1.50000E+02 -X=-1.50000E+02 +Y= 1.50000E+02 -Y=-1.50000E+02 +Z= 9.71560E+00 -Z= 0.00000E+00

THE FLAG TO START NEUTRONS IN THE REFLECTOR WAS TURNED OFF

0.90817 MINUTES WERE REQUIRED FOR STARTING. TOTAL ELAPSED TIME IS 0.93867 MINUTES.

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

UMS\_BWR\_TC, ACCIDENT\_OP, CASK\_ARRAY, 1.0 GM/CC IN, 0.6 GM/CC EX, 300 CM PITCH

GENERATION	K-EFFECTIVE	ELAPSED TIME	AVERAGE	AVG K-EFF	MATRIX	MATRIX K-EFF
KENO MESSAGE NUMBER K5-132	WARNING... ONLY	MINUTES	K-EFFECTIVE	DEVIATION	K-EFFECTIVE	DEVIATION
1	8.91976E-01	1.02067E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	8.34560E-01	1.10217E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	9.18523E-01	1.17717E+00	9.18523E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	8.91156E-01	1.25417E+00	9.04839E-01	1.36835E-02	0.00000E+00	0.00000E+00
5	8.72353E-01	1.32917E+00	8.94010E-01	1.34042E-02	0.00000E+00	0.00000E+00
6	8.98320E-01	1.40700E+00	8.95088E-01	9.53925E-03	0.00000E+00	0.00000E+00
7	8.97553E-01	1.48300E+00	8.95581E-01	7.40550E-03	0.00000E+00	0.00000E+00
8	9.15934E-01	1.56083E+00	8.98973E-01	6.93310E-03	0.00000E+00	0.00000E+00
9	8.45147E-01	1.63867E+00	8.91283E-01	9.66758E-03	0.00000E+00	0.00000E+00
10	8.72145E-01	1.71367E+00	8.88891E-01	8.70746E-03	0.00000E+00	0.00000E+00
11	9.22529E-01	1.78783E+00	8.92629E-01	8.54049E-03	0.00000E+00	0.00000E+00
12	9.28193E-01	1.86200E+00	8.96185E-01	8.42615E-03	0.00000E+00	0.00000E+00
13	8.93256E-01	1.93983E+00	8.95919E-01	7.62638E-03	0.00000E+00	0.00000E+00
14	9.55887E-01	2.01117E+00	9.00916E-01	8.56980E-03	0.00000E+00	0.00000E+00
15	9.27464E-01	2.08617E+00	9.02958E-01	8.14329E-03	0.00000E+00	0.00000E+00
16	9.00227E-01	2.16217E+00	9.02763E-01	7.54174E-03	0.00000E+00	0.00000E+00
17	9.14887E-01	2.23633E+00	9.03571E-01	7.06735E-03	0.00000E+00	0.00000E+00
18	9.16225E-01	2.31050E+00	9.04362E-01	6.65803E-03	0.00000E+00	0.00000E+00
19	8.55365E-01	2.39017E+00	9.01480E-01	6.88630E-03	0.00000E+00	0.00000E+00
20	9.02715E-01	2.46517E+00	9.01549E-01	6.49282E-03	0.00000E+00	0.00000E+00
21	8.87650E-01	2.54033E+00	9.00817E-01	6.18500E-03	0.00000E+00	0.00000E+00
22	9.51076E-01	2.61633E+00	9.03330E-01	6.38308E-03	0.00000E+00	0.00000E+00
23	8.95055E-01	2.69050E+00	9.02936E-01	6.08429E-03	0.00000E+00	0.00000E+00
24	8.54121E-01	2.76733E+00	9.00717E-01	6.21101E-03	0.00000E+00	0.00000E+00
25	9.59268E-01	2.84233E+00	9.03263E-01	6.45776E-03	0.00000E+00	0.00000E+00
26	8.63072E-01	2.92200E+00	9.01588E-01	6.40560E-03	0.00000E+00	0.00000E+00
27	8.82049E-01	2.99433E+00	9.00807E-01	6.19355E-03	0.00000E+00	0.00000E+00
28	9.05072E-01	3.06850E+00	9.00971E-01	5.95283E-03	0.00000E+00	0.00000E+00
29	9.15060E-01	3.14267E+00	9.01493E-01	5.75184E-03	0.00000E+00	0.00000E+00
30	8.93805E-01	3.21683E+00	9.01218E-01	5.54940E-03	0.00000E+00	0.00000E+00
31	8.73765E-01	3.28733E+00	9.00271E-01	5.43767E-03	0.00000E+00	0.00000E+00
32	9.13910E-01	3.36150E+00	9.00726E-01	5.27292E-03	0.00000E+00	0.00000E+00
33	9.01364E-01	3.43733E+00	9.00747E-01	5.10003E-03	0.00000E+00	0.00000E+00
34	9.38928E-01	3.51150E+00	9.01940E-01	5.08019E-03	0.00000E+00	0.00000E+00
35	9.29078E-01	3.58567E+00	9.02762E-01	4.99204E-03	0.00000E+00	0.00000E+00
36	9.54558E-01	3.65983E+00	9.04285E-01	5.07694E-03	0.00000E+00	0.00000E+00
37	9.07369E-01	3.73500E+00	9.04374E-01	4.93054E-03	0.00000E+00	0.00000E+00
38	9.23832E-01	3.80717E+00	9.04914E-01	4.82201E-03	0.00000E+00	0.00000E+00
39	8.71953E-01	3.88050E+00	9.04023E-01	4.77373E-03	0.00000E+00	0.00000E+00
40	9.11720E-01	3.95183E+00	9.04226E-01	4.65083E-03	0.00000E+00	0.00000E+00
41	9.22057E-01	4.02333E+00	9.04683E-01	4.55302E-03	0.00000E+00	0.00000E+00
42	9.11608E-01	4.09933E+00	9.04856E-01	4.44111E-03	0.00000E+00	0.00000E+00

781	9.16381E-01	5.86870E+01	9.10811E-01	8.03059E-04	0.00000E+00	0.00000E+00
782	8.99741E-01	5.87620E+01	9.10797E-01	8.02154E-04	0.00000E+00	0.00000E+00
783	8.77045E-01	5.88362E+01	9.10754E-01	8.02291E-04	0.00000E+00	0.00000E+00
784	9.10366E-01	5.89093E+01	9.10753E-01	8.01264E-04	0.00000E+00	0.00000E+00
785	9.59592E-01	5.89835E+01	9.10815E-01	8.02668E-04	0.00000E+00	0.00000E+00
786	9.15223E-01	5.90558E+01	9.10821E-01	8.01663E-04	0.00000E+00	0.00000E+00
787	8.88340E-01	5.91300E+01	9.10792E-01	8.01153E-04	0.00000E+00	0.00000E+00
788	9.23618E-01	5.92042E+01	9.10809E-01	8.00299E-04	0.00000E+00	0.00000E+00
789	8.93259E-01	5.92820E+01	9.10786E-01	7.99593E-04	0.00000E+00	0.00000E+00
790	8.99815E-01	5.93598E+01	9.10773E-01	7.98699E-04	0.00000E+00	0.00000E+00
791	8.91726E-01	5.94348E+01	9.10748E-01	7.98051E-04	0.00000E+00	0.00000E+00
792	9.03663E-01	5.95100E+01	9.10739E-01	7.97091E-04	0.00000E+00	0.00000E+00
793	9.13110E-01	5.95840E+01	9.10765E-01	7.96507E-04	0.00000E+00	0.00000E+00
794	8.98368E-01	5.96600E+01	9.10750E-01	7.95655E-04	0.00000E+00	0.00000E+00
795	9.10513E-01	5.97342E+01	9.10750E-01	7.94551E-04	0.00000E+00	0.00000E+00
796	9.15524E-01	5.98083E+01	9.10756E-01	7.93672E-04	0.00000E+00	0.00000E+00
797	9.22655E-01	5.98835E+01	9.10770E-01	7.92815E-04	0.00000E+00	0.00000E+00
798	8.84725E-01	5.99603E+01	9.10738E-01	7.92494E-04	0.00000E+00	0.00000E+00
799	9.12757E-01	6.00327E+01	9.10740E-01	7.91503E-04	0.00000E+00	0.00000E+00
800	9.48628E-01	6.01068E+01	9.10788E-01	7.91935E-04	0.00000E+00	0.00000E+00
801	9.07179E-01	6.01837E+01	9.10783E-01	7.90956E-04	0.00000E+00	0.00000E+00
802	9.14006E-01	6.02578E+01	9.10787E-01	7.89977E-04	0.00000E+00	0.00000E+00
803	9.12932E-01	6.03320E+01	9.10790E-01	7.88995E-04	0.00000E+00	0.00000E+00

KENO MESSAGE NUMBER K5-123 EXECUTION TERMINATED DUE TO COMPLETION OF THE SPECIFIED NUMBER OF GENERATIONS

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

UMS BWR TO ACCIDENT OP CASK ARRAY 1.0 GM/CC TO 1.5 GM/CC 1.5 GM/CC 300 CM PITCH

LIFETIME = 4.73026E-05 + OR - 8.19786E-08 GENERATION TIME = 3.71808E-05 + OR - 5.77300E-08  
NU BAR = 2.43758E+00 + OR - 6.41447E-05 AVERAGE FISSION GROUP = 2.23967E+01 + OR - 3.67342E-03  
ENERGY (eV) OF THE AVERAGE LETHARGY CAUSING FISSION = 1.72843E-01 + OR - 5.37154E-04

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.91078	+ OR - 0.00079	0.90999 TO 0.91157	0.90920 TO 0.91236	0.90841 TO 0.91315	800000
4	0.91080	+ OR - 0.00079	0.91001 TO 0.91160	0.90922 TO 0.91239	0.90843 TO 0.91318	799000
5	0.91085	+ OR - 0.00079	0.91006 TO 0.91164	0.90927 TO 0.91243	0.90848 TO 0.91322	798000
6	0.91087	+ OR - 0.00079	0.91008 TO 0.91166	0.90929 TO 0.91245	0.90850 TO 0.91324	797000
7	0.91089	+ OR - 0.00079	0.91009 TO 0.91168	0.90930 TO 0.91247	0.90851 TO 0.91326	796000
8	0.91088	+ OR - 0.00079	0.91009 TO 0.91167	0.90929 TO 0.91246	0.90850 TO 0.91326	795000
9	0.91096	+ OR - 0.00079	0.91017 TO 0.91175	0.90938 TO 0.91254	0.90859 TO 0.91333	794000
10	0.91101	+ OR - 0.00079	0.91022 TO 0.91180	0.90943 TO 0.91259	0.90864 TO 0.91338	793000
11	0.91100	+ OR - 0.00079	0.91021 TO 0.91179	0.90942 TO 0.91258	0.90863 TO 0.91337	792000
12	0.91097	+ OR - 0.00079	0.91018 TO 0.91176	0.90939 TO 0.91256	0.90860 TO 0.91335	791000
17	0.91093	+ OR - 0.00079	0.91014 TO 0.91172	0.90934 TO 0.91251	0.90855 TO 0.91331	786000
22	0.91098	+ OR - 0.00079	0.91019 TO 0.91177	0.90940 TO 0.91257	0.90860 TO 0.91336	781000
27	0.91111	+ OR - 0.00079	0.91032 TO 0.91190	0.90954 TO 0.91269	0.90875 TO 0.91348	776000
...						
772	0.91112	+ OR - 0.00384	0.90728 TO 0.91495	0.90344 TO 0.91879	0.89961 TO 0.92263	31000
777	0.91057	+ OR - 0.00424	0.90634 TO 0.91481	0.90210 TO 0.91904	0.89786 TO 0.92328	26000
782	0.91054	+ OR - 0.00435	0.90619 TO 0.91488	0.90184 TO 0.91923	0.89750 TO 0.92357	21000
787	0.91067	+ OR - 0.00402	0.90664 TO 0.91469	0.90262 TO 0.91872	0.89859 TO 0.92274	16000
792	0.91442	+ OR - 0.00499	0.90943 TO 0.91941	0.90444 TO 0.92439	0.89945 TO 0.92938	11000
797	0.91337	+ OR - 0.00837	0.90500 TO 0.92174	0.89663 TO 0.93012	0.88825 TO 0.93849	6000



Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

UMS\_BWR\_TC, ACCIDENT OP, CASK ARRAY, 1.0 GM/CC IN, 0.6 GM/CC EX, 300 CM PITCH

FREQUENCY FOR GENERATIONS 4 TO 803

0.8444	TO	0.8480	**
0.8480	TO	0.8515	**
0.8515	TO	0.8551	**
0.8551	TO	0.8586	**
0.8586	TO	0.8621	*****
0.8621	TO	0.8657	*****
0.8657	TO	0.8692	*****
0.8692	TO	0.8728	*****
0.8728	TO	0.8763	*****
0.8763	TO	0.8798	*****
0.8798	TO	0.8834	*****
0.8834	TO	0.8869	*****
0.8869	TO	0.8905	*****
0.8905	TO	0.8940	*****
0.8940	TO	0.8975	*****
0.8975	TO	0.9011	*****
0.9011	TO	0.9046	*****
0.9046	TO	0.9082	*****
0.9082	TO	0.9117	*****
0.9117	TO	0.9152	*****
0.9152	TO	0.9188	*****
0.9188	TO	0.9223	*****
0.9223	TO	0.9259	*****
0.9259	TO	0.9294	*****
0.9294	TO	0.9329	*****
0.9329	TO	0.9365	*****
0.9365	TO	0.9400	*****
0.9400	TO	0.9436	*****
0.9436	TO	0.9471	*****
0.9471	TO	0.9506	*****
0.9506	TO	0.9542	*****
0.9542	TO	0.9577	*****
0.9577	TO	0.9613	*****
0.9613	TO	0.9648	*****
0.9648	TO	0.9683	*****
0.9683	TO	0.9719	*****
0.9719	TO	0.9754	*****
0.9754	TO	0.9790	*****
0.9790	TO	0.9825	*****

UMS\_BWR\_TC, ACCIDENT OP, CASK ARRAY, 1.0 GM/CC IN, 0.6 GM/CC EX, 300 CM PITCH

FREQUENCY FOR GENERATIONS 204 TO 803

0.8444	TO	0.8480	**
0.8480	TO	0.8515	**
0.8515	TO	0.8551	**
0.8551	TO	0.8586	**
0.8586	TO	0.8621	*****
0.8621	TO	0.8657	*****
0.8657	TO	0.8692	*****
0.8692	TO	0.8728	*****
0.8728	TO	0.8763	*****
0.8763	TO	0.8798	*****
0.8798	TO	0.8834	*****
0.8834	TO	0.8869	*****
0.8869	TO	0.8905	*****
0.8905	TO	0.8940	*****
0.8940	TO	0.8975	*****
0.8975	TO	0.9011	*****
0.9011	TO	0.9046	*****
0.9046	TO	0.9082	*****
0.9082	TO	0.9117	*****
0.9117	TO	0.9152	*****
0.9152	TO	0.9188	*****
0.9188	TO	0.9223	*****
0.9223	TO	0.9259	*****
0.9259	TO	0.9294	*****
0.9294	TO	0.9329	*****
0.9329	TO	0.9365	*****
0.9365	TO	0.9400	*****
0.9400	TO	0.9436	*****
0.9436	TO	0.9471	*****
0.9471	TO	0.9506	*****
0.9506	TO	0.9542	*****
0.9542	TO	0.9577	*****
0.9577	TO	0.9613	*****
0.9613	TO	0.9648	*****
0.9648	TO	0.9683	*****
0.9683	TO	0.9719	*****
0.9719	TO	0.9754	*****
0.9754	TO	0.9790	*****
0.9790	TO	0.9825	*****

**Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)**

UMS BWR FC, ACCIDENT OF, CASK ARRAY, 1.0 GM/CC IN, 0.6 GM/CC EX, 300 CM PITCH

FREQUENCY FOR GENERATIONS 404 TO 803

0.8444 TO 0.8480  
0.8480 TO 0.8515  
0.8515 TO 0.8551  
0.8551 TO 0.8586  
0.8586 TO 0.8621  
0.8621 TO 0.8657  
0.8657 TO 0.8692  
0.8692 TO 0.8728  
0.8728 TO 0.8763  
0.8763 TO 0.8798  
0.8798 TO 0.8834  
0.8834 TO 0.8869  
0.8869 TO 0.8905  
0.8905 TO 0.8940  
0.8940 TO 0.8975  
0.8975 TO 0.9011  
0.9011 TO 0.9046  
0.9046 TO 0.9082  
0.9082 TO 0.9117  
0.9117 TO 0.9152  
0.9152 TO 0.9188  
0.9188 TO 0.9223  
0.9223 TO 0.9259  
0.9259 TO 0.9294  
0.9294 TO 0.9329  
0.9329 TO 0.9365  
0.9365 TO 0.9400  
0.9400 TO 0.9436  
0.9436 TO 0.9471  
0.9471 TO 0.9506  
0.9506 TO 0.9542  
0.9542 TO 0.9577  
0.9577 TO 0.9613  
0.9613 TO 0.9648  
0.9648 TO 0.9683  
0.9683 TO 0.9719  
0.9719 TO 0.9754  
0.9754 TO 0.9790  
0.9790 TO 0.9825

UMS BWR FC, ACCIDENT OF, CASK ARRAY, 1.0 GM/CC IN, 0.6 GM/CC EX, 300 CM PITCH

FREQUENCY FOR GENERATIONS 604 TO 803

0.8444 TO 0.8480  
0.8480 TO 0.8515  
0.8515 TO 0.8551  
0.8551 TO 0.8586  
0.8586 TO 0.8621  
0.8621 TO 0.8657  
0.8657 TO 0.8692  
0.8692 TO 0.8728  
0.8728 TO 0.8763  
0.8763 TO 0.8798  
0.8798 TO 0.8834  
0.8834 TO 0.8869  
0.8869 TO 0.8905  
0.8905 TO 0.8940  
0.8940 TO 0.8975  
0.8975 TO 0.9011  
0.9011 TO 0.9046  
0.9046 TO 0.9082  
0.9082 TO 0.9117  
0.9117 TO 0.9152  
0.9152 TO 0.9188  
0.9188 TO 0.9223  
0.9223 TO 0.9259  
0.9259 TO 0.9294  
0.9294 TO 0.9329  
0.9329 TO 0.9365  
0.9365 TO 0.9400  
0.9400 TO 0.9436  
0.9436 TO 0.9471  
0.9471 TO 0.9506  
0.9506 TO 0.9542  
0.9542 TO 0.9577  
0.9577 TO 0.9613  
0.9613 TO 0.9648  
0.9648 TO 0.9683  
0.9683 TO 0.9719  
0.9719 TO 0.9754  
0.9754 TO 0.9790  
0.9790 TO 0.9825

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel

```
PRIMARY MODULE ACCESS AND INPUT RECORD SCALE DRIVER - 95/03/29 09:06:37
MODULE CSAS25 WILL BE CALLED
UMS BWR TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH
27GROUPNDF4 LATTICECELL
UO2 1 0.95 293.0 92235 4.00 92238 96.00 END
ZIRCALLOY 2 1.0 293.0 END
H2O 3 0.0001 293.0 END
AL 4 1.0 293.0 END
SS304 5 1.0 293.0 END
AL 6 DEN=2.6849 0.8706 293.0 END
B-10 6 DEN=2.6849 0.0137 293.0 END
B-11 6 DEN=2.6849 0.0830 293.0 END
C 6 DEN=2.6849 0.0281 293.0 END
CARBONSTEEL 7 1.0 293.0 END
PB 8 1.0 293.0 END
B-10 9 0.0 8.553-5 END
B-11 9 0.0 3.422-4 END
AL 9 0.0 7.763-3 END
H 9 0.0 5.854-2 END
O 9 0.0 2.609-2 END
C 9 0.0 2.264-2 END
N 9 0.0 1.394-3 END
H2O 10 0.2 293.0 END
H2O 11 0.2 293.0 END
END COMP
SQUAREPITCH 1.4529 0.9055 1 3 1.0770 2 0.9246 0 END
UMS BWR TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH
READ PARAM TBA=5 RUN=YES PLT=NO TME=5000 GEN=103 NPG=1000 END PARAM
READ GEOM
UNIT 1
COM='FUEL PIN CELL - WITH H2O'
CYLINDER 1 1 0.4528 2P1.7145
CYLINDER 0 1 0.4623 2P1.7145
CYLINDER 2 1 0.5385 2P1.7145
CUBOID 3 1 4P0.7264 2P1.7145
UNIT 2
COM='WATER ROD CELL - WITH H2O'
CYLINDER 3 1 0.4623 2P1.7145
CYLINDER 2 1 0.5385 2P1.7145
CUBOID 3 1 4P0.7264 2P1.7145
UNIT 3
COM='FUEL PIN CELL - WITH ST DISK'
CYLINDER 1 1 0.4528 2P0.7938
CYLINDER 0 1 0.4623 2P0.7938
CYLINDER 2 1 0.5385 2P0.7938
CUBOID 3 1 4P0.7264 2P0.7938
UNIT 4
COM='WATER ROD CELL - WITH ST DISK'
CYLINDER 3 1 0.4623 2P0.7938
CYLINDER 2 1 0.5385 2P0.7938
CUBOID 3 1 4P0.7264 2P0.7938
UNIT 5
COM='FUEL PIN CELL - WITH AL DISK'
CYLINDER 1 1 0.4528 2P0.6350
CYLINDER 0 1 0.4623 2P0.6350
CYLINDER 2 1 0.5385 2P0.6350
CUBOID 3 1 4P0.7264 2P0.6350
UNIT 6
COM='WATER ROD CELL - WITH AL DISK'
CYLINDER 3 1 0.4623 2P0.6350
CYLINDER 2 1 0.5385 2P0.6350
CUBOID 3 1 4P0.7264 2P0.6350
UNIT 7
COM='FUEL PIN ARRAY + CHANNEL - BETWEEN DISKS'
ARRAY 1 -6.5376 -6.5376 -1.7145
CUBOID 3 1 4P6.7031 2P1.7145
CUBOID 2 1 4P6.9063 2P1.7145
UNIT 8
COM='FUEL PIN ARRAY + CHANNEL - ST DISKS'
ARRAY 2 -6.5376 -6.5376 -0.7938
CUBOID 3 1 4P6.7031 2P0.7938
CUBOID 2 1 4P6.9063 2P0.7938
UNIT 9
COM='FUEL PIN ARRAY + CHANNEL - AL DISKS'
ARRAY 3 -6.5376 -6.5376 -0.6350
CUBOID 3 1 4P6.7031 2P0.6350
CUBOID 2 1 4P6.9063 2P0.6350
UNIT 10
COM='X-X BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P1.7145
CUBOID 4 1 2P6.7310 2P0.1714 2P1.7145
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P1.7145
UNIT 11
COM='Y-Y BORAL + COVER SHEET BETWEEN DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P1.7145
CUBOID 4 1 2P0.1714 2P6.7310 2P1.7145
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P1.7145
UNIT 12
COM='X-X BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.7938
CUBOID 4 1 2P6.7310 2P0.1714 2P0.7938
```

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

```
CUBOID 5 1 2P6.7765 40.2168 -0.1714 2P0.7938
UNIT 13
COM='Y-Y BORAL + COVER SHEET WITH ST DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.7938
CUBOID 4 1 2P0.1714 2P6.7310 2P0.7938
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.7938
UNIT 14
COM='X-X BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P6.7310 2P0.1124 2P0.6350
CUBOID 4 1 2P6.7310 2P0.1714 2P0.6350
CUBOID 5 1 2P6.7765 +0.2168 -0.1714 2P0.6350
UNIT 15
COM='Y-Y BORAL + COVER SHEET WITH AL DISKS'
CUBOID 6 1 2P0.1124 2P6.7310 2P0.6350
CUBOID 4 1 2P0.1714 2P6.7310 2P0.6350
CUBOID 5 1 +0.2168 -0.1714 2P6.7765 2P0.6350
UNIT 20
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 21
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 22
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 23
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 24
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 25
COM='FUEL TUBE CELL 2 BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
HOLE 11 +7.7859 0.0 0.0
UNIT 26
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
UNIT 27
COM='FUEL TUBE CELL TOP BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P1.7145
HOLE 10 0.0 +7.7859 0.0
UNIT 28
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE 11 +7.7859 0.0 0.0
UNIT 29
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE 11 +7.7859 0.0 0.0
UNIT 30
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 +0.5867 -0.5867 0.0
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Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

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CUBOID 5 1 4P7.6144 2P1.7145
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P1.7145
HOLE 11 +7.7859 0.0 0.0
UNIT 31
COM='FUEL TUBE CELL NO BORAL SHEETS - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.4930 2P1.7145
HOLE 7 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P1.7145
UNIT 40
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE 12 0.0 +7.7859 0.0
HOLE 13 +7.7859 0.0 0.0
UNIT 41
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE 12 0.0 +7.7859 0.0
HOLE 13 +7.7859 0.0 0.0
UNIT 42
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE 12 0.0 +7.7859 0.0
HOLE 13 +7.7859 0.0 0.0
UNIT 43
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE 12 0.0 +7.7859 0.0
HOLE 13 +7.7859 0.0 0.0
UNIT 44
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE 12 0.0 +7.7859 0.0
HOLE 13 +7.7859 0.0 0.0
UNIT 45
COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE 12 0.0 +7.7859 0.0
HOLE 13 +7.7859 0.0 0.0
UNIT 46
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE 12 0.0 +7.7859 0.0
UNIT 47
COM='FUEL TUBE CELL TOP BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.7938
HOLE 12 0.0 +7.7859 0.0
UNIT 48
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE 13 +7.7859 0.0 0.0
UNIT 49
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE 13 +7.7859 0.0 0.0
UNIT 50
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - STEEL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.7938
HOLE 13 +7.7859 0.0 0.0
UNIT 51
COM='FUEL TUBE CELL NO BORAL SHEETS - STEEL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.7938
HOLE 8 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.7938
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Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

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UNIT 60
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 +0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0

UNIT 61
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0

UNIT 62
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0

UNIT 63
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0

UNIT 64
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (T)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 0.0 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0

UNIT 65
COM='FUEL TUBE CELL 2 BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0
HOLE 15 +7.7859 0.0 0.0

UNIT 66
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (TL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 +0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0

UNIT 67
COM='FUEL TUBE CELL TOP BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +7.6144 -7.6144 +8.0028 -7.6144 +2P0.6350
HOLE 14 0.0 +7.7859 0.0

UNIT 68
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE 15 +7.7859 0.0 0.0

UNIT 69
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (B)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 0.0 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE 15 +7.7859 0.0 0.0

UNIT 70
COM='FUEL TUBE CELL RIGHT BORAL SHEETS - AL DISKS (BR)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 +0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350
CUBOID 3 1 +8.0028 -7.6144 +7.6144 -7.6144 +2P0.6350
HOLE 15 +7.7859 0.0 0.0

UNIT 71
COM='FUEL TUBE CELL NO BORAL SHEETS - AL DISKS (BL)'
CUBOID 3 1 4P7.4930 2P0.6350
HOLE 9 -0.5867 -0.5867 0.0
CUBOID 5 1 4P7.6144 2P0.6350

UNIT 80
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 20 -0.0297 -0.0297 0.0

UNIT 81
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 21 -0.3586 -0.0297 0.0
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Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

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UNIT 82
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 22 -0.3586 -0.3586 0.0
UNIT 83
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 23 -0.0297 -0.3586 0.0
UNIT 84
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (T)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 24 -0.1942 -0.0297 0.0
UNIT 85
COM='DISK OPENING 2 BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 25 -0.1942 -0.3586 0.0
UNIT 86
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (TL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 26 -0.3586 -0.0297 0.0
UNIT 87
COM='DISK OPENING TOP BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 27 -0.3586 -0.3586 0.0
UNIT 88
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 28 -0.3586 -0.3586 0.0
UNIT 89
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (B)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 29 -0.1942 -0.3586 0.0
UNIT 90
COM='DISK OPENING RIGHT BORAL SHEET TUBE - BETWEEN DISKS (BR)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 30 -0.0297 -0.3586 0.0
UNIT 91
COM='DISK OPENING NO BORAL SHEET TUBE - BETWEEN DISKS (BL)'
CUBOID 3 1 4P7.9731 2P1.7145
HOLE 31 -0.3586 -0.3586 0.0
UNIT 100
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 40 -0.0297 -0.0297 0.0
UNIT 101
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 41 -0.3586 -0.0297 0.0
UNIT 102
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 42 -0.3586 -0.3586 0.0
UNIT 103
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 43 -0.0297 -0.3586 0.0
UNIT 104
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 44 -0.1942 -0.0297 0.0
UNIT 105
COM='DISK OPENING 2 BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 45 -0.1942 -0.3586 0.0
UNIT 106
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 46 -0.3586 -0.0297 0.0
UNIT 107
COM='DISK OPENING TOP BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 47 -0.3586 -0.3586 0.0
UNIT 108
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 48 -0.3586 -0.3586 0.0
UNIT 109
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 49 -0.1942 -0.3586 0.0
UNIT 110
COM='DISK OPENING RIGHT BORAL SHEET TUBE - STEEL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 50 -0.0297 -0.3586 0.0
UNIT 111
COM='DISK OPENING NO BORAL SHEET TUBE - STEEL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.7938
HOLE 51 -0.3586 -0.3586 0.0
UNIT 120
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 60 -0.0297 -0.0297 0.0
UNIT 121
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 61 -0.3586 -0.0297 0.0
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Figure 6.6.2.4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

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UNIT 122
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 62 -0.3586 -0.3586 0.0
UNIT 123
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 63 -0.0297 -0.3586 0.0
UNIT 124
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (T)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 64 -0.1942 -0.0297 0.0
UNIT 125
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 65 -0.1942 -0.3586 0.0
UNIT 126
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (TL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 66 -0.3586 -0.0297 0.0
UNIT 127
COM='DISK OPENING TOP BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 67 -0.3586 -0.3586 0.0
UNIT 128
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 68 -0.3586 -0.3586 0.0
UNIT 129
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (B)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 69 -0.1942 -0.3586 0.0
UNIT 130
COM='DISK OPENING RIGHT BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 70 -0.0297 -0.3586 0.0
UNIT 131
COM='DISK OPENING NO BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE 71 -0.3586 -0.3586 0.0
UNIT 140
COM='BASKET STRUCTURE IN TRANSPORT CASK - WATER DISK'
CYLINDER 3 1 +83.5787 2P1.7145
HOLE 90 -70.3885 +8.7986 0.0
HOLE 83 -52.7914 +8.7986 0.0
HOLE 83 -52.7914 +26.3957 0.0
HOLE 90 -52.7914 +43.9928 0.0
HOLE 83 -35.1942 +8.7986 0.0
HOLE 83 -35.1942 +26.3957 0.0
HOLE 83 -35.1942 +43.9928 0.0
HOLE 90 -35.1942 +61.5899 0.0
HOLE 83 -17.5971 +8.7986 0.0
HOLE 83 -17.5971 +26.3957 0.0
HOLE 83 -17.5971 +43.9928 0.0
HOLE 90 -17.5971 +61.5899 0.0
HOLE 85 0.0 +8.7986 0.0
HOLE 85 0.0 +26.3957 0.0
HOLE 85 0.0 +43.9928 0.0
HOLE 89 0.0 +61.5899 0.0
HOLE 82 +17.5971 +8.7986 0.0
HOLE 82 +17.5971 +26.3957 0.0
HOLE 82 +17.5971 +43.9928 0.0
HOLE 88 +17.5971 +61.5899 0.0
HOLE 82 +35.1942 +8.7986 0.0
HOLE 82 +35.1942 +26.3957 0.0
HOLE 82 +35.1942 +43.9928 0.0
HOLE 91 +35.1942 +61.5899 0.0
HOLE 82 +52.7914 +8.7986 0.0
HOLE 87 +52.7914 +26.3957 0.0
HOLE 91 +52.7914 +43.9928 0.0
HOLE 91 +70.3885 +8.7986 0.0
HOLE 80 -70.3885 -8.7986 0.0
HOLE 80 -52.7914 -8.7986 0.0
HOLE 80 -52.7914 -26.3957 0.0
HOLE 80 -52.7914 -43.9928 0.0
HOLE 80 -35.1942 -8.7986 0.0
HOLE 80 -35.1942 -26.3957 0.0
HOLE 80 -35.1942 -43.9928 0.0
HOLE 80 -35.1942 -61.5899 0.0
HOLE 80 -17.5971 -8.7986 0.0
HOLE 80 -17.5971 -26.3957 0.0
HOLE 80 -17.5971 -43.9928 0.0
HOLE 80 -17.5971 -61.5899 0.0
HOLE 84 0.0 -8.7986 0.0
HOLE 84 0.0 -26.3957 0.0
HOLE 84 0.0 -43.9928 0.0
HOLE 84 0.0 -61.5899 0.0
HOLE 81 +17.5971 -8.7986 0.0
HOLE 81 +17.5971 -26.3957 0.0
HOLE 81 +17.5971 -43.9928 0.0
HOLE 81 +17.5971 -61.5899 0.0
HOLE 81 +35.1942 -8.7986 0.0
HOLE 81 +35.1942 -26.3957 0.0
HOLE 81 +35.1942 -43.9928 0.0
HOLE 86 +35.1942 -61.5899 0.0
HOLE 81 +52.7914 -8.7986 0.0
```



Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

```
HOLE 86 +52.7914 -26.3957 0.0
HOLE 86 +52.7914 -43.9928 0.0
HOLE 86 +70.3885 -8.7986 0.0
CYLINDER 5 1 +85.1662 2P1.7145
CYLINDER 10 1 +85.8647 2P1.7145
CYLINDER 5 1 +90.9447 2P1.7145
CYLINDER 8 1 +97.9297 2P1.7145
CYLINDER 5 1 +104.9147 2P1.7145
CYLINDER 9 1 +116.3604 2P1.7145
CYLINDER 0 1 +116.6788 2P1.7145
CYLINDER 5 1 +117.3156 2P1.7145
CUBOID 10 1 4P135.0 2P1.7145
UNIT 141
COM= 'BASKET STRUCTURE IN TRANSPORT CASK - CARBON STEEL DISK'
CYLINDER 7 1 +83.1850 2P0.7938
HOLE 110 -70.3885 +8.7986 0.0
HOLE 103 -52.7914 +8.7986 0.0
HOLE 103 -52.7914 +26.3957 0.0
HOLE 110 -52.7914 +43.9928 0.0
HOLE 103 -35.1942 +8.7986 0.0
HOLE 103 -35.1942 +26.3957 0.0
HOLE 103 -35.1942 +43.9928 0.0
HOLE 110 -35.1942 +61.5899 0.0
HOLE 103 -17.5971 +8.7986 0.0
HOLE 103 -17.5971 +26.3957 0.0
HOLE 103 -17.5971 +43.9928 0.0
HOLE 110 -17.5971 +61.5899 0.0
HOLE 105 0.0 +8.7986 0.0
HOLE 105 0.0 +26.3957 0.0
HOLE 105 0.0 +43.9928 0.0
HOLE 109 0.0 +61.5899 0.0
HOLE 102 +17.5971 +8.7986 0.0
HOLE 102 +17.5971 +26.3957 0.0
HOLE 102 +17.5971 +43.9928 0.0
HOLE 108 +17.5971 +61.5899 0.0
HOLE 102 +35.1942 +8.7986 0.0
HOLE 102 +35.1942 +26.3957 0.0
HOLE 102 +35.1942 +43.9928 0.0
HOLE 111 +35.1942 +61.5899 0.0
HOLE 102 +52.7914 +8.7986 0.0
HOLE 107 +52.7914 +26.3957 0.0
HOLE 111 +52.7914 +43.9928 0.0
HOLE 111 +70.3885 +8.7986 0.0
HOLE 100 -70.3885 -8.7986 0.0
HOLE 100 -52.7914 -8.7986 0.0
HOLE 100 -52.7914 -26.3957 0.0
HOLE 100 -52.7914 -43.9928 0.0
HOLE 100 -35.1942 -8.7986 0.0
HOLE 100 -35.1942 -26.3957 0.0
HOLE 100 -35.1942 -43.9928 0.0
HOLE 100 -35.1942 -61.5899 0.0
HOLE 100 -17.5971 -8.7986 0.0
HOLE 100 -17.5971 -26.3957 0.0
HOLE 100 -17.5971 -43.9928 0.0
HOLE 100 -17.5971 -61.5899 0.0
HOLE 104 0.0 -8.7986 0.0
HOLE 104 0.0 -26.3957 0.0
HOLE 104 0.0 -43.9928 0.0
HOLE 104 0.0 -61.5899 0.0
HOLE 101 +17.5971 -8.7986 0.0
HOLE 101 +17.5971 -26.3957 0.0
HOLE 101 +17.5971 -43.9928 0.0
HOLE 101 +17.5971 -61.5899 0.0
HOLE 101 +35.1942 -8.7986 0.0
HOLE 101 +35.1942 -26.3957 0.0
HOLE 101 +35.1942 -43.9928 0.0
HOLE 106 +35.1942 -61.5899 0.0
HOLE 101 +52.7914 -8.7986 0.0
HOLE 106 +52.7914 -26.3957 0.0
HOLE 106 +52.7914 -43.9928 0.0
HOLE 106 +70.3885 -8.7986 0.0
CYLINDER 3 1 +83.5787 2P0.7938
CYLINDER 5 1 +85.1662 2P0.7938
CYLINDER 10 1 +85.8647 2P0.7938
CYLINDER 5 1 +90.9447 2P0.7938
CYLINDER 8 1 +97.9297 2P0.7938
CYLINDER 5 1 +104.9147 2P0.7938
CYLINDER 9 1 +116.3604 2P0.7938
CYLINDER 0 1 +116.6788 2P0.7938
CYLINDER 5 1 +117.3156 2P0.7938
CUBOID 10 1 4P135.0 2P0.7938
UNIT 142
COM= 'BASKET STRUCTURE IN TRANSPORT CASK - AL DISK'
CYLINDER 4 1 +82.8675 2P0.6350
HOLE 130 -70.3885 +8.7986 0.0
HOLE 123 -52.7914 +8.7986 0.0
HOLE 123 -52.7914 +26.3957 0.0
HOLE 130 -52.7914 +43.9928 0.0
HOLE 123 -35.1942 +8.7986 0.0
HOLE 123 -35.1942 +26.3957 0.0
HOLE 123 -35.1942 +43.9928 0.0
HOLE 130 -35.1942 +61.5899 0.0
HOLE 123 -17.5971 +8.7986 0.0
HOLE 123 -17.5971 +26.3957 0.0
HOLE 123 -17.5971 +43.9928 0.0
HOLE 130 -17.5971 +61.5899 0.0
```

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

```
HOLE 125 0.0 +8.7986 0.0
HOLE 125 0.0 +26.3957 0.0
HOLE 125 0.0 +43.9928 0.0
HOLE 129 0.0 +61.5899 0.0
HOLE 122 +17.5971 +8.7986 0.0
HOLE 122 +17.5971 +26.3957 0.0
HOLE 122 +17.5971 +43.9928 0.0
HOLE 128 +17.5971 +61.5899 0.0
HOLE 122 +35.1942 +8.7986 0.0
HOLE 122 +35.1942 +26.3957 0.0
HOLE 122 +35.1942 +43.9928 0.0
HOLE 131 +35.1942 +61.5899 0.0
HOLE 122 +52.7914 +8.7986 0.0
HOLE 127 +52.7914 +26.3957 0.0
HOLE 131 +52.7914 +43.9928 0.0
HOLE 131 +70.3885 +8.7986 0.0
HOLE 120 -70.3885 -8.7986 0.0
HOLE 120 -52.7914 -8.7986 0.0
HOLE 120 -52.7914 -26.3957 0.0
HOLE 120 -52.7914 -43.9928 0.0
HOLE 120 -35.1942 -8.7986 0.0
HOLE 120 -35.1942 -26.3957 0.0
HOLE 120 -35.1942 -43.9928 0.0
HOLE 120 -35.1942 -61.5899 0.0
HOLE 120 -17.5971 -8.7986 0.0
HOLE 120 -17.5971 -26.3957 0.0
HOLE 120 -17.5971 -43.9928 0.0
HOLE 120 -17.5971 -61.5899 0.0
HOLE 124 0.0 -8.7986 0.0
HOLE 124 0.0 -26.3957 0.0
HOLE 124 0.0 -43.9928 0.0
HOLE 124 0.0 -61.5899 0.0
HOLE 121 +17.5971 -8.7986 0.0
HOLE 121 +17.5971 -26.3957 0.0
HOLE 121 +17.5971 -43.9928 0.0
HOLE 121 +17.5971 -61.5899 0.0
HOLE 121 +35.1942 -8.7986 0.0
HOLE 121 +35.1942 -26.3957 0.0
HOLE 121 +35.1942 -43.9928 0.0
HOLE 126 +35.1942 -61.5899 0.0
HOLE 121 +52.7914 -8.7986 0.0
HOLE 126 +52.7914 -26.3957 0.0
HOLE 126 +52.7914 -43.9928 0.0
HOLE 126 +70.3885 -8.7986 0.0
CYLINDER 3 1 +83.5787 2P0.6350
CYLINDER 5 1 +85.1662 2P0.6350
CYLINDER 10 1 +85.8647 2P0.6350
CYLINDER 5 1 +90.9447 2P0.6350
CYLINDER 8 1 +97.9297 2P0.6350
CYLINDER 5 1 +104.9147 2P0.6350
CYLINDER 9 1 +116.3604 2P0.6350
CYLINDER 0 1 +116.6788 2P0.6350
CYLINDER 5 1 +117.3156 2P0.6350
CUBOID 10 1 4P135.0 2P0.6350
GLOBAL UNIT 143
COM='AXIAL STACK OF BASKET SLICES'
ARRAY 4 -135.0 -135.0 0.0
END GEOM
READ ARRAY
ARA=1 NUX=9 NUY=9 NUZ=1 FILL
36R1
4R1 2 4R1
5R1 2 3R1
27R1
END FILL
ARA=2 NUX=9 NUY=9 NUZ=1 FILL
36R3
4R3 4 4R3
5R3 4 3R3
27R3
END FILL
ARA=3 NUX=9 NUY=9 NUZ=1 FILL
36R5
4R5 6 4R5
5R5 6 3R5
27R5
END FILL
ARA=4 NUX=1 NUY=1 NUZ=4 FILL 140 141 140 142 END FILL
END ARRAY
READ BOUNDS ZPC=PER_YXF=MIRROR_END_BOUNDS
END DATA
```

Figure 6.6.2-4 CSAS Input &amp; Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

CCCCCCCCC	SSSSSSSSSS	AAAAAAA	SSSSSSSSSS	2222222222	SSSSSSSSSS
CCCCCCCCC	SSSSSSSSSS	AAAAAAA	SSSSSSSSSS	2222222222	SSSSSSSSSS
CC	SS	AA	SS	SS	SS
CC	SS	AA	SS	SS	SS
CC	SS	AA	SS	SS	SS
CC	SS	AA	SS	SS	SS
CC	SSSSSSSSSS	AAAAAAA	SSSSSSSSSS	22	SSSSSSSSSS
CC	SSSSSSSSSS	AAAAAAA	SSSSSSSSSS	22	SSSSSSSSSS
CC	SS	AA	SS	SS	SS
CC	SS	AA	SS	SS	SS
CCCCCCCCC	SSSSSSSSSS	AA	SSSSSSSSSS	2222222222	SSSSSSSSSS
CCCCCCCCC	SSSSSSSSSS	AA	SSSSSSSSSS	2222222222	SSSSSSSSSS

SSSSSSSSSS	CCCCCCCCC	AAAAAAA	LL	EEEEEEEEEE	PPPPPPPPPP	CCCCCCCCC
SSSSSSSSSS	CCCCCCCCC	AAAAAAA	LL	EEEEEEEEEE	PPPPPPPPPP	CCCCCCCCC
SS	CC	AA	LL	EE	PP	CC
SS	CC	AA	LL	EE	PP	CC
SS	CC	AA	LL	EE	PP	CC
SSSSSSSSSS	CC	AAAAAAA	LL	EEEEEEEE	PPPPPPPPPP	CC
SSSSSSSSSS	CC	AAAAAAA	LL	EEEEEEEE	PPPPPPPPPP	CC
SS	CC	AA	LL	EE	PP	CC
SS	CC	AA	LL	EE	PP	CC
SSSSSSSSSS	CCCCCCCCC	AA	LLLLLLLLLL	EEEEEEEEEE	PP	CC
SSSSSSSSSS	CCCCCCCCC	AA	LLLLLLLLLL	EEEEEEEEEE	PP	CCCCCCCCC

0000000	44	0000000	7777777777	9999999999	9999999999
000000000	444	000000000	7777777777	9999999999	9999999999
00	444	00	77	99	99
00	44	00	77	99	99
00	44	00	77	99	99
00	44	00	77	99	99
00	44	00	77	99	99
00	44	00	77	99	99
00	4444444444	00	77	99	99
00	4444444444	00	77	99	99
00	44	000000000	77	99	99
000000000	44	000000000	77	99	99
0000000	44	0000000	77	9999999999	9999999999

2222222222	11	44	3333333333	5555555555
2222222222	111	444	3333333333	5555555555
22	1111	4444	33	55
22	11	44	33	55
22	11	44	33	55
22	11	44	33	55
22	11	44	33	55
22	11	44	33	55
22	11	4444444444	33	55
22	11	4444444444	33	55
22	11	4444444444	33	55
2222222222	111111	44	3333333333	5555555555
2222222222	1111111	44	3333333333	5555555555

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

```

SSSSSSSSSS  CCCCCCCCCC  AAAAAAAAAA  LL  EEEEEEEEEEE  PPPPPPPPPPP  CCCCCCCCCC
SSSSSSSSSS  CCCCCCCCCC  AAAAAAAAAA  LL  EEEEEEEEEEE  PPPPPPPPPPP  CCCCCCCCCC
SS      SS  CC      CC  AA      AA  LL  EE      EE  PP      PP  CC      CC
SS      CC  CC      AA  AA      AA  LL  EE      EE  PP      PP  CC      CC
SS      CC  CC      AA  AA      AA  LL  EE      EE  PP      PP  CC      CC
SSSSSSSSSS  CC  AAAAAAAAAA  LL  EEEEEEE  PPPPPPPPPPP  CC
SSSSSSSSSS  CC  AAAAAAAAAA  LL  EEEEEEE  PPPPPPPPPPP  CC
SS      SS  CC  AA      AA  LL  EE      EE  PP      CC
SS      CC  AA      AA  LL  EE      EE  PP      CC
SS      CC  AA      AA  LL  EE      EE  PP      CC
SSSSSSSSSS  CCCCCCCCCC  AA      AA  LLLLLLLLLL  EEEEEEEEEEE  PP      CCCCCCCCCC
SSSSSSSSSS  CCCCCCCCCC  AA      AA  LLLLLLLLLL  EEEEEEEEEEE  PP      CCCCCCCCCC

```

```

*****
*****
*****  PROGRAM VERIFICATION INFORMATION  *****
*****
*****  CODE SYSTEM:  SCALE-PC VERSION:  4.3  *****
*****
*****
*****
*****  PROGRAM:  CSAS  *****
*****
*****  CREATION DATE:  03/08/96  *****
*****
*****  VOLUME:  ENG  *****
*****
*****  LIBRARY:  G:\SCALE43\WIN_NT\EXE  *****
*****
*****  PRODUCTION CODE:  CSAS  *****
*****
*****  VERSION:  3.1  *****
*****
*****  JOBNAME:  SCALE-PC  *****
*****
*****  DATE OF EXECUTION:  04/07/99  *****
*****
*****  TIME OF EXECUTION:  21:43:35  *****
*****
*****
*****
*****

```

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

```

UMS BWR TO NORMAL OP CASE ARRAY: 0.0001 GM/CC IN - 0.2 GM/CC EX, 270 CM PITCH

**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4 LIBRARY
MCK 11 MIXTURES
MSC 20 COMPOSITION SPECIFICATIONS
IZM 4 MATERIAL ZONES
GE LATTICECELL GEOMETRY
MORE 0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN 0 FUEL SOLUTIONS

```

```

**** PROBLEM COMPOSITION DESCRIPTION ****

SC UO2 STANDARD COMPOSITION
MX 1 MIXTURE NO.
VF 0.9500 VOLUME FRACTION
ROTH 10.9600 THEORETICAL DENSITY
NEL 2 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
      92000 1.00 ATOM/MOLECULE
      92235 4.000 WT%
      92238 96.000 WT%
      8016 2.00 ATOMS/MOLECULE
END

```

```

SC ZIRCALLOY STANDARD COMPOSITION
MX 2 MIXTURE NO.
VF 1.0000 VOLUME FRACTION
ROTH 6.5600 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
      40302 1.00 ATOM/MOLECULE
END

```

```

SC H2O STANDARD COMPOSITION
MX 3 MIXTURE NO.
VF 0.0001 VOLUME FRACTION
ROTH 0.9982 THEORETICAL DENSITY
NEL 2 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
      1001 2.00 ATOMS/MOLECULE
      8016 1.00 ATOM/MOLECULE
END

```

```

SC AL STANDARD COMPOSITION
MX 4 MIXTURE NO.
VF 1.0000 VOLUME FRACTION
ROTH 2.7020 THEORETICAL DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
      13027 1.00 ATOM/MOLECULE
END

```

```

SC SS304 STANDARD COMPOSITION
MX 5 MIXTURE NO.
VF 1.0000 VOLUME FRACTION
ROTH 7.9200 THEORETICAL DENSITY
NEL 4 NO. ELEMENTS
ICP 0 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
      24304 19.000 WT%
      25055 2.000 WT%
      26304 69.500 WT%
      28304 9.500 WT%
END

```

```

SC AL STANDARD COMPOSITION
MX 6 MIXTURE NO.
VF 0.8706 VOLUME FRACTION
ROTH 2.6849 SPECIFIED DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
      13027 1.00 ATOM/MOLECULE
END

```

```

SC B-10 STANDARD COMPOSITION
MX 6 MIXTURE NO.
VF 0.0137 VOLUME FRACTION
ROTH 2.6849 SPECIFIED DENSITY
NEL 1 NO. ELEMENTS
ICP 1 0/1 MIXTURE/COMPOUND
TEMP 293.0 DEG KELVIN
      5010 1.00 ATOM/MOLECULE
END

```

```

SC B-11 STANDARD COMPOSITION
MX 6 MIXTURE NO.
VF 0.0830 VOLUME FRACTION
ROTH 2.6849 SPECIFIED DENSITY

```

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

```
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP     293.0 DEG KELVIN
5011     1.00 ATOM/MOLECULE
END
```

```
SC C      STANDARD COMPOSITION
MX      6 MIXTURE NO.
VF      0.0281 VOLUME FRACTION
ROTH     2.6849 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP     293.0 DEG KELVIN
6012     1.00 ATOM/MOLECULE
END
```

```
SC CARBONSTEEL STANDARD COMPOSITION
MX      7 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH     7.8212 THEORETICAL DENSITY
NEL      2 NO. ELEMENTS
ICP      0 0/1 MIXTURE/COMPOUND
TEMP     293.0 DEG KELVIN
26000    99.000 WT%
6012     1.000 WT%
END
```

```
SC PB      STANDARD COMPOSITION
MX      8 MIXTURE NO.
VF      1.0000 VOLUME FRACTION
ROTH     11.3440 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
TEMP     293.0 DEG KELVIN
82000    1.00 ATOM/MOLECULE
END
```

```
SC B-10     STANDARD COMPOSITION
MX      9 MIXTURE NO.
DEN      8.5530E-05 ATOMIC DENSITY
ROTH     1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
5010     1.00 ATOM/MOLECULE
END
```

```
SC B-11     STANDARD COMPOSITION
MX      9 MIXTURE NO.
DEN      3.4220E-04 ATOMIC DENSITY
ROTH     1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
5011     1.00 ATOM/MOLECULE
END
```

```
SC AL      STANDARD COMPOSITION
MX      9 MIXTURE NO.
DEN      7.7630E-03 ATOMIC DENSITY
ROTH     2.7020 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
11027    1.00 ATOM/MOLECULE
END
```

```
SC H      STANDARD COMPOSITION
MX      9 MIXTURE NO.
DEN      5.8540E-02 ATOMIC DENSITY
ROTH     1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
1001     1.00 ATOM/MOLECULE
END
```

```
SC O      STANDARD COMPOSITION
MX      9 MIXTURE NO.
DEN      2.6090E-02 ATOMIC DENSITY
ROTH     1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
8016     1.00 ATOM/MOLECULE
END
```

```
SC C      STANDARD COMPOSITION
MX      9 MIXTURE NO.
DEN      2.2640E-02 ATOMIC DENSITY
ROTH     2.1000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
ICP      1 0/1 MIXTURE/COMPOUND
6012     1.00 ATOM/MOLECULE
END
```

```
SC N      STANDARD COMPOSITION
MX      9 MIXTURE NO.
DEN      1.3940E-03 ATOMIC DENSITY
ROTH     1.0000 THEORETICAL DENSITY
NEL      1 NO. ELEMENTS
```

Figure 6.6.2.4 CSAS Input & Output for Accident Conditions Critically Analysis: BWR Fuel (continued)

```
ICP      1 0/1 MIXTURE/COMPOUND  
END      7014      1.00 ATOM/MOLECULE
```

```
SC H2O      STANDARD COMPOSITION  
MK      10 MIXTURE NO.  
VF      0.2000 VOLUME FRACTION  
ROTH     0.9982 THEORETICAL DENSITY  
NEL      2 NO. ELEMENTS  
ICP      1 0/1 MIXTURE/COMPOUND  
TEMP     293.0 DEG KELVIN  
1001     2.00 ATOMS/MOLECULE  
8016     1.00 ATOM/MOLECULE  
END
```

```
SC H2O      STANDARD COMPOSITION  
MK      11 MIXTURE NO.  
VF      0.2000 VOLUME FRACTION  
ROTH     0.9982 THEORETICAL DENSITY  
NEL      2 NO. ELEMENTS  
ICP      1 0/1 MIXTURE/COMPOUND  
TEMP     293.0 DEG KELVIN  
1001     2.00 ATOMS/MOLECULE  
8016     1.00 ATOM/MOLECULE  
END
```

\*\*\*\* PROBLEM GEOMETRY \*\*\*\*

```
CDP SQUAREPITCH CELL TYPE  
PITCH     1.4529 CM CENTER TO CENTER SPACING  
FUELOD     0.9055 CM FUEL DIAMETER OR SLAB THICKNESS  
MUEL       1 MIXTURE NO. OF FUEL  
MMOD       3 MIXTURE NO. OF MODERATOR  
CLADOD     1.0770 CM CLAD OUTER DIAMETER  
MELAD      2 MIXTURE NO. OF CLAD  
GAPD       0.9246 CM GAP OUTER DIAMETER  
MGAP       0 MIXTURE NO. OF GAP
```

ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY

```
ZONE 1 IS FUEL  
ZONE 2 IS GAP  
ZONE 3 IS CLAD  
ZONE 4 IS MOD
```

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

```

*****
***          UMS BWR TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH ***
***
*****
***          ***** DATA LIBRARY INFORMATION *****
***
***          UNIT          DATA SET NAME          VOLUME          UNIT FUNCTION
***          NUMBER          NAME          NAME          -----
***          -----
***          89          G:\scale43\ATALIB\FT89F001          STANDARD COMPOSITION LIBRARY
***          82          G:\scale43\ATALIB\FT82F001          CROSS SECTION LIBRARY
***          11          D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Ar          SHORT CROSS SECTION LIBRARY
***          90          D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Ar          INPUT DATA DIRECT ACCESS
***
*****
***
***          STANDARD COMPOSITION LIBRARY DATA
***          -----
***
***          UNIT NUMBER : 89
***          DATASET NAME : G:\scale43\ATALIB\FT89F001
***          LIBRARY TITLE: SCALE-4 STANDARD COMPOSITION LIBRARY
***          637 STANDARD COMPOSITIONS, 490 NUCLIDES
***          90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRIBUTIONS.
***          CREATION DATE: 6/30/95
***
***          CROSS SECTION LIBRARY DATA
***          -----
***
***          UNIT NUMBER : 82
***          DATASET NAME : G:\scale43\ATALIB\FT82F001
***          LIBRARY TITLE: SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
***          BASED ON ENDF-B VERSION 4 DATA
***          COMPILED FOR NRC          1/27/89
***          LAST UPDATED
***          L.M. PETRIE - ORNL
***          08/12/94
***
*****
KK      KK      EEEEEEEEEEE     NN      NN      0000000000      VV      VV

```



Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

[illegible][illegible]

00000000	44	7777777777	9999999999	9999999999
00000000	444	7777777777	999999999999	999999999999
00	4444	77	99	99
00	44	77	99	99
00	44 44	77	99	99
00	44 44	77	99	99
00	44 44	77	99	99
00	44 44	77	99	99
00	44	77	999999999999	999999999999
00	44 44	77	999999999999	999999999999
00	444444444444	77	999999999999	999999999999
00	444444444444	77	99	99
00	444444444444	77	99	99
00	44	77	99	99
00000000	44	77	999999999999	999999999999
00000000	44	77	999999999999	999999999999
00000000	44	77	999999999999	999999999999

[illegible]

SSSSSSSSSSS	CCCCCCCCCCC	AAAAAAAAA	LL	EEEEEEEEEEE	PPPPPPPPPPP	CCCCCCCCCCC
SSSSSSSSSSSS	CCCCCCCCCCCC	AAAAAAAAAAAA	LL	EEEEEEEEEEE	PPPPPPPPPPPP	CCCCCCCCCCCC
SS	CC	AA	AA	EE	PP	CC
SS	CC	AA	AA	EE	PP	CC
SS	CC	AA	AA	EE	PP	CC
SSSSSSSSSSS	CC	AAAAAAAAAAAAA	LL	EEEEEEEE	PPPPPPPPPPPP	CC
SSSSSSSSSSS	CC	AAAAAAAAAAAAA	LL	EEEEEEEE	PPPPPPPPPPPP	CC
	SS	CC	AA	EE	PP	CC
	SS	CC	AA	EE	PP	CC
SS	SS	CC	AA	EE	PP	CC
SSSSSSSSSSSS	CCCCCCCCCCCC	AA	AA	LLLLLLLLLLLLL	EEEEEEEEEEEE	CCCCCCCCCCCC
SSSSSSSSSSS	CCCCCCCCCCC	AA	AA	LLLLLLLLLLLLL	EEEEEEEEEEEE	CCCCCCCCCCC

6.6.2-89

```
*****  
BINARY DATA INTERFACE  
YES  
*****  
  
*****  
*** UMS BWR TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH ***  
*****  
***** LOGICAL PARAMETERS *****  
*****  
*** RUN EXECUTE PROBLEM AFTER CHECKING DATA YES PLT PLOT PICTURE MAP(S) NO ***  
*** FLX COMPUTE FLUX NO FDN COMPUTE FISSION DENSITIES NO ***  
*** SMU COMPUTE AVG UNIT SELF-MULTIPLICATION NO NUB COMPUTE NU-BAR & AVG FISSION GROUP YES ***  
*** MKU COMPUTE MATRIX K-EFF BY UNIT NUMBER NO MKP COMPUTE MATRIX K-EFF BY UNIT LOCATION NO ***  
*** CKU COMPUTE COFACTOR K-EFF BY UNIT NUMBER NO CKF COMPUTE COFACTOR K-EFF BY UNIT LOCATION NO ***  
*** FMU PRINT FISSION PROD MATRIX BY UNIT NUMBER NO FMP PRINT FISSION PROD MATRIX BY UNIT LOCATION NO ***  
*** MKH COMPUTE MATRIX K-EFF BY HOLE NUMBER NO MKA COMPUTE MATRIX K-EFF BY ARRAY NUMBER NO ***  
*** CKH COMPUTE COFACTOR K-EFF BY HOLE NUMBER NO CXK COMPUTE COFACTOR K-EFF BY ARRAY NUMBER NO ***  
*** FMH PRINT FISSION PROD MATRIX BY HOLE NUMBER NO FMA PRINT FISSION PROD MATRIX BY ARRAY NUMBER NO ***  
*** HHL COLLECT MATRIX BY HIGHEST HOLE LEVEL NO HAL COLLECT MATRIX BY HIGHEST ARRAY LEVEL NO ***  
*** AMX PRINT ALL MIXED CROSS SECTIONS NO FAR PRINT FIS. AND ABS. BY REGION NO ***  
*** XS1 PRINT 1-D MIXTURE X-SECTIONS NO GAS PRINT FAR BY GROUP NO ***  
*** XS2 PRINT 2-D MIXTURE X-SECTIONS NO FAX PRINT KSEC-ALBEDO CORRELATION TABLES NO ***  
*** XAP PRINT MIXTURE ANGLES & PROBABILITIES NO FWT PRINT WRIGHT AVERAGE ARRAY NO ***  
*** PKI PRINT FISSION SPECTRUM NO PGM PRINT INPUT GEOMETRY NO ***  
*** P1D PRINT EXTRA 1-D CROSS SECTIONS NO BUG PRINT DEBUG INFORMATION NO ***  
*** TRK PRINT TRACKING INFORMATION NO ***  
*****  
PARAMETER INPUT COMPLETED
```

\*\*\*\*\* DATA READING COMPLETED \*\*\*\*\*

```

***
***          UMS BWR TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH ***
***
*****
***
***          UNIT          DATA SET NAME          VOLUME          UNIT FUNCTION
***          NUMBER          -----          NAME          -----
***
***          XSC  14      D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Ar          MIXED CROSS SECTIONS
***
***          ALB  79      G:\scale43\DATA LIB\FT79F001          INPUT ALBEDOS
***
***          WTS  80      G:\scale43\DATA LIB\FT80F001          INPUT WEIGHTS
***
***          SKT  16      UNKNOWN          WRITE SCRATCH DATA
***
***          BIN  95      D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Ar          BINARY INPUT DATA
***
***          RST  95      D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Ar          READ RESTART DATA
***
***          LIB   4      D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Ar          INPUT AMPX WORKING LIBRARY
***
***          8      D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Ar          INPUT DATA DIRECT ACCESS
***
***          9      UNKNOWN          SUPER GROUPED DIRECT ACCESS
***
***          10      UNKNOWN          XSEC MIXING DIRECT ACCESS
***
*****

```

RELATIONS WERE USED PREPARING INPUT DATA

CROSS SECTIONS READ FROM THE AMPX WORKING LIBRARY ON UNIT 1111

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

UMS\_BWR\_TC NORMAL OP CASK ARRAY: 0.0001 GM/CC IN 0.2 GM/CC EX 270 CM PITCH

MIXING TABLE

NUMBER OF SCATTERING ANGLES = 2

CROSS SECTION MESSAGE THRESHOLD = 3.0E-05

MIXTURE = 1 DENSITY(G/CC) = 10.412

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
1008016	4.64617E-02	1.18487E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276 UPDATED
08/12/94						
1092235	9.40641E-04	3.52606E-02	92235	235.0441	URANIUM-235	ENDF/B-IV MAT 1261 UPDATED
08/12/94						
1092238	2.22902E-02	8.46253E-01	92238	238.0510	URANIUM-238	ENDF/B-IV MAT 1262 UPDATED
08/12/94						

MIXTURE = 2 DENSITY(G/CC) = 6.5600

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
2040302	4.33078E-02	1.00000E+00	40000	91.2196	ZIRCALLOY	ENDF/B-IV MAT 1284 UPDATED
08/12/94						

MIXTURE = 3 DENSITY(G/CC) = 0.99817E-04

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
3001001	6.67692E-06	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002 UPDATED
08/12/94						
3008016	3.33846E-06	8.88074E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276 UPDATED
08/12/94						

MIXTURE = 4 DENSITY(G/CC) = 2.7020

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
4013027	6.03066E-02	1.00000E+00	13027	26.9818	AL-27 1193 218 GP 040375(5)	UPDATED
08/12/94						

MIXTURE = 5 DENSITY(G/CC) = 7.9200

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
5024304	1.74286E-02	1.90000E-01	24000	51.9957	CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)	UPDATED
08/12/94						
5025055	1.73633E-03	1.99999E-02	25055	54.9379	MANGANESE-55	ENDF/B-IV MAT 1197 UPDATED
08/12/94						
5026304	5.93579E-02	6.95000E-01	26000	55.8447	FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)	UPDATED
08/12/94						
5028304	7.72070E-03	9.50001E-02	28000	58.6872	NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)	UPDATED
08/12/94						

MIXTURE = 6 DENSITY(G/CC) = 2.6726

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
6005010	2.21228E-03	1.37634E-02	5010	10.0130	B-10 1273 218NGP 042375 P-3 293K	UPDATED
08/12/94						
6005011	1.21898E-02	8.33855E-02	5011	11.0096	BORON-11	ENDF/B-IV MAT 1160 UPDATED
08/12/94						
6006012	3.78620E-03	2.82300E-02	6000	12.0001	CARBON-12	ENDF/B-IV MAT 1274/THRM1065 UPDATED
08/12/94						
6013027	5.21707E-02	8.74621E-01	13027	26.9818	AL-27 1193 218 GP 040375(5)	UPDATED
08/12/94						

MIXTURE = 7 DENSITY(G/CC) = 7.8212

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
7006012	3.92503E-03	1.00001E-02	6000	12.0001	CARBON-12	ENDF/B-IV MAT 1274/THRM1065 UPDATED
08/12/94						
7026000	8.34982E-02	9.90000E-01	26000	55.8447	IRON	ENDF/B-IV MAT 1192 UPDATED
08/12/94						

MIXTURE = 8 DENSITY(G/CC) = 11.344

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
8082000	3.29690E-02	1.00000E+00	82000	207.2100	PB 1288 218NGP 042375 P-3 293K	UPDATED
08/12/94						

MIXTURE = 9 DENSITY(G/CC) = 1.6298

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
9001001	5.85400E-02	6.01023E-02	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002 UPDATED
08/12/94						
9005010	8.55300E-05	8.72589E-04	5010	10.0130	B-10 1273 218NGP 042375 P-3 293K	UPDATED
08/12/94						
9005011	3.42200E-04	3.83863E-03	5011	11.0096	BORON-11	ENDF/B-IV MAT 1160 UPDATED
08/12/94						
9006012	2.26400E-02	2.76813E-01	6000	12.0001	CARBON-12	ENDF/B-IV MAT 1274/THRM1065 UPDATED
08/12/94						
9007014	1.39400E-03	1.98893E-02	7014	14.0033	NITROGEN-14	ENDF/B-IV MAT 1275 UPDATED
08/12/94						
9008016	2.60900E-02	4.25068E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276 UPDATED
08/12/94						
9013027	7.76300E-03	2.13416E-01	13027	26.9818	AL-27 1193 218 GP 040375(5)	UPDATED
08/12/94						

MIXTURE = 10 DENSITY(G/CC) = 0.19963

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
10001001	1.33538E-02	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002 UPDATED
08/12/94						
1008016	5.67692E-03	8.88074E-01	8016	15.9904	OXYGEN-16	ENDF/B-IV MAT 1276 UPDATED
08/12/94						

MIXTURE = 11 DENSITY(G/CC) = 0.19963

NUCLIDE	ATOM-DENS.	WGT. FRAC.	ZA	AWT	NUCLIDE TITLE	
11001001	1.33538E-02	1.11927E-01	1001	1.0077	HYDROGEN	ENDF/B-IV MAT 1269/THRM1002 UPDATED
08/12/94						

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

11008016 6.67692E-03 8.88074E-01 8016 15.9904 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94

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3001001 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED 08/12/94
9001001 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED 08/12/94
10001001 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED 08/12/94
11001001 HYDROGEN ENDF/B-IV MAT 1269/THRM1002 UPDATED 08/12/94
6005010 B-10 1273 218NGP 042375 P-3 293K UPDATED 08/12/94
9005010 B-10 1273 218NGP 042375 P-3 293K UPDATED 08/12/94
6005011 BORON-11 ENDF/B-IV MAT 1160 UPDATED 08/12/94
9005011 BORON-11 ENDF/B-IV MAT 1160 UPDATED 08/12/94
6006012 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED 08/12/94
7006012 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED 08/12/94
9006012 CARBON-12 ENDF/B-IV MAT 1274/THRM1065 UPDATED 08/12/94
9007014 NITROGEN-14 ENDF/B-IV MAT 1275 UPDATED 08/12/94
1008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
3008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
9008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
1008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
11008016 OXYGEN-16 ENDF/B-IV MAT 1276 UPDATED 08/12/94
4013027 AL-27 1193 218 GP 040375(5) UPDATED 08/12/94
6013027 AL-27 1193 218 GP 040375(5) UPDATED 08/12/94
9013027 AL-27 1193 218 GP 040375(5) UPDATED 08/12/94
5024304 CR 1191 WT SS-304(1/EST) P-3 293K SP-5+4(42375) UPDATED 08/12/94
5025055 MANGANESE-55 ENDF/B-IV MAT 1197 UPDATED 08/12/94
7026000 IRON ENDF/B-IV MAT 1192 UPDATED 08/12/94
5026304 FE 1192 WT SS-304(1/EST) P-3 293K SP-5+4(42375) UPDATED 08/12/94
5028304 NI 1190 WT SS-304(1/EST) P-3 293K SP-5+4(42375) UPDATED 08/12/94
2040302 ZIRCALLOY ENDF/B-IV MAT 1284 UPDATED 08/12/94
8082000 PB 1288 218NGP 042375 P-3 293K UPDATED 08/12/94
1092235 URANIUM-235 ENDF/B-IV MAT 1261 UPDATED 08/12/94
1092238 URANIUM-238 ENDF/B-IV MAT 1262 UPDATED 08/12/94

```

KENO MESSAGE NUMBER K5-222 2 TRANSFERS FOR MIXTURE 3 WERE CORRECTED FOR BAD MOMENTS

KENO MESSAGE NUMBER K5-222 1 TRANSFERS FOR MIXTURE 10 WERE CORRECTED FOR BAD MOMENTS

KENO MESSAGE NUMBER K5-222 1 TRANSFERS FOR MIXTURE 11 WERE CORRECTED FOR BAD MOMENTS

0.10'S WERE USED MIXING CROSS-SECTIONS

1-D CROSS SECTION ARRAY ID NUMBERS

1 2002 1452 27 18 1018

0.10'S WERE USED PREPARING THE CROSS SECTIONS

```

*****
*** UMS BWR TC, NORMAL OP, CASK ARRAY, 0.0001 GM/CC IN - 0.2 GM/CC EX, 270 CM PITCH ***
*****
***** ADDITIONAL INFORMATION *****
***
*** NUMBER OF ENERGY GROUPS 27 USE LATTICE GEOMETRY YES ***
*** NO. OF FISSION SPECTRUM SOURCE GROUP 1 GLOBAL ARRAY NUMBER 4 ***
*** NO. OF SCATTERING ANGLES IN XSECS 2 NUMBER OF UNITS IN THE GLOBAL X DIR. 1 ***
*** ENTRIES/NEUTRON IN THE NEUTRON BANK 25 NUMBER OF UNITS IN THE GLOBAL Y DIR. 1 ***
*** ENTRIES/NEUTRON IN THE FISSION BANK 18 NUMBER OF UNITS IN THE GLOBAL Z DIR. 4 ***
*** NUMBER OF MIXTURES USED 10 USE A GLOBAL REFLECTOR YES ***
*** NUMBER OF BIAS ID'S USED 1 USE NESTED HOLES YES ***
*** NUMBER OF DIFFERENTIAL ALBEDOS USED 0 NUMBER OF HOLES 291 ***
*** TOTAL INPUT GEOMETRY REGIONS 222 MAXIMUM HOLE NESTING LEVEL 3 ***
*** NUMBER OF GEOMETRY REGIONS USED 222 USE NESTED ARRAYS YES ***
*** LARGEST GEOMETRY UNIT NUMBER 143 NUMBER OF ARRAYS USED 4 ***
*** LARGEST ARRAY NUMBER 4 MAXIMUM ARRAY NESTING LEVEL 2 ***
***
*** +X BOUNDARY CONDITION MIRROR -X BOUNDARY CONDITION MIRROR ***
*** +Y BOUNDARY CONDITION MIRROR -Y BOUNDARY CONDITION MIRROR ***
*** +Z BOUNDARY CONDITION PER -Z BOUNDARY CONDITION PER ***
*****

```

VOLUME FRACTION OF FISSIONABLE MATERIAL IN THE CORE=1.90886E-02

START TYPE A WAS USED

THE NEUTRONS WERE STARTED WITH A FLAT DISTRIBUTION IN A CUBOID DEFINED BY

+X= 1.35000E+02 -X=-1.35000E+02 +Y= 1.35000E+02 -Y=-1.35000E+02 +Z= 9.71560E+00 -Z=-0.00000E+00

THE FLAG TO START NEUTRONS IN THE REFLECTOR WAS TURNED OFF

0.49917 MINUTES WERE REQUIRED FOR STARTING TOTAL ELAPSED TIME IS 0.51200 MINUTES

Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

UMS BWR\_TC; NORMAL\_OP; CASK\_ARRAY; 0.0001 GM/CC IN 0.2 GM/CC EX; 270 CM PITCH

GENERATION	K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132	WARNING...ONLY	461 INDEPENDENT	FISSION POINTS WERE	GENERATED		
1	3.92213E-01	8.05500E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132	WARNING...ONLY	431 INDEPENDENT	FISSION POINTS WERE	GENERATED		
2	4.03006E-01	1.11317E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132	WARNING...ONLY	461 INDEPENDENT	FISSION POINTS WERE	GENERATED		
3	4.01194E-01	1.41983E+00	4.01194E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	3.87101E-01	1.71183E+00	3.94148E-01	7.04664E-03	0.00000E+00	0.00000E+00
5	3.88707E-01	2.01750E+00	3.92334E-01	4.45430E-03	0.00000E+00	0.00000E+00
6	4.07435E-01	2.31867E+00	3.96109E-01	4.91648E-03	0.00000E+00	0.00000E+00
7	3.98211E-01	2.62167E+00	3.96530E-01	3.83141E-03	0.00000E+00	0.00000E+00
8	3.93015E-01	2.91833E+00	3.95944E-01	3.18269E-03	0.00000E+00	0.00000E+00
9	3.93180E-01	3.22133E+00	3.95549E-01	2.71869E-03	0.00000E+00	0.00000E+00
10	4.03375E-01	3.52617E+00	3.96527E-01	2.54956E-03	0.00000E+00	0.00000E+00
11	3.94734E-01	3.83100E+00	3.96328E-01	2.25731E-03	0.00000E+00	0.00000E+00
12	3.88929E-01	4.13317E+00	3.95588E-01	2.15031E-03	0.00000E+00	0.00000E+00
13	4.08557E-01	4.43617E+00	3.96767E-01	2.27443E-03	0.00000E+00	0.00000E+00
14	4.01625E-01	4.73267E+00	3.97172E-01	2.11536E-03	0.00000E+00	0.00000E+00
15	4.03031E-01	5.03117E+00	3.97623E-01	1.99736E-03	0.00000E+00	0.00000E+00
16	3.89187E-01	5.32400E+00	3.97020E-01	1.94488E-03	0.00000E+00	0.00000E+00
17	4.09429E-01	5.62617E+00	3.97847E-01	1.99063E-03	0.00000E+00	0.00000E+00
18	4.00999E-01	5.92467E+00	3.98044E-01	1.87246E-03	0.00000E+00	0.00000E+00
19	3.93355E-01	6.22850E+00	3.97769E-01	1.78037E-03	0.00000E+00	0.00000E+00
20	3.95445E-01	6.53617E+00	3.97639E-01	1.68351E-03	0.00000E+00	0.00000E+00
21	3.94439E-01	6.83550E+00	3.97471E-01	1.60132E-03	0.00000E+00	0.00000E+00
22	3.91314E-01	7.13567E+00	3.97163E-01	1.55003E-03	0.00000E+00	0.00000E+00
23	4.02865E-01	7.43867E+00	3.97435E-01	1.49916E-03	0.00000E+00	0.00000E+00
24	3.90100E-01	7.73717E+00	3.97101E-01	1.46776E-03	0.00000E+00	0.00000E+00
25	4.01129E-01	8.04650E+00	3.97276E-01	1.41338E-03	0.00000E+00	0.00000E+00
26	3.98353E-01	8.34950E+00	3.97321E-01	1.35396E-03	0.00000E+00	0.00000E+00
27	3.97776E-01	8.64800E+00	3.97339E-01	1.29880E-03	0.00000E+00	0.00000E+00
28	4.04608E-01	8.94817E+00	3.97619E-01	1.27878E-03	0.00000E+00	0.00000E+00
29	4.08161E-01	9.25483E+00	3.98009E-01	1.29097E-03	0.00000E+00	0.00000E+00
30	3.91385E-01	9.55067E+00	3.97773E-01	1.26630E-03	0.00000E+00	0.00000E+00
31	3.91256E-01	9.84533E+00	3.97548E-01	1.24235E-03	0.00000E+00	0.00000E+00
32	4.07376E-01	1.01530E+01	3.97876E-01	1.24413E-03	0.00000E+00	0.00000E+00
33	4.12498E-01	1.04532E+01	3.98347E-01	1.29247E-03	0.00000E+00	0.00000E+00
34	4.09438E-01	1.07635E+01	3.98694E-01	1.29853E-03	0.00000E+00	0.00000E+00
35	4.13813E-01	1.10693E+01	3.99152E-01	1.33937E-03	0.00000E+00	0.00000E+00
36	3.99710E-01	1.13687E+01	3.99169E-01	1.29948E-03	0.00000E+00	0.00000E+00
37	4.06049E-01	1.16808E+01	3.99365E-01	1.27703E-03	0.00000E+00	0.00000E+00
38	3.97738E-01	1.19792E+01	3.99320E-01	1.24187E-03	0.00000E+00	0.00000E+00
39	4.11632E-01	1.22840E+01	3.99653E-01	1.25284E-03	0.00000E+00	0.00000E+00
40	3.93501E-01	1.25843E+01	3.99491E-01	1.23012E-03	0.00000E+00	0.00000E+00
41	4.07966E-01	1.28937E+01	3.99708E-01	1.21771E-03	0.00000E+00	0.00000E+00
42	4.01763E-01	1.32022E+01	3.99760E-01	1.18799E-03	0.00000E+00	0.00000E+00
88	3.97890E-01	2.71487E+01	4.00107E-01	8.16285E-04	0.00000E+00	0.00000E+00
89	4.16076E-01	2.74545E+01	4.00291E-01	8.27461E-04	0.00000E+00	0.00000E+00
90	3.90030E-01	2.77528E+01	4.00174E-01	8.26273E-04	0.00000E+00	0.00000E+00
91	4.25359E-01	2.80650E+01	4.00457E-01	8.64557E-04	0.00000E+00	0.00000E+00
92	3.96664E-01	2.83735E+01	4.00415E-01	8.55935E-04	0.00000E+00	0.00000E+00
93	4.12854E-01	2.86857E+01	4.00552E-01	8.57442E-04	0.00000E+00	0.00000E+00
94	4.03324E-01	2.89942E+01	4.00582E-01	8.48606E-04	0.00000E+00	0.00000E+00
95	4.01746E-01	2.93073E+01	4.00594E-01	8.39525E-04	0.00000E+00	0.00000E+00
96	4.12736E-01	2.96185E+01	4.00724E-01	8.40530E-04	0.00000E+00	0.00000E+00
97	3.98771E-01	2.99188E+01	4.00703E-01	8.31889E-04	0.00000E+00	0.00000E+00
98	4.06101E-01	3.02208E+01	4.00759E-01	8.25096E-04	0.00000E+00	0.00000E+00
99	4.04630E-01	3.05212E+01	4.00799E-01	8.17520E-04	0.00000E+00	0.00000E+00
100	3.87340E-01	3.08168E+01	4.00662E-01	8.20709E-04	0.00000E+00	0.00000E+00
101	4.01485E-01	3.11262E+01	4.00670E-01	8.12419E-04	0.00000E+00	0.00000E+00
102	3.96543E-01	3.14302E+01	4.00629E-01	8.05312E-04	0.00000E+00	0.00000E+00
103	3.89331E-01	3.17277E+01	4.00517E-01	8.05108E-04	0.00000E+00	0.00000E+00

KENO MESSAGE NUMBER K5-123

EXECUTION TERMINATED DUE TO COMPLETION OF THE SPECIFIED NUMBER OF GENERATIONS.



Figure 6.6.2-4 CSAS Input & Output for Accident Conditions Criticality Analysis: BWR Fuel (continued)

```
UMS BWR TC: NORMAL OP: CASK ARRAY: 0.0001 GM/CC IN 0.2 GM/CC EX: 270 CM PITCH

LIFETIME = 1.85310E-05 + OR - 3.47674E-07      GENERATION TIME = 3.64832E-06 + OR - 5.09989E-08
NU BAR   = 2.53710E+00 + OR - 6.18291E-04      AVERAGE FISSION GROUP = 7.26212E+00 + OR - 1.14248E-02
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 3.94854E+04 + OR - 4.84416E+02

NO. OF INITIAL GENERATIONS SKIPPED  AVERAGE K-EFFECTIVE  DEVIATION  67 PER CENT  95 PER CENT  99 PER CENT  NUMBER OF HISTORIES
CONFIDENCE INTERVAL  CONFIDENCE INTERVAL  CONFIDENCE INTERVAL

3 0.40051 + OR - 0.00081 0.39970 TO 0.40132 0.39888 TO 0.40214 0.39807 TO 0.40295 100000
4 0.40065 + OR - 0.00081 0.39984 TO 0.40146 0.39903 TO 0.40227 0.39822 TO 0.40308 99000
5 0.40077 + OR - 0.00081 0.39996 TO 0.40158 0.39915 TO 0.40239 0.39834 TO 0.40319 98000
6 0.40070 + OR - 0.00081 0.39988 TO 0.40151 0.39907 TO 0.40233 0.39826 TO 0.40314 97000
7 0.40072 + OR - 0.00082 0.39990 TO 0.40155 0.39908 TO 0.40237 0.39826 TO 0.40319 96000
8 0.40081 + OR - 0.00083 0.39998 TO 0.40163 0.39915 TO 0.40246 0.39832 TO 0.40329 95000
9 0.40089 + OR - 0.00083 0.40006 TO 0.40172 0.39922 TO 0.40255 0.39839 TO 0.40334 94000
10 0.40086 + OR - 0.00084 0.40002 TO 0.40170 0.39918 TO 0.40254 0.39834 TO 0.40338 93000
11 0.40093 + OR - 0.00085 0.40008 TO 0.40177 0.39923 TO 0.40262 0.39839 TO 0.40347 92000
12 0.40106 + OR - 0.00085 0.40021 TO 0.40190 0.39937 TO 0.40275 0.39852 TO 0.40360 91000
17 0.40098 + OR - 0.00087 0.40011 TO 0.40186 0.39923 TO 0.40273 0.39836 TO 0.40353 86000
22 0.40135 + OR - 0.00091 0.40044 TO 0.40225 0.39953 TO 0.40316 0.39862 TO 0.40407 81000
27 0.40156 + OR - 0.00096 0.40061 TO 0.40252 0.39965 TO 0.40347 0.39870 TO 0.40443 76000

77 0.40135 + OR - 0.00192 0.39943 TO 0.40327 0.39751 TO 0.40518 0.39559 TO 0.40710 26000
82 0.40181 + OR - 0.00219 0.39962 TO 0.40400 0.39744 TO 0.40618 0.39525 TO 0.40837 21000
87 0.40255 + OR - 0.00258 0.39997 TO 0.40514 0.39739 TO 0.40772 0.39480 TO 0.41031 16000
92 0.40135 + OR - 0.00247 0.39888 TO 0.40382 0.39642 TO 0.40629 0.39395 TO 0.40875 11000
97 0.39757 + OR - 0.00322 0.39435 TO 0.40079 0.39113 TO 0.40402 0.38790 TO 0.40724 6000

UMS BWR TC: NORMAL OP: CASK ARRAY: 0.0001 GM/CC IN 0.2 GM/CC EX: 270 CM PITCH

FREQUENCY FOR GENERATIONS 4 TO 103
0.3740 TO 0.3866 **
0.3866 TO 0.3993 *****
0.3993 TO 0.4119 *****
0.4119 TO 0.4246 *****
0.4246 TO 0.4372 *

FREQUENCY FOR GENERATIONS 29 TO 103
0.3740 TO 0.3866 **
0.3866 TO 0.3993 *****
0.3993 TO 0.4119 *****
0.4119 TO 0.4246 *****
0.4246 TO 0.4372 *

FREQUENCY FOR GENERATIONS 54 TO 103
0.3740 TO 0.3866 **
0.3866 TO 0.3993 *****
0.3993 TO 0.4119 *****
0.4119 TO 0.4246 *****
0.4246 TO 0.4372 *

FREQUENCY FOR GENERATIONS 79 TO 103
0.3740 TO 0.3866 **
0.3866 TO 0.3993 *****
0.3993 TO 0.4119 *****
0.4119 TO 0.4246 *****
0.4246 TO 0.4372 *
```

### 6.6.3 MONK8a Input and Output Files

This section contains sample MONK8a input files and output summary files for the criticality analysis of the NAC-UMS Universal Transport Cask under the hypothetical top end drop accident conditions. The summary output files include: the program banner page, the status of input units at the end of stage one processing and the results. All other output sections are not included for brevity.



**Figure 6.6.3-1 MONK8a Input File - UMS Transport Cask PWR Top End Impact**

Columns 1-200

UMS Transport Cask Model  
Version PWRL1.1

always convert. Always converts integers to real numbers

\*\*\*\*\*  
\* Inserting TSC Parameters Here \*

```
qifu = 385.1402
qitcap = 1.7399
qibcap = 1.7399
qiactu = 365.76
qioapie = 7.9501
qocciad = 0.9144
qciadth = 0.05715
qocpelle = 0.78435
qlattice = 17
qrpitch = 1.25984
qodgt = 1.08966
qgth = 0.04064
qodit = 1.22428
qith = 0.0381
qlassem = 403.352
qwfuel = 21.40204
qlbnozz = 6.858
qltnozz = 6.7818
qsgapb = 4.5719
qsguidtube = 24
qmisegment = 1
qmfuelpin = 264
qfuoffz = 11.7093

qfasln = 0.237
qfvoidln = 0.763
qfssun = 0.2801
qfvoidun = 0.7199

qguz35gu02 = 0.037
qguz38gu02 = 0.8445
qoguo2 = 0.1185

qfft = 22.4282
qfth = 0.12192
qfutube = 388.112
qfto = 23.14448
qftoffz = 0.0
qsoffz = 0.0
qsoffx = 0.0
qsoffy = 0.0
qbrl = 20.9042
qblt = 0.1905
qblct = 0.127
qblct = 378.9459
qblct = 0.4572
qblct = 0.0
qbshiftx = 0.0
qbshiftz = 0.0
qsvet = 0.04572
qlcvs = 384.302
qcvoffz = 1.6764
qtboffz = 0.2222
qtboffy = 0.2222

qdiabw = 166.37
qibw = 5.0292
qibwd = 2.54
qibws = 11.2268
qdiabw = 166.37
qltpw = 18.6182
qltpw = 3.175
qocspd = 23.589
qdiarp = 166.5478
qspd = 1.27
qspdx = 13.6628
qspdy = 39.7537
qspz = 65.5271
qspcx = 41.0237
qspcy = 13.6628
qspdz = 39.7537
qspyc = 65.5271
qspyc = 41.0237
qdiact = 165.9128
qcthd = 1.27
qseptubetotop = 1.27
qntd = 29
qnspx = 30
qsscct = 5.6134
qdsact = 4.9784
qlbasket = 413.0294
```

Figure 6.6.3-1

MONK8a Input File - UMS Transport Cask PWR Top End Impact (Continued)

```

@diskstack = 363.6772
@baskoff = 0.0

@canod = 170.3324
@canth = 1.5875
@canl = 444.627
@canbot = 4.4196
@shieldl = 17.526
@structl = 7.62
@cavheight = 415.0614

*****
* The following parameters need to be updated.
*****
@tscMIX = 2 ! Last mixture number of TSC going into cask
@tscMAT = 15 ! Last material number of TSC going into cask
@tscNUM = 16 ! Last part number of TSC going into cask
@fuelMAT = 1 ! Material number of fuel from TSC model
*****

* Cask Parameters
@tporacavLT = 488.95
@topnsOFF = 46.8376
@slopeLT = 12.7
@tporacavOD = 171.7294
@lidrcsOD = 199.0344
@tporctopOD = 216.5604
@lidrcsTH = 16.51
@pbID = 181.8894
@pbOD = 195.8594
@outshlTH = 6.985
@tporctbotTH = 12.7
@botfrgTH = 10.795
@botnsTH = 2.54
@botringdiskTH = 17.78
@strunOFF = 30.8864
@transportLT = 531.495
@strunOD = 30.6324
@ptrunewTH = 5.08
@ptrunbTH = 8.89
@ptrunOD = 30.48
@ptrunTH = 7.62

*****
BEGIN MATERIAL SPECIFICATION
*****

NORMALISE

* Input Mixtures

NMIXTURES @tscMIX

ATOMS
MIXTURE 1
H1 2
O16 1

WEIGHT
MIXTURE 2
U235 @gU235gUO2
U238 @gU238gUO2
O16 @gOgUO2

NMATERIALS [@tscMAT + 5]

*****
* Inserting TSC Materials Here *
*****

WEIGHT
MATERIAL 1 DENSITY 10.412 MIXTURE 2 95% UO2
MATERIAL 2 ZIRCALLOY Fuel pin cladding / End Cap
MATERIAL 3 DENSITY 0.9982 MIXTURE 1 Water in Lattice and Tube
MATERIAL 4 DENSITY 0.9982 MIXTURE 1 Water in Fuel Rod Clad Gap
MATERIAL 5 ZIRCALLOY Guide tube material
MATERIAL 6 ZIRCALLOY Instrument Tube Material

VOLUME
MATERIAL 7
STAINLESS 304L STEEL PROP @fssl
MIXTURE 1 DENSITY 0.9982 PROP @fvoidln Lower Nozzle Material
MATERIAL 8

```

```

STAINLESS 304L STEEL PROP @fssun
MIXTURE 1 DENSITY 0.9982 PROP @fvoidun Upper Nozzle Material

WEIGHT
MATERIAL 9 STAINLESS 304L STEEL Tube wall and cover sheet

VOLUME
MATERIAL 10 BORAL core
AL27 DENSITY 2.6000 PROP 0.4627
B10 DENSITY 2.6000 PROP 0.0568
B11 DENSITY 2.6000 PROP 0.3449
C DENSITY 2.6000 PROP 0.1167
VOID PROP 0.0189

WEIGHT
MATERIAL 11 ALUMINIUM BORAL aluminum clad

WEIGHT
MATERIAL 12 STAINLESS 304L STEEL Structural Disk Material

WEIGHT
MATERIAL 13 STAINLESS 304L STEEL Weldment Material

WEIGHT
MATERIAL 14 ALUMINIUM Heat Transfer Disk Material

WEIGHT
MATERIAL 15 STAINLESS 304L STEEL Canister Material

*****

WEIGHT
@matSS304=1
MATERIAL [@tscMAT + 1] STAINLESS 304L STEEL Steel components of Transport Cask

WEIGHT
@matLead=2
MATERIAL [@tscMAT + 2] DENSITY 11.04 LEAD
PB PROP 1.0000

ATOMS
@matNS4FR=3
MATERIAL [@tscMAT + 3] DENSITY 0.0 INS-4-FR
B10 PROP 8.553E-5
B11 PROP 3.422E-4
AL PROP 7.763E-3
H PROP 5.854E-2
O PROP 2.609E-2
C PROP 2.264E-2
N PROP 1.394E-3

ATOMS
@matCI=4
MATERIAL [@tscMAT + 4] DENSITY 0.9982 Material (water) outside of Canister Inside Cask
H1 PROP 2
O16 PROP 1

ATOMS
@matCB=5
MATERIAL [@tscMAT + 5] DENSITY 0.9982 Material Outside Cask Body
H1 PROP 2
O16 PROP 1
END

*****
BEGIN MATERIAL GEOMETRY
*****

* Inserting TSC Geometry Here *

*
* Fuel Assembly for Standard Opening
*

PART 1. NEST
BOX BHL 0.0 0.0 0.0 @wfuel @wfuel @lassem fuel assembly

* Fuel Assembly. This may be replaced during
* criticality analysis by a different fuel assembly configuration or failed fuel can

PART 2. NAME fuel assembly

*
* BORAL and Cover for Standard Opening
* Unit Composed of BORAL sheet and steel cover sheet
* Assumes BORAL sheet is cut off at the width of the BORAL sheet

```

**Figure 6.6.3-1 MONK8a Input File - UMS Transport Cask PWR Top End Impact (Continued)**

```

PART 1 NEST
BOX B16 gcvt 0.0 (b16+gboffz) gblt gbrl alboral BORAL Sheet - Axial offset from cover sheet bottom
BOX M1 gcvt 0.0 0.0 gblt gbrl gcvls Space under cover sheet that allows sheet to shift under
cover
BOX M0 0.0 0.0 0.0 (gblt+gcvt) gbrl gcvls SS cover sheet for BORAL

* Base PART A (fuel in tubing) for shifting in standard opening - this PART is rotated from 90 to 270 degrees
* Maximum shift implies shift to upper right (+x,y) corner of tube

PART 4
BOX 1 [-1.0*gfuel/2.0+gasoffx] [-1.0*gfuel/2.0+gasoffy] gfuoffz fuel assembly
gfuel gfuel glassm
BOX 2 [-1.0*gwft/2.0] [-1.0*gwft/2.0] 0.0 fuel assembly
gwft gwft gcavheight space inside tube from can lid to bottom
BOX 3 [-1.0*gwft/2.0-gftth] [-1.0*gwft/2.0-gftth] (gbaskoff+gblw+gftoffz)
(gwft+gftth) (gwft+gftth) gfttube fuel tube
BOX 4 [-1.0*gwft/2.0-gftth] [-1.0*gwft/2.0-gftth] 0.0 fuel tube
(gwft+gftth) (gwft+gftth) gcavheight container body extent of basket cavity

ZONES
/Fuel Assembly/ P1 +1
/Space in Tube/ M3 +2 -1
/Fuel Tube/ M9 +3 -2
/Container/ M3 +4 -3 -2

* Base PART B (fuel in tubing) for shifting in corner opening - this PART is rotated from 90 to 270 degrees
* Maximum shift implies shift to upper right (+x,y) corner of tube

PART 5
BOX 1 [-1.0*gfuel/2.0+gasoffx] [-1.0*gfuel/2.0+gasoffy] gfuoffz fuel assembly
gfuel gfuel glassm
BOX 2 [-1.0*gwft/2.0] [-1.0*gwft/2.0] 0.0 fuel assembly
gwft gwft gcavheight space inside tube from can lid to bottom
BOX 3 [-1.0*gwft/2.0-gftth] [-1.0*gwft/2.0-gftth] (gbaskoff+gblw+gftoffz)
(gwft+gftth) (gwft+gftth) gfttube fuel tube
BOX 4 [-1.0*gwft/2.0-gftth] [-1.0*gwft/2.0-gftth] 0.0 fuel tube
(gwft+gftth) (gwft+gftth) gcavheight container body extent of basket cavity

ZONES
/Fuel Assembly/ P2 +1
/Space in Tube/ M3 +2 -1
/Fuel Tube/ M9 +3 -2
/Container/ M3 +4 -3 -2

* Includes the tube in the disk opening shifted in the +x, +y direction (upper
* left).
* For shifts in other directions (such as those required for radial in and out shifting additional PARTS
* are required. It is recommended that the UNIT below is rotated to produce shifted UNITS which can then
* be substituted into PART 8. To minimize renumbering of PARTS the rotated PARTS may be placed starting at PART 9.
* PART 9 and PART 10 will require renumbering if this option is employed.

* Base PART A - Standard disk opening for shifting - this PART is rotated from 90 to 270 degrees
* Maximum shift implies shift to upper right (+x,y) corner of opening

PART 6 CLUSTER
BOX P4 [-1.0*gwft/2.0-gftth] [-1.0*gwft/2.0-gftth] 0.0 Fuel element with fuel tube
(gwft+gftth) (gwft+gftth) gcavheight
BORAL Sheet -x
BOX P3 [-1.0*gwft/2.0] [-1.0*gwft/2.0] 0.0
(-1.0*gwft/2.0) (-1.0*gwft/2.0) 0.0+gshifty/ z
(gbaskoff+gblw+gftoffz+gcvoftz) delta x, delta y, delta z
(gblt+gcvt) gbrl gcvls
BORAL Sheet -x - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [-1.0*gwft/2.0+gftth] [-1.0*gwft/2.0+gftth] 0.0
(-1.0*gwft/2.0) (-1.0*gwft/2.0) 0.0+gshifty/ z
(gbaskoff+gblw+gftoffz+gcvoftz) delta x, delta y, delta z
(gblt+gcvt) gbrl gcvls ZROT 270
(gblt+gcvt) gbrl gcvls ZROT 180
BORAL Sheet -y
BOX P3 [-1.0*gwft/2.0] (-1.0*gwft/2.0) (-1.0*gwft/2.0) 0.0+gshiftx/ z
(-1.0*gwft/2.0) (-1.0*gwft/2.0) 0.0+gshifty/ z
(gbaskoff+gblw+gftoffz+gcvoftz) delta x, delta y, delta z
(gblt+gcvt) gbrl gcvls ZROT 90
BORAL Sheet -y
BOX P3 [-1.0*gwft/2.0] (-1.0*gwft/2.0) (-1.0*gwft/2.0) 0.0+gshiftx/ z
(-1.0*gwft/2.0) (-1.0*gwft/2.0) 0.0+gshifty/ z
(gbaskoff+gblw+gftoffz+gcvoftz) delta x, delta y, delta z
(gblt+gcvt) gbrl gcvls ZROT 270
BOX M3 [-1.0*gcpsd/2.0-gboffx] [-1.0*gcpsd/2.0-gboffy] 0.0 Support disk opening width
gcpsd gcpsd gcavheight

```

Figure 6.6.3-1

MONK8a Input File - UMS Transport Cask PWR Top End Impact (Continued)

```

* Base PART B - Corner disk opening for shifting - this PART is rotated from 90 to 270 degrees
* Maximum shift implies shift to upper right (x,y) corner of opening
*
PART 7 CLUSTER
BOX P5 [(-1.0*ewfto/2.0-efth) (-1.0*ewft/2.0-efth) 0.0
[ewft+2*efth] [ewft+2*efth] @cavheight Fuel element with fuel tube
* BORAL Sheet -X
BOX P3 [(-1.0*ewfto/2.0)] [(-1.0*ewfto/2.0)+(ewfto-ewbrl)/2.0+ebshifty]
[ebaskoff+elbw+eftoffz+ecvoffz] [ebaskoff+elbw+eftoffz+ecvoffz]
[ebilt+ecvst] ewbrl elcvs delta x, delta y, delta z
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*ewfto/2.0)+ewftol] [(-1.0*ewfto/2.0)+(ewfto-ewbrl)/2.0+ebshifty]
[ebaskoff+elbw+eftoffz+ecvoffz] [ebaskoff+elbw+eftoffz+ecvoffz]
[ebilt+ecvst] ewbrl elcvs ZROT 180
* BORAL Sheet +Y
BOX P3 [(-1.0*ewfto/2.0)+(ewfto-ewbrl)/2.0+ebshifty] [(-1.0*ewfto/2.0)+ewftol]
[ebaskoff+elbw+eftoffz+ecvoffz] [ebaskoff+elbw+eftoffz+ecvoffz]
[ebilt+ecvst] ewbrl elcvs ZROT 90 delta x, delta y, delta z
* BORAL Sheet -Y
BOX P3 [(-1.0*ewfto/2.0)+(ewfto-ewbrl)/2.0+ebshifty] [(-1.0*ewfto/2.0)]
[ebaskoff+elbw+eftoffz+ecvoffz] [ebaskoff+elbw+eftoffz+ecvoffz]
[ebilt+ecvst] ewbrl elcvs ZROT 270 delta x, delta y, delta z
BOX M3 [-1.0*opspd/2.0-otboffx] [-1.0*opspd/2.0-otboffy] 0.0
opspd opspd @cavheight Support disk opening width
*
* PWR Canister Cavity
* Models disks in basket at smallest disk diameter (currently heat transfer disk)
*
PART 8 CLUSTER
*Quadrant 1 Openings (2, 5, 6, 10, 11, 12)
BOX P10 [spxl-opspd/2.0] [spy3-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 2
BOX P10 [spxl-opspd/2.0] [spy2-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 5
BOX P13 [spxc-opspd/2.0] [spyc-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 6
BOX P10 [spxl-opspd/2.0] [spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 10
BOX P10 [spxl-opspd/2.0] [spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 11
BOX P10 [spxl-opspd/2.0] [spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 12
*Quadrant 2 Openings (1, 3, 4, 7, 8, 9)
BOX P9 [-1*spxl-opspd/2.0] [spy3-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 1
BOX P9 [-1*spxl-opspd/2.0] [spy2-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 4
BOX P12 [-1*spxc-opspd/2.0] [spyc-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 3
BOX P9 [-1*spxl-opspd/2.0] [spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 9
BOX P9 [-1*spxl-opspd/2.0] [spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 8
BOX P9 [-1*spxl-opspd/2.0] [spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 7
*Quadrant 3 Openings (23, 19, 20, 13, 14, 15)
BOX P6 [-1*spxl-opspd/2.0] [-1*spy3-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 23
BOX P6 [-1*spxl-opspd/2.0] [-1*spy2-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 20
BOX P7 [-1*spxc-opspd/2.0] [-1*spyc-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 19
BOX P6 [-1*spxl-opspd/2.0] [-1*spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 15
BOX P6 [-1*spxl-opspd/2.0] [-1*spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 14
BOX P6 [-1*spxl-opspd/2.0] [-1*spy1-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 13
*Quadrant 4 Openings (24, 21, 22, 16, 17, 18)
BOX P11 [spxl-opspd/2.0] [-1*spy3-opspd/2.0] [-1.0*(ebaskoff+elbw+elbws)]
opspd opspd @cavheight Basket Opening 24

```

Figure 6.6.3-1

MONK8a Input File - UMS Transport Cask PWR Top End Impact (Continued)

```

BOX P11 @cpx1-@cspd/2.0] [-1*@spy2-@cspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
@cspd @cspd @cavheight ! Basket Opening 21
BOX P14 @cpxc-@cspd/2.0] [-1*@spyc-@cspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
@cspd @cspd @cavheight ! Basket Opening 22

BOX P11 @cpx1-@cspd/2.0] [-1*@spy1-@cspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
@cspd @cspd @cavheight ! Basket Opening 16
BOX P11 @cpx2-@cspd/2.0] [-1*@spy1-@cspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
@cspd @cspd @cavheight ! Basket Opening 17
BOX P11 @cpx3-@cspd/2.0] [-1*@spy1-@cspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
@cspd @cspd @cavheight ! Basket Opening 18

ZROD H7 0.0 0.0 [-1.0*(@baskoff+@lbw+@lbws)]
@diaht/2.0] @cavheight ! Basket stack to cavity height

* Standard Opening (PART A) Rotated 90 degrees
* Maximum shift implies shift to lower right corner (+x,-y) of opening
*

PART 9 NEST

BOX P6 0.0 @cspd 0.0
@cspd @cspd @cavheight ZROT 90 Rotated Opening
BOX M3 0.0 0.0 0.0
@cspd @cspd @cavheight container

*
* Standard Opening (PART A) Rotated 180 degrees
* Maximum shift implies shift to lower left corner (-x,-y) of opening
*

PART 10 NEST

BOX P6 @cspd @cspd 0.0
@cspd @cspd @cavheight ZROT 180 Rotated Opening
BOX M3 0.0 0.0 0.0
@cspd @cspd @cavheight container

*
* Standard Opening (PART A) Rotated 270 degrees
* Maximum shift implies shift to upper left corner (-x,+y) of opening
*

PART 11 NEST

BOX P6 @cspd 0.0 0.0
@cspd @cspd @cavheight ZROT 270 Rotated Opening
BOX M3 0.0 0.0 0.0
@cspd @cspd @cavheight container

*
* Corner Opening Rotated 90 degrees
* Maximum shift implies shift to lower right corner (+x,-y) of opening
*

PART 12 NEST

BOX P7 0.0 @cspd 0.0
@cspd @cspd @cavheight ZROT 90 Rotated Opening
BOX M3 0.0 0.0 0.0
@cspd @cspd @cavheight container

*
* Corner Opening Rotated 180 degrees
* Maximum shift implies shift to lower left corner (-x,-y) of opening
*

PART 13 NEST

BOX P7 @cspd @cspd 0.0
@cspd @cspd @cavheight ZROT 180 Rotated Opening
BOX M3 0.0 0.0 0.0
@cspd @cspd @cavheight container

*
* Corner Opening Rotated 270 degrees
* Maximum shift implies shift to upper left corner (-x,+y) of opening
*

PART 14 NEST

BOX P7 @cspd 0.0 0.0
@cspd @cspd @cavheight ZROT 270 Rotated Opening
BOX M3 0.0 0.0 0.0
@cspd @cspd @cavheight container

*
* Basket in Cask Cavity
* Note: Disk to use in the first ZROD is the disk with minimum radius (aluminum)
*

PART 15 NEST

```

Figure 6.6.3-1

MONK8a Input File - UMS Transport Cask PWR Top End Impact (Continued)

```
ZROD P8 0.0 0.0 0.0 0.0 [edist/2.0] [ecavheight] [ecavheight] [Basket inserted - includes Cap to Lid]
ZROD M3 0.0 0.0 0.0 0.0 [ecanod/2.0-ecanhl] [ecavheight] [ecavheight] [Inserts water to canister shell]
```

```
*Canister Used General part due to modification later required for temporary shield and ports
```

```
Note: Existing dimensions Assumes that lids are flush with cavity shell
```

```
This may have to be modified for use of a temporary shield lid or if the shield lid is recessed
```

```
Cavity Height input is also based on a flush lid
```

## PART 16

```
ZROD 1 0.0 0.0 0.0 0.0 [ecanod/2.0-ecanhl] [ecavheight] [ecavheight] [Canister Cavity contents]
ZROD 2 0.0 0.0 0.0 [-1*ecanbot] [ecanod/2.0] [ecanbot] [Canister Bottom plate]
ZROD 3 0.0 0.0 0.0 [ecavheight] [ecanod/2.0-ecanhl] [eshield] [Shield Lid]
ZROD 4 0.0 0.0 0.0 [ecavheight+eshield] [ecanod/2.0-ecanhl] [estructl] [Structural Lid]
ZROD 5 0.0 0.0 0.0 [ecanod/2.0-ecanhl] [ecanod/2.0-ecanhl] [ecanl-ecanbot] [Canister Shell Inner]
ZROD 6 0.0 0.0 0.0 [ecanod/2.0] [ecanod/2.0] [ecanl-ecanbot] [Canister Shell Outer]
ZROD 7 0.0 0.0 0.0 [-1*ecanbot] [ecanod/2.0] [ecanl] [Inner Detector Surface]
```

## ZONES

```
/Cavity/ P15 +1
/Bottomplate/ M15 +2
/Shieldlid/ M15 +3
/Structlid/ M15 +4
/Shell/ M15 +6 -5
/Canister/ M0 +7 -6 -4 -2
```

```
*****
123456789012345678901234567890123456789012345678901234567890123456789012
```

```
PART [etscnum + 1]
```

```
ZROD 1 0.0 0.0 0.0 0.0 [etporttopOD/2] [etporttopLT] [etporttopLT] [Container]
ZROD 2 0.0 0.0 0.0 0.0 [etpOD/2+etushlth] [etportbotTH] [etportbotTH] [Bottom]
ZROD 3 0.0 0.0 0.0 [etportbotTH+etbotfingTH+etbotnsTH] [etportcavOD/2.1] [etportcavLT] [Cavity]
ZROD 4 0.0 0.0 [etportbotTH+etbotfingTH+etbotnsTH+etportcavLT-ecanl] [ecanod/2.0] [ecanl] [Canister]
ZROD 5 0.0 0.0 [ettransportLT-qlidrcsth] [qlidrcsth] [Lid]
ZROD 6 0.0 0.0 [etportbotTH] [etpOD/2.0] [etbotnsTH] [Bottom neutron shield]
ZROD 7 [-1*(etporttopOD/2)-(ettrunbTH+ettrunemTH)-ettrunTH] 0.0 [ettrunOD/2.1] [-2*(-1*(etporttopOD/2)-(ettrunbTH+ettrunemTH)-ettrunTH)] Primary
```

## trunnion

```
ZROD 8 0.0 [-1*(etporttopOD/2)] [ettransportLT-ettrunOD] [ettransportLT-ettrunOD] Secondary trunnion
ZROD 9 0.0 0.0 [ettransportLT-ettrunOD] [etporttopOD/2] [ettrunOD/2] Top shell
ZROD 10 0.0 0.0 0.0 [-1*etpOD/2.0] [ettransportLT] [ettransportLT] Inner shell
ZROD 11 0.0 0.0 [etportbotTH+etbotfingdiskTH] [ettransportLT-ettrunOD] [ettransportLT-ettrunOD] Lead shield
ZROD 12 0.0 0.0 [etportbotTH] [etpOD/2] [etbotfingdiskTH] [etpOD/2+etushlth] Bottom ring/disk
ZCONE 13 0.0 0.0 [ettransportLT-ettrunOD-etpOD/2] [etpOD/2] [etpOD/2] Outer shell OD change
ZROD 14 0.0 0.0 [etportbotTH] [ettransportLT-ettrunOD] [ettransportLT-ettrunOD] Outer shell
```

## ZONES

```
/Transport/ M[etechat + etatCB] +1 -2 -14 -13 -9
/Lid/ M[etechat + etatSS304] +5
/TSC/ P[etscnum]
/Cavity/ M[etechat + etatCI] +3 -4
/Bottom/ M[etechat + etatSS304] +2
/Bottoms/ M[etechat + etatNS4FR] +6
/Primarytrunnion/ M[etechat + etatSS304] +7 +1 -3 -5
/Secondarytrunnion/ M[etechat + etatSS304] +8 +1 -3 -5
/TopShell/ M[etechat + etatSS304] +9 -5 -3 -7 -8
/InnerShell/ M[etechat + etatSS304] +10 -2 -6 -3 -9
/LeadShield/ M[etechat + etatLead] +11 -10
/Bottomringdisk/ M[etechat + etatSS304] +12 -10
/OuterShellCone/ M[etechat + etatSS304] +13 -11
/OuterShell/ M[etechat + etatSS304] +14 -11 -12
```

ALBEDO 1.1

PERIODIC

END

```
*****
BEGIN HOLE DATA
```

```
*****
Inserting TSC Hole Data Here
```

```
*****
NOTE- All HOLE#2-5 coordinate positions should be with respect to HOLE#1 !!! *****
```

Figure 6.6.3-1 MONK8a Input File - UMS Transport Cask PWR Top End Impact (Continued)

```
* Hole 1 - Insert top/bottom endfitting and fuel rod together

PLATE
0.0 0.0 1.0      direction cosines: in the x direction
2                number of planes in the z direction
[glassem-@ltnozz] 8      top nozzle
[@lbnnoz]          -2     space between nozzles (HOLE#2) shifted up by @lbnnoz
7                bottom nozzle

* Hole 2 - 17x17 OPA Westinghouse PWR Element
* Assumes that guide tube has maximum diameter from any tube placed into lattice

LATTICE
@lattice @lattice      lattice size
@rpitch                rod pitch (cm)
[-(@rpitch/2.0)-(@wfuel-@lattice*@rpitch)/2.0]
[(-@rpitch/2.0)-(@wfuel-@lattice*@rpitch)/2.0] offset to center lattice in assembly envelope
PINS
[@odit/2.0] [ @odit/2.0] radius of rod, radius of can-GT/IT OR

34*-3
5*-3 -4 2*-3 -4 2*-3 -4 5*-3
3*-3 -4 9*-3 -4 3*-3
17*-3
2*-3 -4 2*-3 -4 2*-3 -4 2*-3 -4 2*-3
34*-3
2*-3 -4 2*-3 -4 2*-3 -5 2*-3 -4 2*-3 -4 2*-3
34*-3
2*-3 -4 2*-3 -4 2*-3 -4 2*-3 -4 2*-3
17*-3
3*-3 -4 9*-3 -4 3*-3
5*-3 -4 2*-3 -4 2*-3 -4 5*-3
34*-3
3 3

* Hole 3 - Fuel Rod
* Rod is shifted between end-fitting by modifying bottom gap to fuel rod
* Fuel material is shifted in rods by modifying lower plenum space

RZMESH
3                number of radial points
[@odpellet/2.0] [(@odclad/2.0)-@cladth] [ @odclad/2.0]
7                number of axial intervals
@lbnnoz          bottom nozzle elevation - correlates to HOLE 1 geometry
[ @lbnnoz+@fgapb] gap to bottom of fuel rod
[ @lbnnoz+@fgapb+@lbcap] top of bottom end cap region
[ @lbnnoz+@fgapb+@lbcap+@lowple] bottom plenum region ends
[ @lbnnoz+@fgapb+@lbcap+@lowple+@lactfu] top of active fuel region
[ @lbnnoz+@fgapb+@lbfu-@lftcap] bottom of top plug
[ @lbnnoz+@fgapb+@lbfu] top of fuel rod
[ @lassem-@ltnozz] bottom of top nozzle

3 3 3          space from bottom nozzle to bottom of fuel rod
2 2 2          bottom endcap
4 4 2          bottom expansion space (plenum) with cladding
1 4 2          fuel material pin with cladding
4 4 2          upper fuel expansion space (plenum) with cladding
2 2 2          top steel endcap
3 3 3          space above fuel rod to top nozzle
3                outermost material

* Hole 4 - Guide Tube

RZMESH
2                number of radial points
[(@odgt/2.0) - @gtth] [ @odgt/2.0]
1                number of axial intervals
@lbnnoz [glassem - @ltnozz] guide and instrument tubes go all through to top nozzle
3 5          water-filled instrument tube or guide tube
3                outermost material

* Hole 5 - Central Instrument Tube

RZMESH
2                number of radial points
[(@odit/2.0) - @itth] [ @odit/2.0]
1                number of axial intervals
@lbnnoz [glassem - @ltnozz] guide and instrument tubes go all through to top nozzle
3 6          water-filled instrument tube or guide tube
3                outermost material

* Hole 6 - BORAL Core

PLATE
1 0 0
2
[(@blt+@blct)/2.0] 11
[(@blt-@blct)/2.0] 10
11

* Hole 7 - General Basket Structure
* Structured to allow potential modification of weldment detail
```



Figure 6.6.3-1 MONK8a Input File - UMS Transport Cask PWR Top End Impact (Continued)

```

PLATE
0 0 1
5
[01basket-01bws-01bw] 3 Top of Basket
@diskstack -8 Top of Highest Support Disk
0 0 -10 Bottom of Lowest Support Disk
[-1.0*(01bw+01bws)] -9 Bottom of Basket
[-1.0*(01baskoff+01bw+01bws)] 3 Basket Offset
3

* Hole 8 Top Weldment Disk - no structure above the weldment disk
* If for shielding reason this structure is desired an additional elevation
* can be defined and filled by a more detailed plate hole (for example, XYZ mesh)

RZMESH
1 1 number of radial points
[0diatpw/2.0]
1 1 number of axial intervals
[01basket-01bws-01bw-01tpw]
[01basket-01bws-01bw-01tpw+01tpwd] Coordinates inherited from PLATE Hole
13 Plate Material
3 Outside material

* Hole 9 Bottom Weldment Disk - no structure in the weldment disk support

RZMESH
1 1 number of radial points
[0diabw/2.0]
1 1 number of axial intervals
[-1.0*(01bws+01bwd)]
[-1.0*01bws] Coordinates inherited from PLATE Hole
13 Plate Material
3

* Hole 10 Support disk and heat transfer disk stack

PLATE
0 0 1
4
CELL [0tspd+0dsspht+0thtd+0dsspht] Sets up a repeating lattice of cells
[0tspd+0dsspht+0thtd+0dsspht] 3 water
[0tspd+0dsspht+0thtd] 3 water gap
[0tspd+0dsspht] 14 aluminium disk
0tspd 3 water gap
12 steel disk

* Additional holes may be added to add weldment detail using the xyz mesh hole function
*****
END

*****
BEGIN CONTROL DATA
*****

*READ 1 read and check each independently
*SEEK MULTIPLE DEFINITIONS

SEEDS 12345 12345
STAGES -10 810 5000 STDV D 0005

END

*****
BEGIN SOURCE GEOMETRY
*****

ZONEMAT
ALL 1 MATERIAL $fuelMAT

END

```

Figure 6.6.3-2

MONK8a Output Summary -UMS Transport Cask PWR Top End Impact

```

1
  AA  N  NN  SSSSSS  WW  WW  EEEEEEE  RRRRRR  SSSSSS  CCCCCC  OOOOOO  DDDDDD  EEEEEEE
  AAAA  NN  NN  SSSSSSS  WW  WW  EEEEEEE  RRRRRRR  SSSSSSS  CCCCCC  OOOOOOO  DDDDDDD  EEEEEEE
  AA  AA  NNN  NN  SS  WW  WW  EE  RR  RR  SS  CC  OO  DD  DD  EE
  AA  AA  NNNN  NN  SS  WW  WW  EE  RR  RR  SS  CC  OO  DD  DD  EE
  AAAAAAA  NN  NN  NN  SSSSSS  WW  WW  EEEEE  RRRRRRR  SSSSSSS  CC  OO  DD  DD  EEEE
  AAAAAAA  NN  NN  NN  SSSSSS  WW  WW  EEEEE  RRRRRRR  SSSSSSS  CC  OO  DD  DD  EEEE
  AA  AA  NN  NNNN  SS  WW  WW  WW  EE  RR  RR  SS  CC  OO  DD  DD  EE
  AA  AA  NN  NNN  SS  WW  WW  WW  EE  RR  RR  SS  CC  OO  DD  DD  EE
  AA  AA  NN  NN  SSSSSS  WWWWW  EEEEEEE  RR  RR  SSSSSS  CCCCCC  OOOOOOO  DDDDDDD  EEEEEEE
  AA  AA  NN  N  SSSSSS  WW  WW  EEEEEEE  RR  RR  SSSSSS  CCCCCC  OOOOOO  DDDDDD  EEEEEEE

```

```

  M  M  OOOOOO  N  NN  KK  KK  888888  AA
  MM  MM  OOOOOOO  NN  NN  KK  KK  8888888  AAAA
  MM  MM  OO  NN  NN  KK  KK  88 88  AA  AA
  MMMMMM  OO  NN  NN  KK  KK  88 88  AA  AA
  MM  MM  OO  NN  NN  NN  KKKK  888888  AAAAAAA
  MM  MM  OO  NN  NN  NN  KKKK  888888  AAAAAAA
  MM  MM  OO  NN  NNNN  KK  KK  88 88  AA  AA
  MM  MM  OO  NN  NNN  KK  KK  88 88  AA  AA
  MM  MM  OOOOOOO  NN  NN  KK  KK  8888888  AA  AA
  MM  MM  OOOOOO  NN  N  KK  KK  888888  AA  AA

```

Running on machine 57NST ( Windows NT) ....  
Date and time of execution: 11/ 5/2000 - 11.48.0

```

PPPPPPP  CCCCCC  WW  WW  IIIIII  N  NN  N  NN  TTTTTT
PPPPPPP  CCCCCC  WW  WW  IIIIII  NN  NN  NN  NN  TTTTTT
PP  PP  CC  WW  WW  II  NNN  NN  NNN  NN  TT
PP  PP  CC  WW  WW  II  NNNN  NN  NNN  NN  TT
PPPPPPP  CC  WW  WW  II  NN  NN  NN  NN  NN  NN  TT
PPPPPPP  CC  WW  WW  II  NN  NN  NN  NN  NN  NN  TT
PP  CC  WW  WW  WW  II  NN  NNN  NN  NNN  NN  TT
PP  CC  WW  WW  WW  II  NN  NNN  NN  NNN  NN  TT
PP  CCCCCC  WWWWW  IIIIII  NN  NN  NN  NN  TT
PP  CCCCCC  WW  WW  IIIIII  NN  N  NN  N  TT

```

\*\*\*\*\* This Computer Program is Supplied Under Licence by the AEA Technology ANSWERS Software Service \*\*\*\*\*

```

*
*   Program MONK 8A - Release Update 1
*
*   This is the ANSWERS QA Set version of MONK. This
*   program has successfully executed the designated set
*   of test cases on the ANSWERS QA Set computer systems.
*
*   This is the first update release of MONK8A, known as
*   the RUI release. It contains corrections to the errors
*   reported in ANSWERS/CRIT/ERROR(98)28,30,31 and 33
*
*   22 January 1999

```

```

*
*   The MONK program is developed and maintained
*   through a collaboration between AEA Technology PLC
*   and British Nuclear Fuels PLC.
*

```

\*\*\*\*\*QI\*\*\*\*\*  
\* STATUS OF INPUT UNITS AT END OF STAGE ONE PROCESSING \*  
\*\*\*\*\*

PROBLEM CONTROL DATA.	USED-OK
MATERIAL GEOMETRY DATA.	USED-OK
SOURCE GEOMETRY DATA.	USED-OK
HOLE DATA	USED-OK
MATERIAL SPECIFICATION	USED-OK

Figure 6.6.3-2 MONK8a Output Summary - UMS Transport Cask PWR Top End Impact (Continued)

AT THE START OF THE TRACKING PROCESS THERE IS OVER A WEEK OF CPU TIME AVAILABLE

A TIME OF 10.000 SECS WILL BE ALLOWED FOR CREATING DUMP AND OUTPUT FILES

STAGE -10 COMPLETED AFTER	2.07 MIN	- K(THREE) = 0.9142 ( 0.0046)
STAGE -9 COMPLETED AFTER	4.36 MIN	- K(THREE) = 0.9205 ( 0.0031)
STAGE -8 COMPLETED AFTER	6.69 MIN	- K(THREE) = 0.9231 ( 0.0024)
STAGE -7 COMPLETED AFTER	9.02 MIN	- K(THREE) = 0.9250 ( 0.0021)
STAGE -6 COMPLETED AFTER	11.34 MIN	- K(THREE) = 0.9259 ( 0.0019)
STAGE -5 COMPLETED AFTER	13.63 MIN	- K(THREE) = 0.9282 ( 0.0017)
STAGE -4 COMPLETED AFTER	15.88 MIN	- K(THREE) = 0.9291 ( 0.0016)
STAGE -3 COMPLETED AFTER	18.13 MIN	- K(THREE) = 0.9298 ( 0.0015)
STAGE -2 COMPLETED AFTER	20.33 MIN	- K(THREE) = 0.9299 ( 0.0014)
STAGE -1 COMPLETED AFTER	22.69 MIN	- K(THREE) = 0.9311 ( 0.0013)
STAGE 0 COMPLETED AFTER	25.03 MIN	- K(THREE) = 0.9315 ( 0.0012)
STAGE 1 COMPLETED AFTER	27.48 MIN	- K(THREE) = 0.9259 ( 0.0041)
STAGE 2 COMPLETED AFTER	30.06 MIN	- K(THREE) = 0.9281 ( 0.0029)
STAGE 3 COMPLETED AFTER	32.56 MIN	- K(THREE) = 0.9298 ( 0.0023)
STAGE 4 COMPLETED AFTER	34.91 MIN	- K(THREE) = 0.9311 ( 0.0021)
STAGE 5 COMPLETED AFTER	37.32 MIN	- K(THREE) = 0.9314 ( 0.0019)
STAGE 6 COMPLETED AFTER	39.85 MIN	- K(THREE) = 0.9321 ( 0.0017)
STAGE 7 COMPLETED AFTER	42.31 MIN	- K(THREE) = 0.9324 ( 0.0016)
STAGE 8 COMPLETED AFTER	44.69 MIN	- K(THREE) = 0.9320 ( 0.0015)
STAGE 9 COMPLETED AFTER	47.12 MIN	- K(THREE) = 0.9315 ( 0.0014)
STAGE 10 COMPLETED AFTER	49.58 MIN	- K(THREE) = 0.9319 ( 0.0013)
STAGE 11 COMPLETED AFTER	51.93 MIN	- K(THREE) = 0.9323 ( 0.0013)
STAGE 12 COMPLETED AFTER	54.24 MIN	- K(THREE) = 0.9328 ( 0.0012)
STAGE 13 COMPLETED AFTER	56.77 MIN	- K(THREE) = 0.9327 ( 0.0012)
STAGE 14 COMPLETED AFTER	59.12 MIN	- K(THREE) = 0.9325 ( 0.0011)
STAGE 15 COMPLETED AFTER	61.55 MIN	- K(THREE) = 0.9322 ( 0.0011)
STAGE 16 COMPLETED AFTER	63.94 MIN	- K(THREE) = 0.9324 ( 0.0010)
STAGE 17 COMPLETED AFTER	66.30 MIN	- K(THREE) = 0.9324 ( 0.0010)
STAGE 18 COMPLETED AFTER	68.72 MIN	- K(THREE) = 0.9324 ( 0.0010)
STAGE 19 COMPLETED AFTER	71.14 MIN	- K(THREE) = 0.9325 ( 0.0010)
STAGE 20 COMPLETED AFTER	73.65 MIN	- K(THREE) = 0.9328 ( 0.0009)
STAGE 21 COMPLETED AFTER	76.05 MIN	- K(THREE) = 0.9329 ( 0.0009)
STAGE 22 COMPLETED AFTER	78.47 MIN	- K(THREE) = 0.9333 ( 0.0009)
STAGE 23 COMPLETED AFTER	81.02 MIN	- K(THREE) = 0.9336 ( 0.0009)
STAGE 24 COMPLETED AFTER	83.46 MIN	- K(THREE) = 0.9338 ( 0.0008)
STAGE 25 COMPLETED AFTER	85.92 MIN	- K(THREE) = 0.9340 ( 0.0008)
STAGE 26 COMPLETED AFTER	88.31 MIN	- K(THREE) = 0.9339 ( 0.0008)
STAGE 27 COMPLETED AFTER	90.70 MIN	- K(THREE) = 0.9338 ( 0.0008)
STAGE 28 COMPLETED AFTER	93.12 MIN	- K(THREE) = 0.9336 ( 0.0008)
STAGE 29 COMPLETED AFTER	95.51 MIN	- K(THREE) = 0.9335 ( 0.0008)
STAGE 30 COMPLETED AFTER	97.99 MIN	- K(THREE) = 0.9336 ( 0.0008)
STAGE 31 COMPLETED AFTER	100.41 MIN	- K(THREE) = 0.9337 ( 0.0007)
STAGE 32 COMPLETED AFTER	102.76 MIN	- K(THREE) = 0.9336 ( 0.0007)
STAGE 33 COMPLETED AFTER	105.22 MIN	- K(THREE) = 0.9336 ( 0.0007)
STAGE 34 COMPLETED AFTER	107.64 MIN	- K(THREE) = 0.9337 ( 0.0007)
STAGE 35 COMPLETED AFTER	110.14 MIN	- K(THREE) = 0.9338 ( 0.0007)
STAGE 36 COMPLETED AFTER	112.57 MIN	- K(THREE) = 0.9340 ( 0.0007)
STAGE 37 COMPLETED AFTER	114.87 MIN	- K(THREE) = 0.9339 ( 0.0007)
STAGE 38 COMPLETED AFTER	117.31 MIN	- K(THREE) = 0.9340 ( 0.0007)
STAGE 39 COMPLETED AFTER	119.77 MIN	- K(THREE) = 0.9340 ( 0.0007)
STAGE 40 COMPLETED AFTER	122.19 MIN	- K(THREE) = 0.9340 ( 0.0007)
STAGE 41 COMPLETED AFTER	124.61 MIN	- K(THREE) = 0.9341 ( 0.0006)
STAGE 42 COMPLETED AFTER	126.97 MIN	- K(THREE) = 0.9340 ( 0.0006)
STAGE 43 COMPLETED AFTER	129.46 MIN	- K(THREE) = 0.9341 ( 0.0006)
STAGE 44 COMPLETED AFTER	131.87 MIN	- K(THREE) = 0.9342 ( 0.0006)
STAGE 45 COMPLETED AFTER	134.35 MIN	- K(THREE) = 0.9342 ( 0.0006)
STAGE 46 COMPLETED AFTER	136.70 MIN	- K(THREE) = 0.9342 ( 0.0006)
STAGE 47 COMPLETED AFTER	139.11 MIN	- K(THREE) = 0.9342 ( 0.0006)
STAGE 48 COMPLETED AFTER	141.50 MIN	- K(THREE) = 0.9342 ( 0.0006)
STAGE 49 COMPLETED AFTER	143.91 MIN	- K(THREE) = 0.9341 ( 0.0006)
STAGE 50 COMPLETED AFTER	146.35 MIN	- K(THREE) = 0.9341 ( 0.0006)
STAGE 51 COMPLETED AFTER	148.68 MIN	- K(THREE) = 0.9341 ( 0.0006)
STAGE 52 COMPLETED AFTER	151.39 MIN	- K(THREE) = 0.9341 ( 0.0006)
STAGE 53 COMPLETED AFTER	153.89 MIN	- K(THREE) = 0.9343 ( 0.0006)
STAGE 54 COMPLETED AFTER	156.30 MIN	- K(THREE) = 0.9344 ( 0.0006)
STAGE 55 COMPLETED AFTER	158.76 MIN	- K(THREE) = 0.9344 ( 0.0006)
STAGE 56 COMPLETED AFTER	161.13 MIN	- K(THREE) = 0.9343 ( 0.0006)
STAGE 57 COMPLETED AFTER	163.58 MIN	- K(THREE) = 0.9343 ( 0.0005)
STAGE 58 COMPLETED AFTER	165.93 MIN	- K(THREE) = 0.9341 ( 0.0005)
STAGE 59 COMPLETED AFTER	168.26 MIN	- K(THREE) = 0.9340 ( 0.0005)
STAGE 60 COMPLETED AFTER	170.69 MIN	- K(THREE) = 0.9340 ( 0.0005)
STAGE 61 COMPLETED AFTER	173.02 MIN	- K(THREE) = 0.9339 ( 0.0005)
STAGE 62 COMPLETED AFTER	175.39 MIN	- K(THREE) = 0.9339 ( 0.0005)
STAGE 63 COMPLETED AFTER	177.74 MIN	- K(THREE) = 0.9337 ( 0.0005)
STAGE 64 COMPLETED AFTER	180.03 MIN	- K(THREE) = 0.9336 ( 0.0005)
STAGE 65 COMPLETED AFTER	182.52 MIN	- K(THREE) = 0.9337 ( 0.0005)
STAGE 66 COMPLETED AFTER	184.86 MIN	- K(THREE) = 0.9336 ( 0.0005)
STAGE 67 COMPLETED AFTER	187.25 MIN	- K(THREE) = 0.9335 ( 0.0005)
STAGE 68 COMPLETED AFTER	189.61 MIN	- K(THREE) = 0.9335 ( 0.0005)
STAGE 69 COMPLETED AFTER	192.07 MIN	- K(THREE) = 0.9335 ( 0.0005)

\*\*\*\*\*  
\* REQUIRED ACCURACY (SD= 0.000500) REACHED BY K(THREE) \*  
\* EXECUTION ENDS AFTER STAGE 69  
\*\*\*\*\*

Figure 6.6.3-2

MONK8a Output Summary -UMS Transport Cask PWR Top End Impact (Continued)

OUTPUT FROM MONK8A (1/2/1998) AT 15° 0.15' ON 11/5/2000  
=====00=====

NUMBER OF SUPERHISTORIES POST-SETTLING = 345000  
NUMBER OF SAMPLES POST-SETTLING = 3452237  
FIRST STAGE RUN = -10  
FINAL STAGE COMPLETED = 69  
TOTAL C.P.U. TIME (SECONDS) = 11524.281  
AVERAGE TIME PER SAMPLE(SECONDS) = 0.029  
AVERAGE TIME PER STAGE(SECONDS) = 144.054  
AVERAGE SAMPLES PER SECONDS = 34  
NUMBER OF RANDOM NUMBERS USED = 1462709598  
AFTER SEEDING WITH VALUES = 12345  
TRAJECTORIES TRACKED THIS RUN = 148082462  
NUMBER OF COLLISIONS THIS RUN = 194833026  
ZONE SEARCH LOCATIONS USED(PAIRS) = 297

***** CUMULATIVE K-EFFECTIVE ESTIMATORS *****										
STAGE	K(COLL)	STDV	K(SCORE)	STDV	A(SCORE)	STDV	ALPHA	BETA	K(THREE)	STDV
1	0.9294	0.0056	0.9287	0.0064	1.0028	0.0036	0.2157	1.0774	0.9259	0.0041
2	0.9324	0.0038	0.9291	0.0044	1.0018	0.0025	0.2393	1.0082	0.9281	0.0029
3	0.9319	0.0030	0.9311	0.0035	1.0016	0.0020	0.2557	0.9686	0.9298	0.0023
4	0.9312	0.0027	0.9295	0.0031	0.9989	0.0017	0.2293	0.9859	0.9311	0.0021
5	0.9317	0.0024	0.9297	0.0027	0.9988	0.0016	0.2217	1.0036	0.9314	0.0019
6	0.9325	0.0022	0.9305	0.0025	0.9989	0.0014	0.2253	1.0065	0.9321	0.0017
7	0.9329	0.0020	0.9301	0.0023	0.9983	0.0013	0.2203	1.0024	0.9324	0.0016
8	0.9323	0.0019	0.9294	0.0022	0.9980	0.0012	0.2231	0.9881	0.9320	0.0015
9	0.9326	0.0018	0.9288	0.0020	0.9981	0.0012	0.2159	0.9997	0.9315	0.0014
10	0.9329	0.0017	0.9294	0.0019	0.9982	0.0011	0.2158	1.0058	0.9319	0.0013
11	0.9330	0.0016	0.9299	0.0019	0.9982	0.0010	0.2154	1.0055	0.9323	0.0013
12	0.9331	0.0016	0.9308	0.0018	0.9985	0.0010	0.2180	1.0059	0.9328	0.0012
13	0.9335	0.0015	0.9308	0.0017	0.9987	0.0010	0.2184	1.0058	0.9327	0.0012
14	0.9331	0.0015	0.9303	0.0016	0.9984	0.0009	0.2170	1.0016	0.9325	0.0011
15	0.9329	0.0014	0.9306	0.0016	0.9989	0.0009	0.2195	1.0033	0.9322	0.0011
16	0.9329	0.0014	0.9310	0.0015	0.9990	0.0009	0.2199	0.9995	0.9324	0.0010
17	0.9327	0.0013	0.9305	0.0015	0.9986	0.0008	0.2184	0.9989	0.9324	0.0010
18	0.9328	0.0013	0.9309	0.0015	0.9990	0.0008	0.2182	1.0018	0.9324	0.0010
19	0.9329	0.0013	0.9310	0.0014	0.9989	0.0008	0.2157	1.0058	0.9325	0.0010
20	0.9330	0.0012	0.9311	0.0014	0.9987	0.0008	0.2174	1.0005	0.9328	0.0009
21	0.9329	0.0012	0.9313	0.0013	0.9988	0.0008	0.2211	0.9997	0.9329	0.0009
22	0.9330	0.0012	0.9317	0.0013	0.9986	0.0008	0.2216	0.9959	0.9333	0.0009
23	0.9336	0.0011	0.9320	0.0013	0.9987	0.0007	0.2182	1.0009	0.9336	0.0009
24	0.9336	0.0011	0.9322	0.0013	0.9987	0.0007	0.2210	0.9969	0.9338	0.0008
25	0.9338	0.0011	0.9325	0.0012	0.9988	0.0007	0.2216	0.9958	0.9340	0.0008
26	0.9338	0.0011	0.9324	0.0012	0.9988	0.0007	0.2191	0.9966	0.9339	0.0008
27	0.9338	0.0010	0.9324	0.0012	0.9989	0.0007	0.2185	0.9996	0.9338	0.0008
28	0.9337	0.0010	0.9324	0.0012	0.9990	0.0007	0.2191	0.9995	0.9336	0.0008
29	0.9335	0.0010	0.9324	0.0011	0.9991	0.0007	0.2197	0.9969	0.9335	0.0008
30	0.9336	0.0010	0.9327	0.0011	0.9993	0.0006	0.2193	0.9968	0.9336	0.0008
31	0.9337	0.0010	0.9328	0.0011	0.9993	0.0006	0.2196	0.9958	0.9337	0.0007
32	0.9336	0.0010	0.9327	0.0011	0.9993	0.0006	0.2184	0.9958	0.9336	0.0007
33	0.9336	0.0010	0.9331	0.0011	0.9996	0.0006	0.2206	0.9953	0.9336	0.0007
34	0.9337	0.0009	0.9331	0.0011	0.9996	0.0006	0.2199	0.9980	0.9337	0.0007
35	0.9340	0.0009	0.9334	0.0010	0.9997	0.0006	0.2191	0.9993	0.9338	0.0007
36	0.9341	0.0009	0.9336	0.0010	0.9997	0.0006	0.2196	1.0000	0.9340	0.0007
37	0.9340	0.0009	0.9334	0.0010	0.9996	0.0006	0.2206	0.9980	0.9339	0.0007
38	0.9340	0.0009	0.9332	0.0010	0.9994	0.0006	0.2205	0.9961	0.9340	0.0007
39	0.9339	0.0009	0.9334	0.0010	0.9995	0.0006	0.2239	0.9933	0.9340	0.0007
40	0.9338	0.0009	0.9335	0.0010	0.9995	0.0006	0.2236	0.9939	0.9340	0.0007
41	0.9340	0.0009	0.9335	0.0010	0.9995	0.0006	0.2230	0.9940	0.9341	0.0006
42	0.9338	0.0008	0.9334	0.0010	0.9994	0.0005	0.2234	0.9941	0.9340	0.0006
43	0.9338	0.0008	0.9335	0.0009	0.9994	0.0005	0.2229	0.9944	0.9341	0.0006
44	0.9339	0.0008	0.9336	0.0009	0.9995	0.0005	0.2243	0.9939	0.9342	0.0006
45	0.9339	0.0008	0.9337	0.0009	0.9996	0.0005	0.2245	0.9939	0.9342	0.0006
46	0.9339	0.0008	0.9337	0.0009	0.9995	0.0005	0.2246	0.9938	0.9342	0.0006
47	0.9338	0.0008	0.9336	0.0009	0.9995	0.0005	0.2256	0.9911	0.9342	0.0006
48	0.9338	0.0008	0.9338	0.0009	0.9996	0.0005	0.2268	0.9896	0.9342	0.0006
49	0.9337	0.0008	0.9337	0.0009	0.9996	0.0005	0.2276	0.9885	0.9341	0.0006
50	0.9338	0.0008	0.9336	0.0009	0.9995	0.0005	0.2263	0.9893	0.9341	0.0006
51	0.9339	0.0008	0.9336	0.0009	0.9996	0.0005	0.2269	0.9891	0.9341	0.0006
52	0.9339	0.0008	0.9336	0.0009	0.9996	0.0005	0.2261	0.9895	0.9341	0.0006
53	0.9341	0.0007	0.9338	0.0009	0.9996	0.0005	0.2265	0.9900	0.9343	0.0006
54	0.9342	0.0007	0.9340	0.0008	0.9997	0.0005	0.2261	0.9926	0.9344	0.0006
55	0.9342	0.0007	0.9339	0.0008	0.9996	0.0005	0.2256	0.9921	0.9344	0.0006
56	0.9341	0.0007	0.9338	0.0008	0.9996	0.0005	0.2268	0.9911	0.9343	0.0006
57	0.9342	0.0007	0.9339	0.0008	0.9996	0.0005	0.2275	0.9897	0.9343	0.0005
58	0.9340	0.0007	0.9337	0.0008	0.9996	0.0005	0.2277	0.9884	0.9341	0.0005
59	0.9339	0.0007	0.9336	0.0008	0.9997	0.0005	0.2278	0.9889	0.9340	0.0005
60	0.9339	0.0007	0.9336	0.0008	0.9997	0.0005	0.2277	0.9884	0.9340	0.0005
61	0.9338	0.0007	0.9334	0.0008	0.9996	0.0005	0.2273	0.9881	0.9339	0.0005
62	0.9337	0.0007	0.9334	0.0008	0.9996	0.0005	0.2273	0.9886	0.9339	0.0005
63	0.9335	0.0007	0.9332	0.0008	0.9996	0.0004	0.2285	0.9868	0.9337	0.0005
64	0.9332	0.0007	0.9331	0.0008	0.9996	0.0004	0.2292	0.9849	0.9336	0.0005
65	0.9333	0.0007	0.9334	0.0008	0.9997	0.0004	0.2301	0.9854	0.9337	0.0005
66	0.9331	0.0007	0.9333	0.0008	0.9997	0.0004	0.2303	0.9853	0.9336	0.0005
67	0.9331	0.0007	0.9333	0.0008	0.9997	0.0004	0.2305	0.9851	0.9335	0.0005
68	0.9330	0.0007	0.9331	0.0008	0.9996	0.0004	0.2290	0.9868	0.9335	0.0005
69	0.9330	0.0007	0.9331	0.0007	0.9996	0.0004	0.2300	0.9853	0.9335	0.0005

Figure 6.6.3-2

MONK8a Output Summary - UMS Transport Cask PWR Top End Impact (Continued)

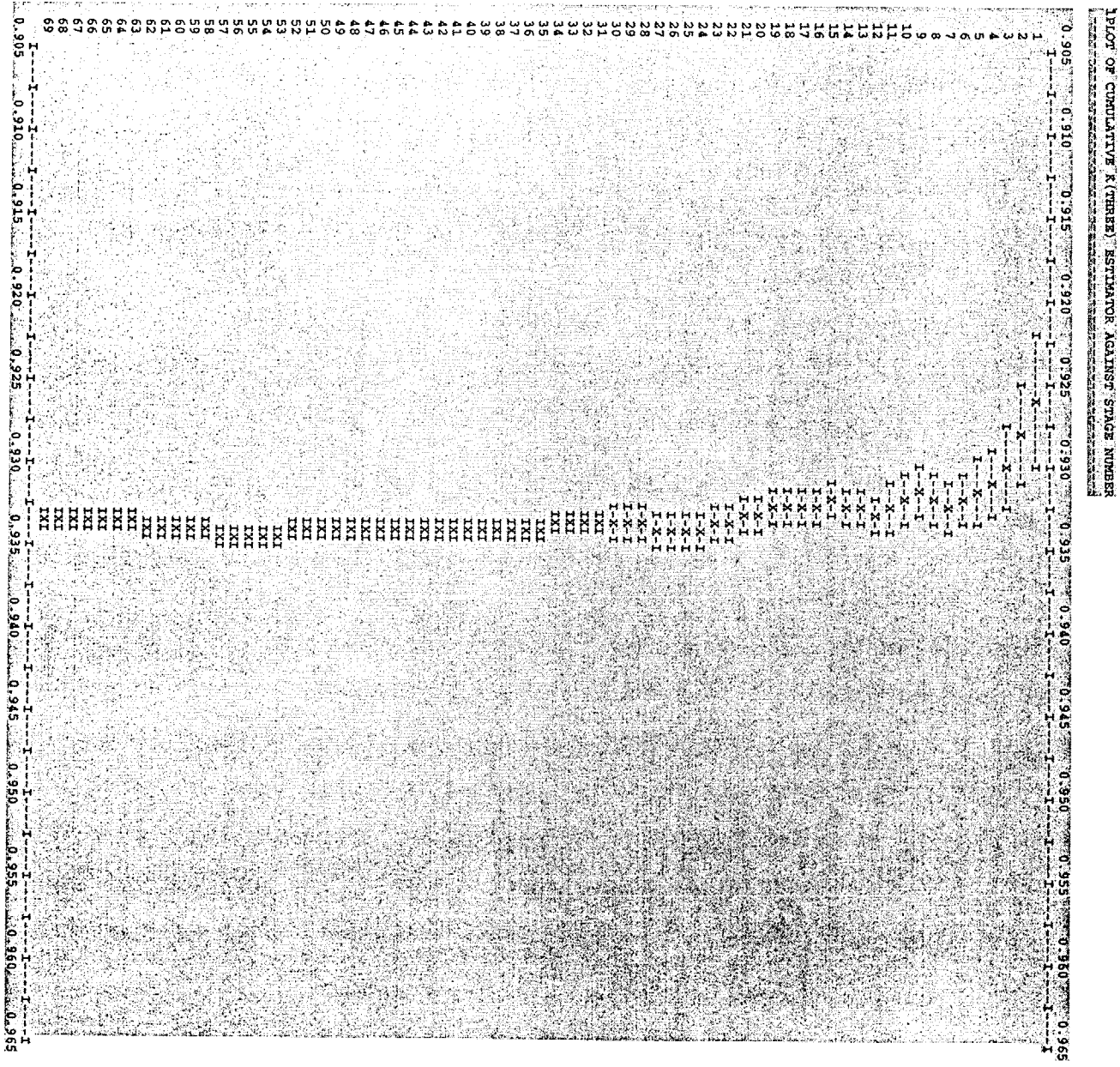


Figure 6.6.3-2 MONK8a Output Summary -UMS Transport Cask PWR Top End Impact (Continued)

ICASE CATEGORISATION  
\*\*\*\*\*

```
THERE ARE 972 CATEGORIES SPLIT AS FOLLOWS :
*****
A=1:URANIUM SYSTEMS..... 1 - 324
A=2:PLUTONIUM SYSTEMS..... 325 - 648
A=3:OTHER SYSTEMS..... 649 - 974

WITHIN EACH 324 NUMBER SEGMENT :
B=1:LOW NON-FUEL ABSORPTION..... 1 - 108
B=2:MEDIUM NON-FUEL ABSORPTION... 109 - 216
B=3:HIGH NON-FUEL ABSORPTION..... 217 - 324

WITHIN EACH 108 NUMBER SEGMENT :
C=1:LOW ASSEMBLIES..... 1 - 36
C=2:MEDIUM LEAKAGE SYSTEMS..... 37 - 72
C=3:HIGH LEAKAGE SYSTEMS..... 73 - 108

WITHIN EACH 36 NUMBER SEGMENT :
D=1:LOW RESONANCE ABSORPTION..... 1 - 12
D=2:MEDIUM RESONANCE ABSORPTION... 13 - 24
D=3:HIGH RESONANCE ABSORPTION.... 25 - 36

WITHIN EACH 12 NUMBER SEGMENT :
E=1:LOW FAST FISSION..... 1 - 4
E=2:MEDIUM FAST FISSION..... 5 - 8
E=3:HIGH FAST FISSION..... 9 - 12

WITHIN EACH 4 NUMBER SEGMENT :
F=1:NO HYDROGEN..... 1
F=2:LOW HYDROGEN CONTENT..... 2
F=3:MEDIUM HYDROGEN CONTENT..... 3
F=4:HIGH HYDROGEN CONTENT..... 4
```

```
TYPE OF SYSTEM ..... A = 1 ..... FRACTION OF FISSIONS IN URANIUM AND PLUTONIUM = 1.0000 0.0000
NON-FUEL ABSORPTION ..... B = 2 ..... FRACTION OF TOTAL ABSORPTIONS IN FUEL = 0.5835
LEAKAGE ..... C = 1 ..... FRACTION OF NEUTRONS LEAKING = 0.0000
RESONANCE ABSORPTION ..... D = 3 ..... FRACTION OF ABSORPTIONS IN RESONANCE PARTITION = 0.2659
FAST FISSION ..... E = 1 ..... MEASURE OF FAST FISSION = 0.0255
FUEL HYDROGEN CONTENT ..... F = 1 ..... MEASURE OF HYDROGEN CONTENT = 0.0000
```

```
*****
* THIS CASE FALLS INTO CATEGORY NUMBER 133 *
*****
```

THE CATEGORY NUMBER IS NOT A GUARANTEED INDICATOR OF THE BIAS TO BE EXPECTED ON THE FINAL VALUE OF K-EFFECTIVE  
IT SHOULD BE USED WITH CAUTION SINCE MANY OTHER FACTORS ARE INVOLVED (E.G., UNUSUAL/EXOTIC MATERIALS AND NUCLIDES)

ISAMPLING GUIDANCE  
\*\*\*\*\*

```
1. NO PARTICLE TRACKS IN ZONE 60 FOR 80 STAGES
The first 20 stages that this occurred are:
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 63 FOR 80 STAGES
The first 20 stages that this occurred are:
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 66 FOR 80 STAGES
The first 20 stages that this occurred are:
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 69 FOR 80 STAGES
The first 20 stages that this occurred are:
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 72 FOR 80 STAGES
The first 20 stages that this occurred are:
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 75 FOR 80 STAGES
The first 20 stages that this occurred are:
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 81 FOR 56 STAGES
The first 20 stages that this occurred are:
```

Figure 6.6.3-2 MONK8a Output Summary -UMS Transport Cask PWR Top End Impact (Continued)

```

-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
NO PARTICLE TRACKS IN ZONE 83 FOR STAGES
54
NO PARTICLE TRACKS IN ZONE 88 FOR STAGES
53 54 57
NO PARTICLE TRACKS IN ZONE 91 FOR STAGES
26 34 37 53 54 60 63 67 69
NO PARTICLE TRACKS IN ZONE 92 FOR 31 STAGES
The first 20 stages that this occurred are:
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
NO PARTICLE TRACKS IN ZONE 93 FOR 42 STAGES
The first 20 stages that this occurred are:
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
NO PARTICLE TRACKS IN ZONE 94 FOR 29 STAGES
The first 20 stages that this occurred are:
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
NO PARTICLE TRACKS IN ZONE 95 FOR STAGES
54
NO PARTICLE TRACKS IN ZONE 98 FOR 71 STAGES
The first 20 stages that this occurred are:
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
NO PARTICLE TRACKS IN ZONE 99 FOR STAGES
53
2. SOURCE PARTICLES STARTED FROM ALL FISSION ZONES IN ALL STAGES
3. CONSISTENCY OF ESTIMATORS
Individual stage values of K(COLL) and K(SCORE) agree for all stages
Individual stage values of A(SCORE) agree with 1.0 for all stages
4. TEST FOR NORMALITY OF INDIVIDUAL STAGE ESTIMATORS
(Level of significance > .1% for pass)
K(COLL) PASSED Level of significance = 2.19%
K(SCORE) PASSED Level of significance = 60.66%
K(THREE) PASSED Level of significance = 74.81%
5. CHI-SQUARED TEST FOR ADEQUATE SETTLING

```

	No. of Settling stages	Chi squared per degree of freedom	Probability	
K(COLL)	11	0.319	0.9978	PASSED
K(SCORE)	11	0.754	0.7648	PASSED
K(THREE)	11	0.861	0.6332	PASSED

```

FINAL VALUE OF K(THREE) = 0.9335 (1 STDV) = 0.0005
K(THREE) + (3 x STDV) = 0.9350
*****
* MONK PROCESSING COMPLETED TO STAGE 3
*****

```

Figure 6.6.3-3

MONK8a Input File - UMS Transport Cask BWR Top End Impact

```
columns 1 200

* UMS Transport Cask Model BWR *
* Version 1.1 -- Shifted *

always convert ! Always converts intergers to real numbers

*****
* Inserting TSC Parameters Here *
*****

@lftu = 410.464
@ltcap = 4.2342
@lbcap = 0.9017
@lactfu = 381
@lowple = 12.164
@odclad = 1.077
@cladth = 0.0762
@odpallet = 0.9055
@lattice = 9
@rpitch = 1.4529
@odwr = 1.077
@wrth = 0.0762
@chwidth = 14.0005
@chth = 0.2032
@lassem = 435.2493
@wfuel = 14.0005
@lbnozz = 17.6276
@ltnozz = 7.1577
@nwaterrods = 2
@nfuelpin = 79
@fuoffx = 18.674

@fssln = 0.1655
@fvoidln = 0.8345
@fssun = 0.1755
@fvoidun = 0.8245

@gU235gUO2 = 0.0353
@gU238gUO2 = 0.8462
@gOgUO2 = 0.1185

@wft = 14.986
@ftth = 0.12192
@lftube = 409.448
@wfto = 15.61846
@wftonb = 15.22984
@ftoffx = 0.0
@asoffx = 0.5867
@asoffy = 0.5867
@wbrl = 13.5636
@bit = 0.3429
@blct = 0.127
@lboral = 396.21714
@blo = 0.4572
@boffx = 0.0
@bshiftx = 0.0
@bshifty = 0.0
@cvst = 0.04572
@lcvs = 398.526
@cvoffx = 1.6764
@tboffx = 0.1637
@tboffy = 0.1637
@tboffxnb = 0.358
@tboffynb = 0.358
@ovwft = 15.367
@ovwfto = 15.99946
@ovwftonb = 15.61084
@ovasoffx = 0.7772
@ovasoffy = 0.7772
@ovtboffx = 0.1637
@ovtboffy = 0.1637
@ovtboffxnb = 0.358
@ovtboffynb = 0.358

@diabw = 166.37
@lbw = 12.6492
@lbwd = 2.54
@lfs = 8.1407
@diatpw = 166.37
@ltpw = 28.7782
@ltpwd = 2.54
@opspd = 15.9461
@diaspd = 166.5478
@tspd = 1.5875
@spxl = 17.5839
@spx2 = 35.1942
@spx3 = 52.7914
```



Figure 6.6.3-3MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```

$spv4 = 70.3885
$spv1 = 8.7985
$spv2 = 26.3957
$spv3 = 43.9828
$spv4 = 61.5693
$clant = 185.735
$cthd = 1.27
$capubetotop = 1.27
$nttd = 17
$nspt = 41
$sspcht = 4.064
$dspsht = 3.429
$lbasket = 452.1454
$diskstack = 390.4869
$bkasoff = 0.0
$ovopsptd = 16.3271

$canod = 170.3324
$canth = 1.5975
$canl = 483.489
$canbot = 4.4196
$shldl = 17.526
$strutl = 7.62
$avneight = 453.9234

*****
The following parameters need to be updated.
*****
$tschx = 2      ! Last mixture number of TSC going into cask
$tschmat = 15   ! Last material number of TSC going into cask
$tschnum = 27   ! Last part number of TSC going into cask
$fuellmat = 1   ! Material number of fuel from TSC model
*****

* Cask Parameters
$portcavlt = 488.95
$opnsOFF = 46.8376
$slpsalt = 12.7
$portcavOD = 171.7294
$ldrcsOD = 199.0344
$porttopOD = 216.5604
$ldrcsRH = 16.51
$pbid = 181.8894
$pbOD = 195.8594
$coutshth = 6.985
$portbotTH = 12.7
$botfrgth = 10.795
$botnstH = 2.54
$botringdiskH = 17.78
$trunOFF = 30.8864
$transportLT = 531.495
$strunOD = 30.6324
$strunemTH = 5.08
$ptrunbTH = 8.89
$ptrunOD = 30.48
$ptrunTH = 7.62

```

```

*****
BEGIN MATERIAL SPECIFICATION
*****

```

## NORMALISE

\* Input Mixtures

NMIXTURES \$tschx

## ATOMS

MIXTURE 1

H1 2

O16 1

## WEIGHT

MIXTURE 2

U235 90U235UO2

U238 90U238UO2

O16 90O16UO2

NMATERIALS (\$tschmat \* 5)

```

*****
* Inserting TSC Materials Here
*****

```

## WEIGHT

MATERIAL 1 DENSITY 10.412 MIXTURE 2 95% UO2

**Figure 6.6.3-3 MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)**

```

MATERIAL 2 ZIRCALLOY Fuel pin cladding / End Caps
MATERIAL 3 DENSITY 0.9982 MIXTURE 1 Water In Lattice and Tube
MATERIAL 4 DENSITY 0.9982 MIXTURE 1 Water In Fuel Rod Clad Gap
MATERIAL 5 ZIRCALLOY Water Rod Material
MATERIAL 6 ZIRCALLOY Channel Material

VOLUME
MATERIAL 7
STAINLESS 304L STEEL PROP @fssln
MIXTURE 1 DENSITY 0.9982 PROP @fvoidln Lower Nozzle Material

MATERIAL 8
STAINLESS 304L STEEL PROP @fssun
MIXTURE 1 DENSITY 0.9982 PROP @fvoidun Upper Nozzle Material

WEIGHT
MATERIAL 9 STAINLESS 304L STEEL Tube wall and cover sheet

VOLUME
MATERIAL 10 BORAL core
AL27 DENSITY 2.6633 PROP 0.7692
B10 DENSITY 2.6633 PROP 0.0244
B11 DENSITY 2.6633 PROP 0.1482
C DENSITY 2.6633 PROP 0.0501
VOID PROP 0.0189

WEIGHT
MATERIAL 11 ALUMINIUM BORAL aluminum clad

WEIGHT
MATERIAL 12 STAINLESS 304L STEEL Structural Disk Material

WEIGHT
MATERIAL 13 STAINLESS 304L STEEL Weldment Material

WEIGHT
MATERIAL 14 ALUMINIUM Heat Transfer Disk Material

WEIGHT
MATERIAL 15 STAINLESS 304L STEEL Canister Material

*****
WEIGHT
@matSS304=1
MATERIAL [@tscMAT + 1] STAINLESS 304L STEEL Steel components of Transport Cask

WEIGHT
@matLead=2
MATERIAL [@tscMAT + 2] DENSITY 11.04 LEAD
PB PROP 1.0000

ATOMS
@matNS4FR=3
MATERIAL [@tscMAT + 3] DENSITY 0.0 INS-4-FR
B10 PROP 8.553E-5
B11 PROP 3.422E-4
AL PROP 7.763E-3
H PROP 5.854E-2
O PROP 2.609E-2
C PROP 2.264E-2
N PROP 1.394E-3

ATOMS
@matCI=4
MATERIAL [@tscMAT + 4] DENSITY 0.9982 Material (water) outside of Canister Inside Cask
H1 PROP 2
O16 PROP 1

ATOMS
@matCE=5
MATERIAL [@tscMAT + 5] DENSITY 0.9982 Material Outside Cask Body
H1 PROP 2
O16 PROP 1
END

*****
BEGIN MATERIAL GEOMETRY
*****

* Inserting TSC Geometry Here *
*
* Fuel Assembly for Standard Opening
*

```

Figure 6.6.3-3

MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

## PART I INVEST

[illegible]

\* Fuel Assembly. This may be replaced during criticality analysis by a different fuel assembly configuration of failed fuel can

**PART 2 SAME 1 ! fuel assembly**

- \* BORAL and Cover for Standard Opening
- \* Unit Composed of BORAL sheet and steel cover sheet
- \* Assumes BORAL sheet is cut off at the width of the BORAL sheet

**PART 3 NEST**

[illegible]

\* Base PART A (fuel in tubing) for shifting in standard opening - this PART is rotated from 90 to 270 degrees

**PART 4**

```
BOX 1 [-1.0*gwfuel/2.0+asoff] [-1.0*gwfuel/2.0+asoff] @knofz  
      gwfuel gwfuel classm  
BOX 2 [-1.0*gwft/2.0] [-1.0*gwft/2.0] 0.0  
      gwft gwft gcavheight  
BOX 3 [-1.0*gwft/2.0-eth] [-1.0*gwft/2.0-eth] @basokoff+g1bw+eftoff  
      [gwft+2*gwft] [gwft+2*gwft] g1tubc  
BOX 4 [-1.0*gwft/2.0-eth] [-1.0*gwft/2.0-eth] 0.0  
      [gwft+2*gwft] [gwft+2*gwft] gcavheight  
      ; container body ; extent of basket cavity
```

**SEND**

/Fuel Assembly/	P1	+1
/Space in Tube/	M3	+2 -1
/Fuel Tube/	M9	+3 -2
/Container/	M3	+4 -3 -2

\* Base PART B (fuel in tubing) for shifting in oversize opening - this PART is rotated from 90 to 270 degrees  
\* Maximum shift implies shift to upper right (x,y) corner of tube

## PART 5

[illegible]

## ZONES

/Fuel Assembly/	P2	+1
/Space in Tube/	M3	+2 -1
/Fuel Tube/	M9	+3 -2
/Container/	M3	+4 -3 -2

\* Includes the tube in the disk opening shifted, in the tx, ty direction (upper, left).

For shifts in other directions (such as those required for radial in and out shifting additional PARTS are required. It is recommended that the UNIT below is rotated to produce shifted UNITS which can then be substituted into PART 8. To minimize renumbering of PARTS the rotated PARTS may be placed starting at PART 9. PART 9 and PART 10 will require renumbering if this option is employed.

Base PART A - Standard disk opening for shifting - this PART is rotated from 90 to 270 degrees  
Maximum shift implies shift to upper right (+x,+y), corner of opening

2 BORAL SHEET - 0111

6.6.3-20

Figure 6.6.3-3 MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```

PART_6_CLUSTER
BOX P4 [-1.0*ewfto/2.0] [-1.0*ewfto/2.0] 0.0
[ewft+2*efth] [ewft+2*efth] scavheight Fuel element with fuel tube
* BORAL Sheet x - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [-1.0*ewfto/2.0]*ewfto]
[(-1.0*ewfto/2.0)*(ewfto+ewbrl)/2.0+0.5shift]
[ebaskoff+elbw+eftoff+ecvoffz]
[elbt+ecvst] ewbrl elcvs ZROT 180 delta x, delta y, delta z
* BORAL Sheet y
BOX P3 [-1.0*ewfto/2.0]*(ewfto+ewbrl)/2.0+0.5shift]
[(-1.0*ewfto/2.0)*ewfto]
[ebaskoff+elbw+eftoff+ecvoffz]
[elbt+ecvst] ewbrl elcvs ZROT 90 delta x, delta y, delta z
BOX M3 [-1.0*evpspd/2.0+0.5boffx] [-1.0*evpspd/2.0+0.5boffx] 0.0
evpspd evpspd scavheight Support disk opening width
* RIGHT BORAL SHEET QIV Shift
PART_7_CLUSTER
BOX P17 [-1.0*ewfto/2.0] [-1.0*ewfto/2.0] 0.0
[ewft+2*efth] [ewft+2*efth] scavheight Fuel element with fuel tube
* BORAL Sheet x - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [-1.0*ewfto/2.0]*ewfto]
[(-1.0*ewfto/2.0)*(ewfto+ewbrl)/2.0+0.5shift]
[ebaskoff+elbw+eftoff+ecvoffz]
[elbt+ecvst] ewbrl elcvs ZROT 180 delta x, delta y, delta z
BOX M3 [-1.0*evpspd/2.0+0.5boffx] [-1.0*evpspd/2.0+0.5boffx] 0.0
evpspd evpspd scavheight Support disk opening width
* TOP BORAL SHEET - Could also be generated by rotating right BORAL - QI Shift
PART_8_CLUSTER
BOX P18 [-1.0*ewfto/2.0] [-1.0*ewfto/2.0] 0.0
[ewft+2*efth] [ewft+2*efth] scavheight Fuel element with fuel tube
* BORAL Sheet y
BOX P3 [-1.0*ewfto/2.0]*ewfto]
[(-1.0*ewfto/2.0)*(ewfto+ewbrl)/2.0+0.5shift]
[ebaskoff+elbw+eftoff+ecvoffz]
[elbt+ecvst] ewbrl elcvs ZROT 90 delta x, delta y, delta z
BOX M3 [-1.0*evpspd/2.0+0.5boffx] [-1.0*evpspd/2.0+0.5boffx] 0.0
evpspd evpspd scavheight Support disk opening width
* NO BORAL SHEET - QI Shift
PART_9_CLUSTER
BOX P18 [-1.0*ewfto/2.0] [-1.0*ewfto/2.0] 0.0
[ewft+2*efth] [ewft+2*efth] scavheight Fuel element with fuel tube
BOX M3 [-1.0*evpspd/2.0+0.5boffx] [-1.0*evpspd/2.0+0.5boffx] 0.0
evpspd evpspd scavheight Support disk opening width
* Base PART 9 - Oversize disk opening for shifting - this PART is rotated from 90 to 270 degrees
* Maximum shift implies shift to upper right (+x,y) corner of opening
* 2 BORAL Sheet QIV
PART_10_CLUSTER
BOX P5 [-1.0*ewfto/2.0] [-1.0*ewfto/2.0] 0.0
[ewft+2*efth] [ewft+2*efth] scavheight Fuel element with fuel tube
* BORAL Sheet x - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [-1.0*ewfto/2.0]*ewfto]
[(-1.0*ewfto/2.0)*(ewfto+ewbrl)/2.0+0.5shift]
[ebaskoff+elbw+eftoff+ecvoffz]
[elbt+ecvst] ewbrl elcvs ZROT 180 delta x, delta y, delta z
* BORAL Sheet y
BOX P3 [-1.0*ewfto/2.0]*(ewfto+ewbrl)/2.0+0.5shift]
[(-1.0*ewfto/2.0)*ewfto]
[ebaskoff+elbw+eftoff+ecvoffz]
[elbt+ecvst] ewbrl elcvs ZROT 90 delta x, delta y, delta z
BOX M3 [-1.0*evpspd/2.0+0.5boffx] [-1.0*evpspd/2.0+0.5boffx] 0.0
evpspd evpspd scavheight Support disk opening width
* Right BORAL Sheet QIV
PART_11_CLUSTER
BOX P20 [-1.0*ewfto/2.0] [-1.0*ewfto/2.0] 0.0
[ewft+2*efth] [ewft+2*efth] scavheight Fuel element with fuel tube
* BORAL Sheet x - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [-1.0*ewfto/2.0]*ewfto]
[(-1.0*ewfto/2.0)*(ewfto+ewbrl)/2.0+0.5shift]
[ebaskoff+elbw+eftoff+ecvoffz]
[elbt+ecvst] ewbrl elcvs ZROT 180 delta x, delta y, delta z
BOX M3 [-1.0*evpspd/2.0+0.5boffx] [-1.0*evpspd/2.0+0.5boffx] 0.0
evpspd evpspd scavheight Support disk opening width
* Top BORAL Sheet QIV

```

Figure 6.6.3-3

MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

## PART 12 CLUSTER

[illegible]

## No BORAL Sheet. Q1

**PART 13. CLUSTER**

```

BOX P21 [-1.0*%ovwftnb/2.0] [-1.0*%ovwftnb/2.0] 0.0
          (%ovwft+2*%ftth) (%ovwft+2*%ftth) %cavheight
          ! Fuel element with fuel tube

BOX M3 [-1.0*%ovwpsd/2.0*%ovthoffxnb] [-1.0*%ovwpsd/2.0*%ovthoffxnb] 0.0
          %ovwpsd %ovwpsd %cavheight
          ! Support disk opening width

```

\* BWR Canister Cavity

\* Models disks in basket at smallest disk diameter (currently Heat T. Disk)

**PART 14 CLUSTER**

\*Top Openings (1, 2, 3, 4, 5)

BOX	P7	[ -1.0*(@exp2d @opspd/2.0) [ @spv4-@opspd/2.0] [-1.0*(@baskoff+@lwb+@lfs)]
		@opspd @opspd @cavheight
BOX	P7	[ -1.0*(@exp2d @opspd/2.0) [ @spv4-@opspd/2.0] [-1.0*(@baskoff+@lwb+@lfs)]
		@opspd @opspd @cavheight
BOX	P7	[ -1.0*(@exp2d @opspd/2.0) [ @spv4-@opspd/2.0] [-1.0*(@baskoff+@lwb+@lfs)]
		@opspd @opspd @cavheight
BOX	P26	[ @spv1-@opspd/2.0] [ @spv4-@opspd/2.0] [-1.0*(@baskoff+@lwb+@lfs)]
		@opspd @opspd @cavheight
BOX	P9	[ @spv2-@opspd/2.0] [ @spv4-@opspd/2.0] [-1.0*(@baskoff+@lwb+@lfs)]
		@opspd @opspd @cavheight
BOX	P9	[ @spv3-@opspd/2.0] [ @spv4-@opspd/2.0] [-1.0*(@baskoff+@lwb+@lfs)]
		@opspd @opspd @cavheight
BOX	P9	[ @spv4-@opspd/2.0] [ @spv4-@opspd/2.0] [-1.0*(@baskoff+@lwb+@lfs)]
		@opspd @opspd @cavheight
BOX	P9	[ @spv5-@opspd/2.0] [ @spv4-@opspd/2.0] [-1.0*(@baskoff+@lwb+@lfs)]
		@opspd @opspd @cavheight

\* Openings (6, 7, 8, 9, 10, 11, 12)

[illegible]

\* Openings (13, 14, 15, 16, 17, 18, 19)

BOX	P23	[ -1.0°@sp3d-@opspd/2.0 ] [ @sp2y-@opspd/2.0 ] [ @sp2z-@opspd/2.0 ] [ -1.0°*(@basketoff+@lbw+@lfls) ]   Basket Opening 13
BOX	P23	@opspd @opspd @cavheight [ -1.0°@sp2d-@opspd/2.0 ] [ @sp2y-@opspd/2.0 ] [ -1.0°*(@basketoff+@lbw+@lfls)   Basket Opening 14
BOX	P23	@opspd @opspd @cavheight [ -1.0°@sp1d-@opspd/2.0 ] [ @sp2y-@opspd/2.0 ] [ -1.0°*(@basketoff+@lbw+@lfls)   Basket Opening 15
BOX	P23	@opspd @opspd @cavheight [ -1.0°@sp0d-@opspd/2.0 ] [ @sp2y-@opspd/2.0 ] [ -1.0°*(@basketoff+@lbw+@lfls)   Basket Opening 16
BOX	P24	@sp1d @opspd @cavheight [ @sp1d-@opspd/2.0 ] [ @sp2y-@opspd/2.0 ] [ -1.0°*(@basketoff+@lbw+@lfls)   Basket Opening 17
BOX	P24	@sp2d @opspd @cavheight [ @sp2d-@opspd/2.0 ] [ @sp2y-@opspd/2.0 ] [ -1.0°*(@basketoff+@lbw+@lfls)   Basket Opening 18
BOX	P8	@sp3d @opspd @cavheight [ @sp3d-@opspd/2.0 ] [ @sp2y-@opspd/2.0 ] [ -1.0°*(@basketoff+@lbw+@lfls)   Basket Opening 19

\* Openings (20, 21, 22, 23, 24, 25, 26, 27, 28)

BOX	P7	$[-1.0^{\circ} \text{exp}(-\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	
BOX	P23	$[-1.0^{\circ} \text{exp}(-\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 20
BOX	P23	$[-1.0^{\circ} \text{exp}(-\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 21
BOX	P23	$[-1.0^{\circ} \text{exp}(-\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 22
BOX	P23	$[-1.0^{\circ} \text{exp}(-\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 23
BOX	P24	$[\text{exp}(\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 24
BOX	P24	$[\text{exp}(\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 25
BOX	P24	$[\text{exp}(\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 26
BOX	P9	$[\text{exp}(\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 27
BOX	P24	$[\text{exp}(\text{expspd}/2.0)] \text{ [expy1-expspd}/2.0] \text{ [-1.0^{\circ} (baskoff-qlbw+qlfs)]}$	expspd expspd csaveheight	! Basket Opening 28

Openings 129, 30, 31, 32, 33, 34, 35, 36, 37

Figure 6.6.3-3

MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

[illegible]

\* Openings (38, 39, 40, 41, 42, 43, 44)

	Openings [-8, -5, -2, 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100]	
BOX P6	[-1.0* $\theta$ spnd -6pspd/2.0] [-1.0* $\theta$ spy2 -6pspd/2.0] [-1.0* $\theta$ ( $\theta$ skstoffs+ $\theta$ blw+ $\theta$ fls)]	
	$\theta$ spnd $\theta$ pspd $\theta$ csheight	! Basket Opening 38
BOX P6	[-1.0* $\theta$ spx2 -6pspd/2.0] [-1.0* $\theta$ spy2 -6pspd/2.0] [-1.0* $\theta$ ( $\theta$ skstoffs+ $\theta$ blw+ $\theta$ fls)]	
	$\theta$ spnd $\theta$ pspd $\theta$ csheight	! Basket Opening 39
BOX P6	[-1.0* $\theta$ spx1 -6pspd/2.0] [-1.0* $\theta$ spy2 -6pspd/2.0] [-1.0* $\theta$ ( $\theta$ skstoffs+ $\theta$ blw+ $\theta$ fls)]	
	$\theta$ spnd $\theta$ pspd $\theta$ csheight	! Basket Opening 40
BOX P6	[-1.0* $\theta$ spx2/2.0] [-1.0* $\theta$ spy2 -6pspd/2.0] [-1.0* $\theta$ ( $\theta$ skstoffs+ $\theta$ blw+ $\theta$ fls)]	
	$\theta$ spnd $\theta$ pspd $\theta$ csheight	! Basket Opening 41
BOX P25	[ $\theta$ spx1 -6pspd/2.0] [-1.0* $\theta$ spy2 -6pspd/2.0] [-1.0* $\theta$ ( $\theta$ skstoffs+ $\theta$ blw+ $\theta$ fls)]	
	$\theta$ spnd $\theta$ pspd $\theta$ csheight	! Basket Opening 42
BOX P25	[ $\theta$ spx2 -6pspd/2.0] [-1.0* $\theta$ spy2 -6pspd/2.0] [-1.0* $\theta$ ( $\theta$ skstoffs+ $\theta$ blw+ $\theta$ fls)]	
	$\theta$ spnd $\theta$ pspd $\theta$ csheight	! Basket Opening 43
BOX P27	[ $\theta$ spx3 -6pspd/2.0] [-1.0* $\theta$ spy2 -6pspd/2.0] [-1.0* $\theta$ ( $\theta$ skstoffs+ $\theta$ blw+ $\theta$ fls)]	
	$\theta$ spnd $\theta$ pspd $\theta$ csheight	! Basket Opening 44

\* Openings (45, 46, 47, 48, 49, 50, 51)

[illegible]

\*Bottom Openings (52, 53, 54, 55, 56)

BOX P5	[1.0*espx2-6opspd/2.0] [-1.0*espy4-6opspd/2.0] [-1.0* $(\text{esbaskoff}+\text{albw}+\text{qlfa})$ ]	Basket Opening 52
BOX P6	[espx2-6opspd/2.0] [-1.0*espy4-6opspd/2.0] [-1.0* $(\text{esbaskoff}+\text{albw}+\text{qlfa})$ ]	Basket Opening 53
BOX P5	[1.0*espx1-6opspd/2.0] [-1.0*espy4-6opspd/2.0] [-1.0* $(\text{esbaskoff}+\text{albw}+\text{qlfa})$ ]	Basket Opening 54
BOX P6	[1.0*espx1-6opspd/2.0] [-1.0*espy4-6opspd/2.0] [-1.0* $(\text{esbaskoff}+\text{albw}+\text{qlfa})$ ]	Basket Opening 55
BOX P27	[espx2-6opspd/2.0] [-1.0*espy4-6opspd/2.0] [-1.0* $(\text{esbaskoff}+\text{albw}+\text{qlfa})$ ]	Basket Opening 56

```
ZPROD H5 0.0 0.0 [-1.0*(@baskoff+@lbw+@lfs)] 17
[ @diant/2.0 ] @cavheight [Basket stack to cavity height
```

\* \* \* Basket in Cask Cavity

\* Note: Disk to use in the first ZROD is the disk with minimum radius (aluminum)

● 3

**PART '15' NEST**

	2RD P14	0.0	0.0	0.0	0.0	(diaht/2.0)	@cavheight	Basket Inserted - Includes Gap to Lid
2RD M3	0.0	0.0	0.0	0.0	0.0	@canod/2.0-@canth	@cavheight	Inserts water to canister shell

\* Canister - Used general part due to modification later required for temporary shield and ports

\* Note: Existing Dimensions Assumes that lids are flush with cavity shell

note: existing dimensions assumes that illos are flush w/tn cavity shell

\* This may have to be modified for use of a temporary shield lid or if the shield lid is recessed

\* Cavity Height input is also based on a flush lid

PART 16

[illegible]

6.6.3-23

Figure 6.6.3-3

MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```

ZONES
/Cavity/      P15  +1
/BottomPlate/ M15  +2
/ShieldLid/   M15  +3
/StructLid/   M15  +4
/Shell/       M15  +6 -5
/Canister/    M0   +7 -6 -4 -3

*Version_BWR1: 0

*
* This file contains the geometry parts for the fuel tube.
*
* These PARTS are based on the assumption that shift magnitude is the same
* for all assemblies.
*
* Standard fuel tube (PART A) Rotated 90 degrees
* Maximum shift implies shift to lower right corner (+x,-y) of fuel tube
*
*QII
PART 17 NEST
BOX P4 0.0 0.0 0.0 0.0 0.0 0.0
      [0wft+2*0ftth] [0wft+2*0ftth] 0.0
      [0wft+2*0ftth] [0wft+2*0ftth] @cavheight ZROT 90 Rotated fuel tube
BOX M3 0.0 0.0 0.0 0.0 0.0 0.0
      [0wft+2*0ftth] [0wft+2*0ftth] @cavheight container
*
* Standard fuel tube (PART A) Rotated 180 degrees
* Maximum shift implies shift to lower left corner (-x,-y) of fuel tube
*
*QI
PART 18 NEST
BOX P4 [0wft+2*0ftth] [0wft+2*0ftth] 0.0
      [0wft+2*0ftth] [0wft+2*0ftth] @cavheight ZROT 180 Rotated fuel tube
BOX M3 0.0 0.0 0.0 0.0 0.0 0.0
      [0wft+2*0ftth] [0wft+2*0ftth] @cavheight container
*
* Standard fuel tube (PART A) Rotated 270 degrees
* Maximum shift implies shift to upper left corner (-x,+y) of fuel tube
*
*QIV
PART 19 NEST
BOX P4 [0wft+2*0ftth] 0.0 0.0
      [0wft+2*0ftth] [0wft+2*0ftth] @cavheight ZROT 270 Rotated fuel tube
BOX M3 0.0 0.0 0.0 0.0 0.0 0.0
      [0wft+2*0ftth] [0wft+2*0ftth] @cavheight container
*
* Corner/oversize fuel tube Rotated 90 degrees
* Maximum shift implies shift to lower right corner (+x,-y) of fuel tube
*
*QII
PART 20 NEST
BOX P5 0.0 0.0 0.0 0.0 0.0 0.0
      [0ovwft+2*0ftth] [0ovwft+2*0ftth] @cavheight ZROT 90 Rotated fuel tube
BOX M3 0.0 0.0 0.0 0.0 0.0 0.0
      [0ovwft+2*0ftth] [0ovwft+2*0ftth] @cavheight container
*
* Corner fuel tube Rotated 180 degrees
* Maximum shift implies shift to lower left corner (-x,-y) of fuel tube
*
*QI
PART 21 NEST
BOX P5 [0ovwft+2*0ftth] [0ovwft+2*0ftth] 0.0
      [0ovwft+2*0ftth] [0ovwft+2*0ftth] @cavheight ZROT 180 Rotated fuel tube
BOX M3 0.0 0.0 0.0 0.0 0.0 0.0
      [0ovwft+2*0ftth] [0ovwft+2*0ftth] @cavheight container
*
* Corner fuel tube Rotated 270 degrees
* Maximum shift implies shift to upper left corner (-x,+y) of fuel tube
*
*QIV

```

Figure 6.6.3-3 MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```

PART 22 NBSST
BOX P5 [(0*ewft+2*eftth) 0.0 0.0 0.0
      (0*ewft+2*eftth) (0*ewft+2*eftth) 0*avheight ZROT 270 Rotated fuel tube
BOX M3 0.0 0.0
      [(0*ewft+2*eftth) (0*ewft+2*eftth) 0*avheight] contains
* Version BWR1.0
* This file contains the geometry parts for the disk opening.
* These PARTS are based on the assumption that shift magnitude is the same
  for all openings. This input also assumes that shift is same in all quadrants
  (i.e., radial in or radial out shift, for right or left shift use original file)
* Standard Opening (PART A) Rotated 90 degrees
* Maximum shift implies shift to lower right corner (x,y) of fuel tube

* Disk Opening 2 BORAL Sheet Tube QIV
* Direction changed for tboff variables

PART 23 CLUSTER
BOX P17 [(-1.0*ewfto/2.0) [(-1.0*ewfto/2.0) 0.0
      (ewft+2*eftth) (ewft+2*eftth) 0*avheight Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*ewfto/2.0)+ewftol
      [(-1.0*ewfto/2.0)+(ewfto+ewbrl)/2.0+0*ebshift] x y
      [0*askoff+0*lbw+0*toffz+0*cvoffz] z
      [0*lt+0*cvst] ewbrl 0*cvst ZROT 180 delta x, delta y, delta z
* BORAL Sheet +Y
BOX P3 [(-1.0*ewfto/2.0)+(ewfto+ewbrl)/2.0+0*ebshift] x
      [(-1.0*ewfto/2.0)+ewftol y
      [0*askoff+0*lbw+0*toffz+0*cvoffz] z
      [0*lt+0*cvst] ewbrl 0*cvst ZROT 90 delta x, delta y, delta z
BOX M3 [(-1.0*ewpspd/2.0+0*etboffx) [(-1.0*ewpspd/2.0+0*etboffy) 0.0
      0*pspd 0*pspd 0*avheight Support disk opening width

* Disk Opening 2 BORAL Sheet Tube QI
* Direction changed for tboff variables

PART 24 CLUSTER
BOX P18 [(-1.0*ewfto/2.0) [(-1.0*ewfto/2.0) 0.0
      (ewft+2*eftth) (ewft+2*eftth) 0*avheight Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*ewfto/2.0)+ewftol
      [(-1.0*ewfto/2.0)+(ewfto+ewbrl)/2.0+0*ebshift] x y
      [0*askoff+0*lbw+0*toffz+0*cvoffz] z
      [0*lt+0*cvst] ewbrl 0*cvst ZROT 180 delta x, delta y, delta z
* BORAL Sheet +Y
BOX P3 [(-1.0*ewfto/2.0)+(ewfto+ewbrl)/2.0+0*ebshift] x
      [(-1.0*ewfto/2.0)+ewftol y
      [0*askoff+0*lbw+0*toffz+0*cvoffz] z
      [0*lt+0*cvst] ewbrl 0*cvst ZROT 90 delta x, delta y, delta z
BOX M3 [(-1.0*ewpspd/2.0+0*etboffx) [(-1.0*ewpspd/2.0+0*etboffy) 0.0
      0*pspd 0*pspd 0*avheight Support disk opening width

* Disk Opening 2 BORAL Sheet Tube QIV
* Direction changed for tboff variables

PART 25 CLUSTER
BOX P19 [(-1.0*ewfto/2.0) [(-1.0*ewfto/2.0) 0.0
      (ewft+2*eftth) (ewft+2*eftth) 0*avheight Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*ewfto/2.0)+ewftol
      [(-1.0*ewfto/2.0)+(ewfto+ewbrl)/2.0+0*ebshift] x y
      [0*askoff+0*lbw+0*toffz+0*cvoffz] z
      [0*lt+0*cvst] ewbrl 0*cvst ZROT 180 delta x, delta y, delta z
* BORAL Sheet +Y
BOX P3 [(-1.0*ewfto/2.0)+(ewfto+ewbrl)/2.0+0*ebshift] x
      [(-1.0*ewfto/2.0)+ewftol y
      [0*askoff+0*lbw+0*toffz+0*cvoffz] z
      [0*lt+0*cvst] ewbrl 0*cvst ZROT 90 delta x, delta y, delta z
BOX M3 [(-1.0*ewpspd/2.0+0*etboffx) [(-1.0*ewpspd/2.0+0*etboffy) 0.0
      0*pspd 0*pspd 0*avheight Support disk opening width

* Disk Opening Right BORAL Sheet Tube QI
* Direction changed for tboff variables

PART 26 CLUSTER
BOX P18 [(-1.0*ewfto/2.0) [(-1.0*ewfto/2.0) 0.0

```



Figure 6.6.3-3

MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```

[delta*2+offth] [delta*2+offth] fuel element with fuel tube
BORAL Sheet x - prior to rotation shift fuel assembly width inner and half sheet up
BOX p3 ((1.0*swfo(2.0)*swto)
[(-1.0*swfo(2.0)*swto)
[swasloff+1bw+offtoz+swcvozf]
[swto*swcvt] swbr slvcs ZROT 180
[(-1.0*swpsd/2.0*stboff) [-1.0*swpsd/2.0*stboff] 0.0
BOX M3 [delta*x delta*x delta*x
swpsd swpsd swcwhsht
Support dist opening width

```

\* TOP BORAL SHEET ~ QIV Shift

**PART 27. CLUSTER**

BOX P19 [-1.0\*9wftomb/2.0] [-1.0\*9wfto/2.0] 0.0

**\* BORAL SHEET + Y**

$$[(-1.0 * \text{ewftr}/2.0) + \text{ewftr}] \quad y$$

```
[@b1t+@cvst] @wbr1 @lcvs ZROT 90
```

Gopsd Gopsd Scavheight / Support disk opening width

1234567890123456789012345678901234567890123456789012

PART [0ESCNUM + 1]

```
ZROD 2      0.0  0.0  0.0  [9pbod/2+eoutslTH]  @tportbotTH  Bottom
```

```
[@portcavOD/2.1  [@portcavLT]  Cavity
```

[@canod/2.0]	@canl	Canister
--------------	-------	----------

[elidrcsOD/2] elidrcsTH elidrcsTH Ltd

```
XROD 7 [-1*(6tporrtopOD/2)-(6ptrunbTH-6ptrunemTH)-6ptrunTH] 0.0
```

```
[0ptrun0D/2, 1, [-2* (-1*(0ptrunbTX-0ptrunemTH)-0ptrunTH)]
```

```
YROD 8 0.0 [-1*(@porttopOD/2)] @transportLT-@trunOFF]
```

```
ZROD 9 0.0 0.0 (transportLT-stopnsoff)
```

```

ZROD 10 0.0 0.0 0.0 [ @pbid/2.0 ] @transportLT
ZROD 11 0.0 0.0 0.0 [ @transportLT ] @transportLT
ZROD 12 0.0 0.0 0.0 [ @transportLT ] @transportLT

```

```
[ epbod/2.0 ] [ettransportLT-etstopsoff-etportboth-etbotringdiskTH] | Lead shi
```

```
ZCONE
13 0.0 0.0 [0transportLT-0stopnsOFF-0slopeLT] [0pbOD/2+0outshlTH]
(0transportnsOFF-0slopeLT) [0pbOD/2+0outshlTH]
```

```
ZROD 14      0.0  0.0  @tportbotTH
```

## ZONES

```

/Transport/
M[0tscMAT + 0matCS] +1 -2 -14 -13 -9

```

16

$$M[\text{BtscMAT} + \text{GmatSS304}] + 2$$

/PrimaryTrunion/ W[otSchMAT + @matSS304]	+7	+1	-3
(SecondaryTrunion/ W[otSchMAT + @matSS304]	+8	+1	-3

	-8	-7	-6	-5	+9	+0
/TopShell/					M[QtschMAT + @matSS304]	
InnerShell1						
InnerShell2						
InnerShell3						
InnerShell4						
InnerShell5						
InnerShell6						
InnerShell7						
InnerShell8						
InnerShell9						
InnerShell10						
InnerShell11						
InnerShell12						
InnerShell13						
InnerShell14						
InnerShell15						
InnerShell16						
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InnerShell80						
InnerShell81						
InnerShell82						
InnerShell83						
InnerShell84						
InnerShell85						

```

/LeadShield/ M[0tscMAT + 6matLead] +11 -10
/BottomShield/ M[0tscMAT + 6matLead] +11 -10

```

```
/OuterShellCone/ M[0tscMAT + @matSS304] +13 -11
```

$\mathcal{H}^1(\mathbb{R}^n) \cap \mathcal{H}^1(\mathbb{R}^n) = \mathcal{H}^1(\mathbb{R}^n)$

**ALBERTO L. L. I.**

1000

100

**BEGIN HO**

1000

**\*Insert:**

\* Hole 1 - 9x9" 79 Fuel Rod

...assumes that guide tube has maximum diameter, from any tube placed into lattice

**Lattice Lattice**

$$I - (\text{orpitch}/2, 0) \quad I - (\text{orpitch}/2, 0) \quad I - (\text{orpitch}/2, 0)$$

(00dwr/2:0] [00dwr/2:]

100

Figure 6.6.3-3 MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```

2 -2 -2 -2 -2 -2 -2 -2
2 -2 -2 -2 -2 -2 -2 -2
2 -2 -2 -2 -2 -3 -2 -2
2 -2 -2 -2 -3 -2 -2 -2
2 -2 -2 -2 -2 -2 -2 -2
2 -2 -2 -2 -2 -2 -2 -2
2 -2 -2 -2 -2 -2 -2 -2
2 -2 -2 -2 -2 -2 -2 -2
2 -2 -2 -2 -2 -2 -2 -2
3.3 material of clad and material outside (clad is 0 thickness in this model)

* Hole 2 - Fuel Rod
* Rod is shifted between end-fitting by modifying bottom gap to fuel rod
* Fuel material is shifted in rods by modifying lower plenum space

RZMESH
3 ! number of radial points
[ @odpelt/2.0 ] [ @odclad/2.0 ] - @cladth [ @odclad/2.0 ]
51 number of axial intervals
0.0 ! lower end of fuel rod elevation (top of lower nozzle) reset to 0
@lbcap ! top of bottom end cap region
[ @lbcap+@lowple ] ! bottom plenum region ends
[ @lbcap+@lowple+@lactfu ] ! top of active fuel region
[ @lfu-@lbcap ] ! bottom of top plug
@lfu ! bottom of top nozzle

2 2 2 ! bottom endcap
4 4 2 ! bottom expansion space (plenum) with cladding
1 4 2 ! fuel material pin with cladding
4 4 2 ! upper fuel expansion space (plenum) with cladding
2 2 2 ! top steel endcap
3 ! outermost material

* Hole 3 - Water Rod

GLOBE
2 ! number of radial points
[ @odwr/2.0 ] 5 ! water rods
[ ( @odwr/2.0 ) - @wrth ] 3 ! water-filled water rods
3 ! outermost material

* Hole 4 - BORAL Core

PLATE
1 0.0
2
[ ( @b1t+@b1ct ) / 2.0 ] 11
[ ( @b1t-@b1ct ) / 2.0 ] 10
11

* Hole 5 - General Basket Structure
* Structured to allow potential modification of weldment detail

PLATE
0.0.1
7
[ @lbasket-@lfs-@lbw ] 3 ! Top of Basket
@diskstack -6 ! Top of Highest Support Disk
[ 9.0*( @tspd+@lfs )+@nhtd*( @tspd+@dspsht+@thtd+@dsspsht ) ] -8 ! Bottom of Support Disk that starts Support Disk Array
[ 9.0*( @tspd+@lfs ) ] -9 ! Bottom of Support Disk that starts Al Array
0.0 -8 ! Bottom of Lowest Support Disk
[ -1.0*( @lbw+@lfs ) ] -7 ! Bottom of Basket
[ -1.0*( @baskoff+@lbw+@lfs ) ] 3 ! Basket Offset
3

* Hole 6 Top Weldment Disk - no structure above the weldment disk
* If for shielding reason this structure is desired an additional elevation
* can be defined and filled by a more detailed plate hole (for example, XYZ mesh)

RZMESH
1 ! number of radial points
[ @diatpw/2.0 ]
1 ! number of axial intervals
[ @lbasket-@lfs-@lbw-@ltpw ] ! Coordinates inherited from PLATE Hole
[ @lbasket-@lfs-@lbw-@ltpw+@ltpwd ] ! Coordinates inherited from PLATE Hole
13 ! Plate Material
3 ! Outside material

* Hole 7 Bottom Weldment Disk - no structure in the weldment disk support

RZMESH
1 ! number of radial points
[ @diabw/2.0 ]
1 ! number of axial intervals
[ -1.0*( @lfs+@lbwd ) ] ! Coordinates inherited from PLATE Hole
[ -1.0*( @lfs ) ] ! Coordinates inherited from PLATE Hole
13 ! Plate Material
3

* Hole 8 Support disk stack with water

PLATE
ORIGIN 0.0.0.0.0.0.0
0.0.1
1
CELL [ @tspd+@lfs ] Sets up a repeating lattice of cells

```

Figure 6.6.3-3

MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```
@tspd 3 water gap
12 steel disk

* Hole 9 Support disk and heat transfer disk stack

PLATE
ORIGIN 0.0 0.0 0.0
0.0 1
4
CELL [ @tspd+@dspsht+@thtd+@dspsht ] Sets up a repeating lattice of cells
[ @tspd+@dspsht+@thtd+@dspsht ] 3 water
[ @tspd+@dspsht+@thtd ] 3 water gap
[ @tspd+@dspsht ] 14 aluminium disk
@tspd 3 water gap
12 steel disk

* Additional holes may be added to add weldment detail using the xyz_mesh_hole function
*****

END

*****
BEGIN CONTROL DATA
*****

*READ read and check each independently
*SEK MULTIPLE DEFINITIONS

SEEDS 12345 12345
STAGES 10 810 5000 STDV 0.0005

END

*****
BEGIN SOURCE GEOMETRY
*****

ZONEMAT
ALL / MATERIAL @fuelMAT

END
```

Figure 6.6.3.4

# MONK8a Output Summary - UMS Transport Cask BWR Top End Impact

A	N	SSSSS	W	W	EEEEEE	RRRRR	SSSSS	00000	DDDDDD	EEEEEE
A	N	SSSSSS	W	W	EEEEEE	RRRRRR	SSSSSSS	0000000	DDDDDDDD	EEEEEEEE
AA	AA	SS	W	W	E	RR	SS	00	DD	EE
AA	NNNN	SS	W	W	ER	RR	RR	00	DD	EE
AAAAAAA	NN	SSSSSS	W	W	EEEE	RRRRRR	SSSSSS	00	DD	EEEE
AAAAAAA	NN	SSSSSS	W	W	EEEE	RRRRR	SSSSSS	00	DD	EEEE
AA	AA	SS	W	W	E	RR	SS	00	DD	EE
AA	NNNN	SS	W	W	EE	RR	RR	00	DD	EE
AA	NN	SSSSSSS	WWWW	W	EEEEEE	RR	SSSSSSS	0000000	DDDDDDDD	EEEEEEEE
AA	AA	SSSSS	W	W	EEEEEE	RR	SSSSS	000000	DDDDDD	EEEEEE
AA	NN	SSSSS	W	W	EEEEEE	RR	SSSSS	000000	DDDDDD	EEEEEE
AA	NN	SSSSS	W	W	EEEEEE	RR	SSSSS	000000	DDDDDD	EEEEEE

[illegible]

Running on machine 57NST ( Windows NT) ...  
Date and time of execution: 10/ 5/2000 - 18.41.58

\*\*\*\*\* This Computer Program is Supplied Under Licence by the ARA Technology ANSWERS Software Service \*\*\*\*\*

Program MONK 8A - Release Update 1

\* This is the ANSWERS QA Set version of MONK. This program has successfully executed the designated set of test cases on the ANSWERS QA Set computer systems.

\* This is the first update release of MONKSA, known as  
\* the RU1 release. It contains corrections to the errors  
\* reported in ANSWERS/CRT/ERROR(98)28, 30, 31 and 33

22 January 1999

The MONK program is developed and maintained through a collaboration between AEA Technology PLC and British Nuclear Fuels PLC.

STATUS OF INPUT UNITS AT END OF STAGE ONE PROCESSING \*

PROBLEM CONTROL DATA.	USED-OK
MATERIAL GEOMETRY DATA.	USED-OK
SOURCE GEOMETRY DATA.	USED-OK
HOLE DATA	USED-OK
MATERIAL SPECIFICATION	USED-OK

Figure 6.6.3-4 MONK8a Output Summary - UMS Transport Cask BWR Top End Impact (Continued)

AT THE START OF THE TRACKING PROCESS THERE IS OVER A WEEK OF CPU TIME AVAILABLE.

A TIME OF 30,000 SECS WILL BE ALLOWED FOR CREATING DUMP AND OUTPUT FILES

STAGE 10 COMPLETED AFTER	3.73 MIN	-	K(THREE) = 0.9886	(0.0046)
STAGE 9 COMPLETED AFTER	8.24 MIN	-	K(THREE) = 0.9271	(0.0031)
STAGE 8 COMPLETED AFTER	12.85 MIN	-	K(THREE) = 0.9034	(0.0024)
STAGE 7 COMPLETED AFTER	17.26 MIN	-	K(THREE) = 0.9053	(0.0021)
STAGE 6 COMPLETED AFTER	22.09 MIN	-	K(THREE) = 0.9081	(0.0019)
STAGE 5 COMPLETED AFTER	26.79 MIN	-	K(THREE) = 0.9105	(0.0017)
STAGE 4 COMPLETED AFTER	31.71 MIN	-	K(THREE) = 0.9124	(0.0016)
STAGE 3 COMPLETED AFTER	37.81 MIN	-	K(THREE) = 0.9149	(0.0015)
STAGE 2 COMPLETED AFTER	47.15 MIN	-	K(THREE) = 0.9173	(0.0014)
STAGE 1 COMPLETED AFTER	56.47 MIN	-	K(THREE) = 0.9186	(0.0013)
STAGE 0 COMPLETED AFTER	65.81 MIN	-	K(THREE) = 0.9207	(0.0013)
STAGE 1 COMPLETED AFTER	75.57 MIN	-	K(THREE) = 0.9326	(0.0041)
STAGE 2 COMPLETED AFTER	85.78 MIN	-	K(THREE) = 0.9333	(0.0028)
STAGE 3 COMPLETED AFTER	95.79 MIN	-	K(THREE) = 0.9340	(0.0023)
STAGE 4 COMPLETED AFTER	105.85 MIN	-	K(THREE) = 0.9341	(0.0020)
STAGE 5 COMPLETED AFTER	115.98 MIN	-	K(THREE) = 0.9337	(0.0018)
STAGE 6 COMPLETED AFTER	124.87 MIN	-	K(THREE) = 0.9334	(0.0017)
STAGE 7 COMPLETED AFTER	134.88 MIN	-	K(THREE) = 0.9338	(0.0015)
STAGE 8 COMPLETED AFTER	144.75 MIN	-	K(THREE) = 0.9342	(0.0014)
STAGE 9 COMPLETED AFTER	154.78 MIN	-	K(THREE) = 0.9340	(0.0014)
STAGE 10 COMPLETED AFTER	165.28 MIN	-	K(THREE) = 0.9349	(0.0013)
STAGE 11 COMPLETED AFTER	175.27 MIN	-	K(THREE) = 0.9351	(0.0012)
STAGE 12 COMPLETED AFTER	185.53 MIN	-	K(THREE) = 0.9350	(0.0012)
STAGE 13 COMPLETED AFTER	195.88 MIN	-	K(THREE) = 0.9351	(0.0011)
STAGE 14 COMPLETED AFTER	206.30 MIN	-	K(THREE) = 0.9351	(0.0011)
STAGE 15 COMPLETED AFTER	216.43 MIN	-	K(THREE) = 0.9350	(0.0011)
STAGE 16 COMPLETED AFTER	226.56 MIN	-	K(THREE) = 0.9351	(0.0010)
STAGE 17 COMPLETED AFTER	236.84 MIN	-	K(THREE) = 0.9352	(0.0010)
STAGE 18 COMPLETED AFTER	246.93 MIN	-	K(THREE) = 0.9352	(0.0010)
STAGE 19 COMPLETED AFTER	257.22 MIN	-	K(THREE) = 0.9351	(0.0009)
STAGE 20 COMPLETED AFTER	267.74 MIN	-	K(THREE) = 0.9355	(0.0009)
STAGE 21 COMPLETED AFTER	278.23 MIN	-	K(THREE) = 0.9358	(0.0009)
STAGE 22 COMPLETED AFTER	288.07 MIN	-	K(THREE) = 0.9357	(0.0009)
STAGE 23 COMPLETED AFTER	298.44 MIN	-	K(THREE) = 0.9357	(0.0009)
STAGE 24 COMPLETED AFTER	304.11 MIN	-	K(THREE) = 0.9358	(0.0008)
STAGE 25 COMPLETED AFTER	309.72 MIN	-	K(THREE) = 0.9359	(0.0008)
STAGE 26 COMPLETED AFTER	315.51 MIN	-	K(THREE) = 0.9361	(0.0008)
STAGE 27 COMPLETED AFTER	1118.73 MIN	-	K(THREE) = 0.9363	(0.0008)
STAGE 28 COMPLETED AFTER	1112.94 MIN	-	K(THREE) = 0.9363	(0.0008)
STAGE 29 COMPLETED AFTER	1107.01 MIN	-	K(THREE) = 0.9365	(0.0008)
STAGE 30 COMPLETED AFTER	1101.23 MIN	-	K(THREE) = 0.9367	(0.0007)
STAGE 31 COMPLETED AFTER	1095.42 MIN	-	K(THREE) = 0.9369	(0.0007)
STAGE 32 COMPLETED AFTER	1089.77 MIN	-	K(THREE) = 0.9371	(0.0007)
STAGE 33 COMPLETED AFTER	1084.30 MIN	-	K(THREE) = 0.9369	(0.0007)
STAGE 34 COMPLETED AFTER	1078.75 MIN	-	K(THREE) = 0.9368	(0.0007)
STAGE 35 COMPLETED AFTER	1073.27 MIN	-	K(THREE) = 0.9367	(0.0007)
STAGE 36 COMPLETED AFTER	1067.91 MIN	-	K(THREE) = 0.9367	(0.0007)
STAGE 37 COMPLETED AFTER	1062.23 MIN	-	K(THREE) = 0.9368	(0.0007)
STAGE 38 COMPLETED AFTER	1056.71 MIN	-	K(THREE) = 0.9366	(0.0007)
STAGE 39 COMPLETED AFTER	1051.10 MIN	-	K(THREE) = 0.9366	(0.0007)
STAGE 40 COMPLETED AFTER	1045.75 MIN	-	K(THREE) = 0.9364	(0.0007)
STAGE 41 COMPLETED AFTER	1040.26 MIN	-	K(THREE) = 0.9364	(0.0006)
STAGE 42 COMPLETED AFTER	1034.74 MIN	-	K(THREE) = 0.9364	(0.0006)
STAGE 43 COMPLETED AFTER	1029.41 MIN	-	K(THREE) = 0.9364	(0.0006)
STAGE 44 COMPLETED AFTER	1023.93 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 45 COMPLETED AFTER	1018.27 MIN	-	K(THREE) = 0.9362	(0.0006)
STAGE 46 COMPLETED AFTER	1012.74 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 47 COMPLETED AFTER	1007.35 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 48 COMPLETED AFTER	1001.96 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 49 COMPLETED AFTER	996.57 MIN	-	K(THREE) = 0.9362	(0.0006)
STAGE 50 COMPLETED AFTER	990.92 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 51 COMPLETED AFTER	985.23 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 52 COMPLETED AFTER	979.40 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 53 COMPLETED AFTER	973.63 MIN	-	K(THREE) = 0.9364	(0.0006)
STAGE 54 COMPLETED AFTER	968.08 MIN	-	K(THREE) = 0.9362	(0.0006)
STAGE 55 COMPLETED AFTER	963.61 MIN	-	K(THREE) = 0.9362	(0.0006)
STAGE 56 COMPLETED AFTER	959.87 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 57 COMPLETED AFTER	956.11 MIN	-	K(THREE) = 0.9363	(0.0006)
STAGE 58 COMPLETED AFTER	952.61 MIN	-	K(THREE) = 0.9361	(0.0005)
STAGE 59 COMPLETED AFTER	948.71 MIN	-	K(THREE) = 0.9362	(0.0005)
STAGE 60 COMPLETED AFTER	944.98 MIN	-	K(THREE) = 0.9362	(0.0005)
STAGE 61 COMPLETED AFTER	941.36 MIN	-	K(THREE) = 0.9363	(0.0005)
STAGE 62 COMPLETED AFTER	937.41 MIN	-	K(THREE) = 0.9364	(0.0005)
STAGE 63 COMPLETED AFTER	933.49 MIN	-	K(THREE) = 0.9364	(0.0005)
STAGE 64 COMPLETED AFTER	929.65 MIN	-	K(THREE) = 0.9365	(0.0005)
STAGE 65 COMPLETED AFTER	925.95 MIN	-	K(THREE) = 0.9365	(0.0005)
STAGE 66 COMPLETED AFTER	922.22 MIN	-	K(THREE) = 0.9364	(0.0005)
STAGE 67 COMPLETED AFTER	918.44 MIN	-	K(THREE) = 0.9364	(0.0005)
STAGE 68 COMPLETED AFTER	914.55 MIN	-	K(THREE) = 0.9365	(0.0005)

Figure 6.6.3-4 MONK8a Output Summary - UMS Transport Cask BWR Top End Impact (Continued)

*****										
* REQUIRED ACCURACY (SD= 0.000500) REACHED BY K(THREE)										
* EXECUTION ENDS AFTER STAGE 68										
*****										
OUTPUT FROM MONK8a (1/2/1998) AT 3.28.13 ON 11/5/2000										
*****										
=====										
NUMBER OF SUPERHISTORIES POST-SETTLING = 340000										
NUMBER OF SAMPLES POST-SETTLING = 3396184										
FIRST STAGE RUN = -10										
FINAL STAGE COMPLETED = 68										
TOTAL C.P.U. TIME (SECONDS) = -54872.992										
AVERAGE TIME PER SAMPLE(SECONDS) = -0.139										
AVERAGE TIME PER STAGE(SECONDS) = -694.595										
AVERAGE SAMPLES PER SECONDS = -7										
NUMBER OF RANDOM NUMBERS USED = 1930307058										
AFTER SEEDING WITH VALUES = 12345										
TRAJECTORIES TRACKED THIS RUN = 205696646										
NUMBER OF COLLISIONS THIS RUN = 249336509										
ZONE SEARCH LOCATIONS USED(PAIRS) = 562										
*****										
***** CUMULATIVE K-EFFECTIVE ESTIMATORS *****										
STAGE	K(COLL)	STDV	K(SCORE)	STDV	A(SCORE)	STDV	ALPHA	BETA	K(THREE)	STDV
1	0.9258	0.0055	0.9331	0.0062	0.9979	0.0037	0.3027	0.8204	0.9326	0.0041
2	0.9296	0.0039	0.9356	0.0043	1.0007	0.0027	0.2793	0.8656	0.9333	0.0028
3	0.9314	0.0032	0.9389	0.0036	1.0032	0.0022	0.2873	0.8671	0.9340	0.0023
4	0.9325	0.0028	0.9390	0.0031	1.0035	0.0019	0.2797	0.8667	0.9341	0.0020
5	0.9322	0.0025	0.9371	0.0027	1.0025	0.0017	0.2677	0.8726	0.9337	0.0018
6	0.9310	0.0023	0.9371	0.0025	1.0024	0.0016	0.2702	0.8750	0.9334	0.0017
7	0.9319	0.0021	0.9367	0.0024	1.0019	0.0015	0.2677	0.8742	0.9338	0.0015
8	0.9331	0.0020	0.9377	0.0022	1.0025	0.0014	0.2589	0.8981	0.9342	0.0014
9	0.9330	0.0019	0.9368	0.0021	1.0020	0.0013	0.2554	0.8939	0.9340	0.0014
10	0.9341	0.0018	0.9377	0.0020	1.0021	0.0012	0.2509	0.8975	0.9349	0.0013
11	0.9342	0.0017	0.9379	0.0019	1.0020	0.0012	0.2508	0.8945	0.9351	0.0012
12	0.9339	0.0016	0.9375	0.0018	1.0019	0.0011	0.2531	0.8924	0.9350	0.0012
13	0.9341	0.0015	0.9377	0.0017	1.0018	0.0011	0.2581	0.8818	0.9351	0.0011
14	0.9342	0.0015	0.9370	0.0016	1.0014	0.0010	0.2524	0.8797	0.9351	0.0011
15	0.9342	0.0014	0.9367	0.0016	1.0012	0.0010	0.2536	0.8791	0.9350	0.0011
16	0.9346	0.0014	0.9364	0.0015	1.0009	0.0010	0.2479	0.8785	0.9351	0.0010
17	0.9345	0.0013	0.9363	0.0015	1.0008	0.0009	0.2479	0.8806	0.9352	0.0010
18	0.9345	0.0013	0.9367	0.0014	1.0012	0.0009	0.2482	0.8788	0.9352	0.0010
19	0.9347	0.0013	0.9364	0.0014	1.0009	0.0009	0.2483	0.8772	0.9351	0.0009
20	0.9348	0.0012	0.9368	0.0014	1.0009	0.0009	0.2515	0.8732	0.9355	0.0009
21	0.9354	0.0012	0.9367	0.0013	1.0007	0.0008	0.2512	0.8714	0.9358	0.0009
22	0.9352	0.0012	0.9363	0.0013	1.0004	0.0008	0.2475	0.8747	0.9357	0.0009
23	0.9352	0.0012	0.9362	0.0013	1.0003	0.0008	0.2482	0.8734	0.9357	0.0009
24	0.9352	0.0011	0.9361	0.0012	1.0000	0.0008	0.2434	0.8768	0.9358	0.0008
25	0.9353	0.0011	0.9361	0.0012	1.0000	0.0008	0.2440	0.8755	0.9359	0.0008
26	0.9354	0.0011	0.9363	0.0012	1.0000	0.0008	0.2450	0.8750	0.9361	0.0008
27	0.9359	0.0011	0.9365	0.0012	1.0001	0.0007	0.2448	0.8773	0.9363	0.0008
28	0.9359	0.0010	0.9366	0.0012	1.0001	0.0007	0.2468	0.8733	0.9363	0.0008
29	0.9362	0.0010	0.9370	0.0011	1.0003	0.0007	0.2488	0.8726	0.9365	0.0008
30	0.9365	0.0010	0.9374	0.0011	1.0005	0.0007	0.2503	0.8717	0.9367	0.0007
31	0.9367	0.0010	0.9376	0.0011	1.0005	0.0007	0.2493	0.8778	0.9369	0.0007
32	0.9368	0.0010	0.9373	0.0011	1.0001	0.0007	0.2476	0.8779	0.9371	0.0007
33	0.9366	0.0010	0.9370	0.0011	0.9999	0.0007	0.2474	0.8781	0.9369	0.0007
34	0.9363	0.0009	0.9366	0.0010	0.9998	0.0007	0.2475	0.8776	0.9368	0.0007
35	0.9364	0.0009	0.9366	0.0010	0.9998	0.0006	0.2469	0.8775	0.9367	0.0007
36	0.9363	0.0009	0.9365	0.0010	0.9996	0.0006	0.2467	0.8794	0.9367	0.0007
37	0.9364	0.0009	0.9365	0.0010	0.9997	0.0006	0.2441	0.8829	0.9368	0.0007
38	0.9361	0.0009	0.9363	0.0010	0.9996	0.0006	0.2447	0.8820	0.9366	0.0007
39	0.9361	0.0009	0.9365	0.0010	0.9998	0.0006	0.2445	0.8837	0.9366	0.0007
40	0.9359	0.0009	0.9362	0.0010	0.9998	0.0006	0.2443	0.8837	0.9364	0.0007
41	0.9359	0.0009	0.9361	0.0010	0.9997	0.0006	0.2449	0.8818	0.9364	0.0006
42	0.9359	0.0009	0.9362	0.0009	0.9997	0.0006	0.2448	0.8830	0.9364	0.0006
43	0.9357	0.0008	0.9361	0.0009	0.9996	0.0006	0.2467	0.8824	0.9364	0.0006
44	0.9355	0.0008	0.9361	0.0009	0.9996	0.0006	0.2475	0.8821	0.9363	0.0006
45	0.9355	0.0008	0.9360	0.0009	0.9996	0.0006	0.2473	0.8817	0.9362	0.0006
46	0.9354	0.0008	0.9361	0.0009	0.9995	0.0006	0.2478	0.8829	0.9363	0.0006
47	0.9352	0.0008	0.9362	0.0009	0.9996	0.0006	0.2491	0.8824	0.9363	0.0006
48	0.9351	0.0008	0.9362	0.0009	0.9996	0.0006	0.2502	0.8807	0.9363	0.0006
49	0.9351	0.0008	0.9363	0.0009	0.9997	0.0006	0.2499	0.8826	0.9362	0.0006
50	0.9352	0.0008	0.9363	0.0009	0.9998	0.0005	0.2509	0.8812	0.9363	0.0006
51	0.9353	0.0008	0.9363	0.0009	0.9998	0.0005	0.2510	0.8825	0.9363	0.0006
52	0.9354	0.0008	0.9365	0.0009	0.9999	0.0005	0.2518	0.8829	0.9363	0.0006
53	0.9355	0.0008	0.9367	0.0008	1.0000	0.0005	0.2527	0.8817	0.9364	0.0006
54	0.9354	0.0008	0.9365	0.0008	1.0000	0.0005	0.2533	0.8812	0.9362	0.0006
55	0.9354	0.0007	0.9365	0.0008	1.0001	0.0005	0.2526	0.8817	0.9362	0.0006
56	0.9354	0.0007	0.9364	0.0008	0.9999	0.0005	0.2522	0.8809	0.9363	0.0006
57	0.9354	0.0007	0.9363	0.0008	0.9999	0.0005	0.2512	0.8814	0.9361	0.0005
58	0.9354	0.0007	0.9361	0.0008	0.9998	0.0005	0.2506	0.8818	0.9361	0.0005
59	0.9354	0.0007	0.9362	0.0008	0.9998	0.0005	0.2514	0.8802	0.9362	0.0005
60	0.9354	0.0007	0.9362	0.0008	0.9998	0.0005	0.2517	0.8805	0.9362	0.0005
61	0.9354	0.0007	0.9363	0.0008	0.9998	0.0005	0.2522	0.8808	0.9363	0.0005
62	0.9356	0.0007	0.9363	0.0008	0.9997	0.0005	0.2515	0.8809	0.9364	0.0005
63	0.9357	0.0007	0.9364	0.0008	0.9998	0.0005	0.2513	0.8802	0.9364	0.0005
64	0.9358	0.0007	0.9366	0.0008	0.9999	0.0005	0.2518	0.8807	0.9365	0.0005
65	0.9358	0.0007	0.9366	0.0008	0.9999	0.0005	0.2522	0.8793	0.9365	0.0005
66	0.9357	0.0007	0.9365	0.0008	0.9999	0.0005	0.2531	0.8782	0.9364	0.0005
67	0.9357	0.0007	0.9365	0.0008	0.9999	0.0005	0.2532	0.8783	0.9364	0.0005
68	0.9357	0.0007	0.9365	0.0007	0.9998	0.0005	0.2532	0.8777	0.9365	0.0005

**Figure 6.6.3-4** **MONK8a Output Summary - UMS Transport Cask BWR Top End Impact (Continued)**

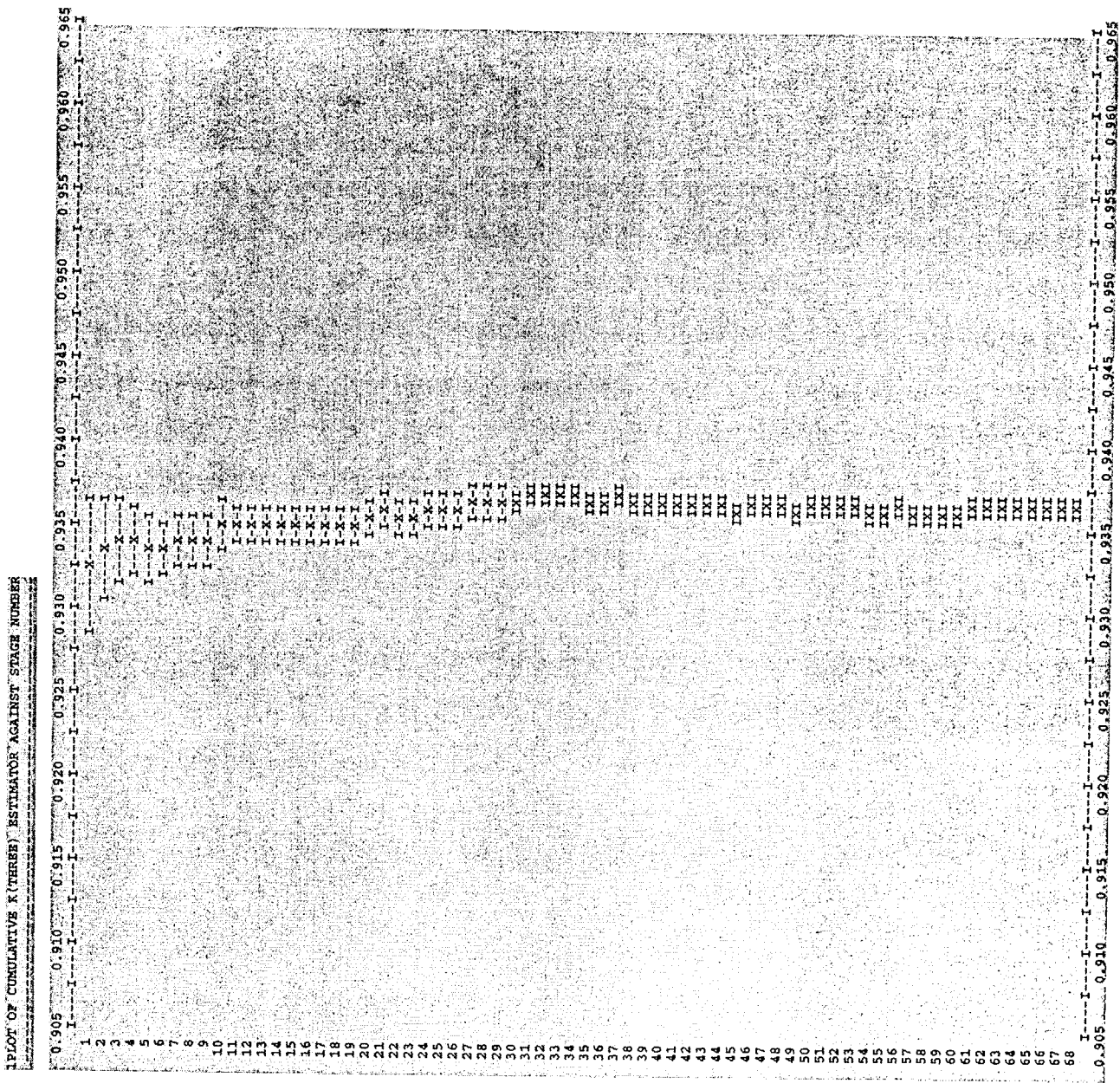


Figure 6.6.3-4 MONK8a Output Summary - UMS Transport Cask BWR Top End Impact (Continued)

1CASE CATEGORISATION  
=====

THERE ARE 972 CATEGORIES SPLIT AS FOLLOWS	A=1: URANIUM SYSTEMS	1 - 324
	A=2: PLUTONIUM SYSTEMS	325 - 648
	A=3: OTHER SYSTEMS	649 - 972
WITHIN EACH 324 NUMBER SEGMENT	B=1: LOW NON-FUEL ABSORPTION	1 - 108
	B=2: MEDIUM NON-FUEL ABSORPTION	109 - 216
	B=3: HIGH NON-FUEL ABSORPTION	217 - 324
WITHIN EACH 108 NUMBER SEGMENT	C=1: LOW ASSEMBLIES	1 - 36
	C=2: MEDIUM LEAKAGE SYSTEMS	37 - 72
	C=3: HIGH LEAKAGE SYSTEMS	73 - 108
WITHIN EACH 36 NUMBER SEGMENT	D=1: LOW RESONANCE ABSORPTION	1 - 12
	D=2: MEDIUM RESONANCE ABSORPTION	13 - 24
	D=3: HIGH RESONANCE ABSORPTION	25 - 36
WITHIN EACH 12 NUMBER SEGMENT	E=1: LOW FAST FISSION	1 - 4
	E=2: MEDIUM FAST FISSION	5 - 8
	E=3: HIGH FAST FISSION	9 - 12
WITHIN EACH 4 NUMBER SEGMENT	F=1: NO HYDROGEN	1
	F=2: LOW HYDROGEN CONTENT	2
	F=3: MEDIUM HYDROGEN CONTENT	3
	F=4: HIGH HYDROGEN CONTENT	4

TYPE OF SYSTEM ..... A = 1 ..... FRACTION OF FISSIONS IN URANIUM AND PLUTONIUM = 1.0000 0.0000  
 NON-FUEL ABSORPTION ..... B = 2 ..... FRACTION OF TOTAL ABSORPTIONS IN FUEL = 0.5711  
 LEAKAGE ..... C = 1 ..... FRACTION OF NEUTRONS LEAKING = 0.0000  
 RESONANCE ABSORPTION ..... D = 2 ..... FRACTION OF ABSORPTIONS IN RESONANCE PARTITION = 0.1773  
 FAST FISSION ..... E = 1 ..... MEASURE OF FAST FISSION = 0.0230  
 FUEL HYDROGEN CONTENT ..... F = 1 ..... MEASURE OF HYDROGEN CONTENT = 0.0000

\*\*\*\*\*  
 \* THIS CASE FALLS INTO CATEGORY NUMBER 121 \*  
 \*\*\*\*\*

THE CATEGORY NUMBER IS NOT A GUARANTEED INDICATOR OF THE BIAS TO BE EXPECTED ON THE FINAL VALUE OF K-EFFECTIVE  
 IT SHOULD BE USED WITH CAUTION SINCE MANY OTHER FACTORS ARE INVOLVED (E.G. UNUSUAL/EXOTIC MATERIALS AND NUCLIDES)

1SAMPLING GUIDANCE  
=====

NO PARTICLE TRACKS IN ZONE 4 FOR 59 STAGES  
 The first 20 stages that this occurred are:  
 1 6 7 8 9 10 11 12 14 15 16 18 19 20 24 25 26 27 28  
 NO PARTICLE TRACKS IN ZONE 10 FOR 75 STAGES  
 The first 20 stages that this occurred are:  
 9 5 4 3 2 1 0 2 3 4 5 6 7 8 9 10 11 12  
 NO PARTICLE TRACKS IN ZONE 11 FOR 79 STAGES  
 NO PARTICLE TRACKS IN ZONE 121 FOR 73 STAGES  
 The first 20 stages that this occurred are:  
 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8  
 NO PARTICLE TRACKS IN ZONE 128 FOR 79 STAGES  
 The first 20 stages that this occurred are:  
 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8  
 NO PARTICLE TRACKS IN ZONE 131 FOR 79 STAGES  
 The first 20 stages that this occurred are:  
 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8  
 NO PARTICLE TRACKS IN ZONE 134 FOR 79 STAGES  
 The first 20 stages that this occurred are:  
 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8



**Figure 6.6.3-4 MONK8a Output Summary - UMS Transport Cask BWR Top End Impact (Continued)**

```

NO PARTICLE TRACKS IN ZONE 137 FOR 79 STAGES
The first 20 stages that this occurred are:
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 140 FOR 79 STAGES
The first 20 stages that this occurred are:
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 143 FOR 79 STAGES
The first 20 stages that this occurred are:
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

NO PARTICLE TRACKS IN ZONE 169 FOR STAGES:
-9

NO PARTICLE TRACKS IN ZONE 172 FOR STAGES:
-10 -9

NO PARTICLE TRACKS IN ZONE 173 FOR STAGES:
-10 -9 -8 11 61

NO PARTICLE TRACKS IN ZONE 174 FOR 26 STAGES
The first 20 stages that this occurred are:
-10 -7 -2 0 1 6 8 9 11 12 20 22 27 30 32 34 35 36 41

NO PARTICLE TRACKS IN ZONE 175 FOR 22 STAGES
The first 20 stages that this occurred are:
-9 -5 -1 3 8 19 20 21 22 24 30 31 36 38 39 43 50 51 57

NO PARTICLE TRACKS IN ZONE 179 FOR 63 STAGES
The first 20 stages that this occurred are:
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 1 2 3 4 5 6 7 8 9

2. SOURCE PARTICLES STARTED FROM ALL FISSILE ZONES IN ALL STAGES
3. CONSISTENCY OF ESTIMATORS
Individual stage values of K(COLL) and K(SCORE) agree for all stages
Difference between individual stage value of A(SCORE) and 1.0 is greater than 3 SD
Stage : 32
A(SCORE) : 0.99
Difference in SD units: 3.31

4. TEST FOR NORMALITY OF INDIVIDUAL STAGE ESTIMATORS
(Level of significance > 1% for pass)
K(COLL) PASSED Level of significance = 88.31%
K(SCORE) PASSED Level of significance = 6.86%
K(THREE) PASSED Level of significance = 82.20%

5. CHI-SQUARED TEST FOR ADEQUATE SETTLING

```

	No. of Settling stages	Chi squared per degree of freedom	Probability	
K(COLL)	11	0.726	0.7955	PASSED
K(SCORE)	11	0.915	0.5642	PASSED
K(THREE)	11	0.550	0.9412	PASSED

```

FINAL VALUE OF K(THREE) = 0.9365 (STDEV = 0.0005)
K(THREE) + (3 * STDEV) = 0.9380

*****
* MONK PROCESSING COMPLETED TO STAGE 3 *
*****

```

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## 7.0 OPERATING PROCEDURES

The Universal Transport Cask is designed to transport spent nuclear fuel and Greater Than Class C (GTCC) waste. The cask is dry loaded in the spent fuel building or at the onsite Independent Spent Fuel Storage Installation (ISFSI). This chapter outlines the procedures for dry loading or unloading at either location, conducting the receiving inspection, preparing the cask prior to loading or unloading, and preparing the cask for transport following loading or unloading. These procedures are based on the assumption that an empty cask is hauled onsite by a railcar or heavy haul trailer. Table 7-1 summarizes the major torque values to be used in the procedures.

The operating procedures outlined in this chapter represent the minimum generic requirements to ensure safe and reliable operation of the cask. The cask user is responsible for developing, preparing, and approving site-specific procedures in accordance with these procedures, the package certificate of compliance, and the user's quality assurance program. Following the user-approved operating procedures will assure that cask handling and shipping activities are performed in accordance with the Certificate of Compliance, safety analysis report, and applicable U.S. Nuclear Regulatory Commission and U.S. Department of Transportation regulations governing the packaging and transport of radioactive materials.

The generic procedures primarily address the loading and unloading of a Universal Transport Cask with a Transportable Storage Canister that has already been loaded with spent fuel or GTCC waste (Sections 7.1.3 and 7.3.3). These procedures describe the use of the transfer cask, which is primarily a lifting device, but also provides biological shielding when it contains a loaded canister. The transfer cask is used for the vertical transfer of the canister between workstations and the storage or transport casks. The transfer cask is more fully described in the Safety Analysis Report (SAR) for the UMS® Universal Storage System, Docket No. 72-1015.

The procedures provided in Section 7.5.1 (spent fuel) and in Section 7.5.2 (GTCC waste) address the direct loading of a Transportable Storage Canister installed in the transfer cask.

Table 7-1 Torque Values

Component*	Number Used	Fastener	Torque Value
Cask lid bolt	48	2 - 8 UN - Socket Head Bolt	3,900 ± 100 ft-lb
Vent/drain port coverplate bolt	8	1/2 - 13 UNC - Socket Head Cap Screw	300 ± 50 in-lb
Lid o-ring test port plug	1	Parker #16 P5N	30 ± 5 in-lb
Vent/Drain o-ring test port plug	2	Cajon #SS-2-PST	125 ± 5 in-lb
Impact limiter retaining rods	32	ASTM A193 GRB8S Aust. Stainless Steel	75 ± 5 ft-lb [5]
Impact limiter nut	32	1-1/4 - 7 UNC Heavy Hex Nut	35 ± 2 ft-lb
Impact limiter jam nut	32	1-1/4 - 7 UNC Hex Jam Nut	75 ± 5 ft-lb
Adapter plate bolts	4	1-1/4 - 7 UNC - Socket Head Cap Screw	250 ± 30 ft-lb [5]
Secondary trunnion bolts	24	1-1/8 - 12 UNF Socket Head Cap Screw	500 ± 50 ft-lb
Personnel barrier (Tie Down Bolts)	6	3/8 - 16 UNC Hex Head Bolt	35 ± 2 ft-lb
Impact limiter positioner (upper and lower)	6	3/4 - 10 UNC Socket Head Cap Screw	50 ± 5 in-lb

\* Torque values for components not shown in this table are provided on the appropriate license drawings in Section 1.3.4.

Note: Threaded fasteners shall be lightly lubricated with Nuclear Grade NEOLUBE® or equivalent.

Table 7-2 Containment Verification Leak Test Requirements

	Post-Fabrication and Annual Maintenance <sup>3</sup>	Loaded Transport (O-Ring Replacement) <sup>2,3</sup>	Loaded Transport (No O-Ring Replacement) <sup>2</sup>	Empty Transport
Allowable Reference Leak Rate <sup>1</sup>	$2.4 \times 10^{-5} \text{ cm}^3/\text{sec}$	$2.4 \times 10^{-5} \text{ cm}^3/\text{sec}$	$1 \times 10^{-3} \text{ cm}^3/\text{sec}$	$1 \times 10^{-3} \text{ cm}^3/\text{sec}$
Allowable Helium Leak Rate <sup>1</sup>	$3.3 \times 10^{-5} \text{ cm}^3/\text{sec}$	$3.3 \times 10^{-5} \text{ cm}^3/\text{sec}$		

- 1 The allowable leak rate is based on the bounding fuel and is the same for the transport of GTCC waste.
- 2 The need for o-ring replacement is determined by inspection or by leak test results.
- 3 All o-rings are replaced during Annual Maintenance. Only the appropriate set of o-rings is replaced as necessary during use.



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## 7.1 Receiving Universal Transport Cask and Loading Transportable Storage Canister into Universal Transport Cask

The assumptions underlying these procedures are as follows.

- The cask has been fabricated, inspected, and tested.
- The cask is in compliance with the Certificate of Compliance prior to release from the fabrication facility.



For casks previously loaded and transported, the receiving inspections will be required to include performance of radiation and removable contamination surveys of the empty cask and vehicle in accordance with 10 CFR 20, 10 CFR 71, 49 CFR 173 and IAEA Safety Series No. 6 [1 thru 4].

### 7.1.1 Receiving Inspection

1. Remove the personnel barrier.
2. While the cask is secured to the transport vehicle in the horizontal orientation, visually inspect the cask for any signs of damage. Verify the integrity of the impact limiter lockwires and the tamper indicating seals between the upper impact limiter and a lifting trunnion and between the lower impact limiter and the shipping support frame.
3. Wash the cask support structure and transport vehicle to remove any road dirt or dust, if needed.
4. Move the transport vehicle with the cask and support structure to the cask receiving area.
5. Secure the vehicle by applying the parking brake and placing rail car or truck wheel chocks, as applicable.
6. Attach slings to the upper impact limiter lifting lugs and remove impact limiter seal wires, jam nuts, nuts, and retaining rods, and tamper indicating seal.
7. Remove the upper impact limiter and store it in an upright transport position within the storage support frame.
8. Repeat Steps 6 and 7 for the lower impact limiter.
9. Remove the lower impact limiter positioner.
10. Release the tiedown assembly from the front support by removing the front tiedown pins and retaining pins.

11. Attach a sling to the tiedown assembly lifting lugs and remove the tiedown assembly from the transport vehicle.
12. Attach the cask lifting yoke to a crane hook with **an** appropriate load rating.
13. Engage the yoke with the primary (welded) lifting trunnions at the top end of the cask.
14. Rotate/lift the cask to the vertical orientation and raise the cask off the blocks of the transport vehicle's rear support structure.

15. Place the cask in the vertical orientation in a decontamination area or other suitable location identified by the user.

**Note:** If the cask is to be lifted using the redundant lift system, the secondary trunnion bolt torque must be verified to be in accordance with Table 7-1. Redundant lift yoke system must also be installed prior to lifting the cask.

16. Disengage the cask lifting yoke from the lifting trunnions.
17. Record all inspection results on a cask-receiving inspection checklist.

#### 7.1.2 Preparing the Universal Transport Cask for Dry Loading

The Universal Transport Cask is dry loaded in the spent fuel building or at the onsite ISFSI by using a transfer cask and attendant support hardware. Operation of the transfer cask is described in NAC-approved site-specific procedures.

The assumptions underlying this procedure are **■**:

- The cask has just been inspected and accepted and is positioned in the spent fuel building or the ISFSI area designated for loading.
- The cask is being prepared for first-time fuel loading following fabrication or the scheduled annual maintenance required by the certificate of compliance has been successfully completed within the previous 12 months.
- Previously used casks have been externally decontaminated and are empty of **■** contents.

The steps for preparing the cask for dry loading are **■**:

1. Install appropriate work platforms/scaffolding to allow access to the top of the cask.

2. Detorque and remove the vent coverplate bolts.
3. Remove the vent port coverplate from the lid.
- Note:** The drain port coverplate need not be removed for dry loading or unloading.
4. Visually inspect the port coverplate o-rings for damage or defects and replace if necessary. Store the coverplate so that the o-rings and o-ring grooves are protected from incidental damage.
5. Detorque the cask lid bolts using the reverse torquing sequence.
6. Remove the bolts and store them in a temporary storage area.
7. Clean and visually inspect bolts for damage. Replace any damaged bolts.
8. Install the two cask lid alignment pins.
9. Install lifting hoist rings in the lid-lifting holes.
10. Attach the lid-lifting device to the lid and an overhead crane.  
**Caution:** Ensure that the o-rings and o-ring grooves in the lid are protected from any incidental damage to the seal area in its temporary storage position.
11. Remove the lid and store in a temporary storage area.
12. Decontaminate the lid and visually inspect the lid o-rings for damage and wear and replace as necessary.  
**Note:** Visually Inspecting and cleaning of bolts can be performed in parallel to other operations performed in this procedure.
13. Clean and visually inspect the threaded connections in the top forging.
14. Remove the two cask lid alignment pins.
15. Visually examine the internal cavity to ensure that no damage has occurred during transit and that no foreign materials are present.
16. Record all inspection results.
17. Install the cask adapter ring to protect the cask sealing surfaces.
18. If a canister spacer is to be installed:
  - a) Attach the spacer lift fixture to the spacer.
  - b) Using an appropriate crane, lower the spacer into the cask cavity and remove the lift fixture.
19. Install the transfer cask adapter plate guide pins.
20. Install the adapter plate on top of the cask.
21. Remove the adapter plate guide pins.
22. Install the transfer cask on the adapter plate.

### 7.1.3 Loading Transportable Storage Canister into Universal Transport Cask

A transfer cask is used to load the Transportable Storage Canister into the Universal Transport Cask at the spent fuel building or at the ISFSI loading area. The assumptions underlying this procedure are:

- The canister is already loaded with fuel or GTCC waste.
- The canister is seal welded, vacuum dried, and helium backfilled.
- The canister is located in a transfer cask. (The procedures for closing the canister following fuel loading, and for draining, sealing, drying, inerting, and leak testing the canister and installing hoist rings are provided in Section 7.5.)
- All of the required steps of Section 7.1.2 are complete, including adapter plate and bottom spacer installation (if necessary).
- 
- The Universal Transport Cask is positioned in the designated area in the spent fuel building or at the ISFSI with the cask lid off.

The movement and operation of the transfer cask with a loaded canister prior to inserting the canister into the Universal Transport Cask are part of in-plant operations and preparation for storage. Steps for these operations are therefore not included in the following procedures.

1. Verify that the retaining ring is installed on the transfer cask.
2. Lift the transfer cask and lower it on top of the adapter plate on the transport cask and engage the hydraulic cylinders with the doors.
3. Engage the transportable storage canister lifting sling's master ring with the crane hook and engage the individual sling hooks with their respective hoist rings located on the structural lid of the transportable storage canister.
4. Raise the canister enough to remove the load on the Transfer Cask doors and then open the doors.

**CAUTION:** While lowering the canister in Step 5, be careful to avoid contact with the interior cavity wall of the Universal Transport Cask.

5. Lower the canister into the Universal Transport Cask.
6. Disengage the lift sling hooks from the hoist rings and close the Transfer Cask doors.
7. Remove the Transfer Cask and store it in the designated location.
8. Remove the hoist rings from the top of the canister structural lid and install threaded plugs.
9. Attach the adapter plate lifting sling to the adapter plate.
10. Remove the four bolts attaching the adapter plate to the Universal Transport Cask.
11. Remove the adapter plate and store it in the designated location.
12. Remove the cask adapter ring and clean the sealing surface.
- 13.
14. Install the cask lid alignment pins.
15. Attach the lid-lifting device to the lid and to the overhead crane.
16. Install the lid, using the alignment pins to assist in proper seating.
17. Install 10 cask lid bolts equally spaced and torque hand-tight.
18. Remove the lid alignment pins.
19. Install the remaining cask lid bolts and torque all of the bolts to the value specified in Table 7-1.
20. If previously removed, re-install the drain port coverplate.
21. Connect a pressure test fixture to the drain port coverplate O-ring test port and pressurize to 15 (+2, -0) psig and hold for a minimum of 10 minutes. There must be no pressure drop in the test period.  
**Note:** If the test condition is not met, remove the drain port coverplate and inspect and clean the o-rings and o-ring sealing surfaces and re-perform the test. If the test condition is not met on the second attempt, replace the o-rings, cleaning the o-ring grooves and sealing surface. A small amount of vacuum grease may be used to lubricate new o-rings.  
**Caution:** If the drain port o-rings are replaced as a result of the inspection, then a helium leak test of the new o-rings must be performed at Step 29. Using a helium leak detector with a sensitivity of  $1.6 \times 10^{-5}$  cm<sup>3</sup>/sec, establish a vacuum in the o-ring annulus and test for helium leakage. The leak rate must be less than  $3.3 \times 10^{-5}$  cm<sup>3</sup>/sec (helium) in accordance with Table 7-2.
22. Connect the Vacuum Drying System vacuum pump to the cask vent port and evacuate the cask cavity to a stable vacuum pressure of 3 mm Hg for 10 minutes.
23. Backfill the cask with high purity helium(99.9%) to 1 atm (absolute) pressure.

24. Operate the vacuum system to obtain a vacuum pressure of 3 mm Hg. When the vacuum pressure is obtained, backfill the cask with high purity helium (99.9% minimum) to 1 atm (absolute) pressure.
25. Disconnect the vacuum system and helium supply.
26. Install the vent port coverplate and torque the bolts as specified in Table 7-1.
27. Connect a pressure test fixture to the lid o-ring test port (marked "Seal Test" on cask lid) and pressurize to 15 (+2, -0) psig and hold for a minimum of 10 minutes. There must be no pressure drop in the test period.  
**Note:** If the test condition is not met, replace the o-rings, cleaning the o-ring grooves and sealing surface. A small amount of vacuum grease may be used to lubricate new o-rings.  
**Caution:** If the lid o-rings are replaced as a result of the inspection in Step 12 of Section 7.1.2, then a helium leak test of the new o-rings must be performed. Using a helium leak detector with a sensitivity of  $1.6 \times 10^{-5} \text{ cm}^3/\text{sec}$ , establish a vacuum in the o-ring annulus and test for helium leakage. The leak rate must be less than  $3.3 \times 10^{-5} \text{ cm}^3/\text{sec}$  in accordance with Table 7-2.
28. Install the plug in the lid Seal Test port, verifying that the test plug O-ring is in place, and torque the plug to the value specified in Table 7-1.
29. Connect a pressure test fixture to the vent coverplate o-ring test port and pressurize to 15 (+2, -0) psig and hold for a minimum of 10 minutes. There must be no pressure drop in the test period.  
**Note:** If the test condition is not met, remove the vent port coverplate and inspect and clean the o-rings and o-ring sealing surfaces and re-perform the test. If the test condition is not met on the second attempt, replace the o-rings, cleaning the o-ring grooves and sealing surface. A small amount of vacuum grease may be used to lubricate new o-rings.  
**Caution:** If the vent and/or drain port o-rings are replaced as a result of the inspection, then a helium leak test of the new o-rings must be performed. Using a helium leak detector with a sensitivity of  $1.6 \times 10^{-5} \text{ cm}^3/\text{sec}$ , establish a vacuum in the o-ring annulus and test for helium leakage. The leak rate must be less than  $3.3 \times 10^{-5} \text{ cm}^3/\text{sec}$  in accordance with Table 7-2.
30. Install the vent port O-ring test plug, verifying that the test plug o-ring is in place and torque the test plug to the value specified in Table 7-1.
31. Perform external decontamination activities and radiation surveys to verify that contamination is within acceptable levels (2,200 dpm/100 cm<sup>2</sup>  $\beta$ ,  $\gamma$ , and 220 dpm/100 cm<sup>2</sup>  $\alpha$ ) as identified in 10 CFR 71.87 [2].

32. Record the results of the survey.
33. Review the loading checklist and verify that all required activities have been accomplished.
34. Visually inspect the cask to verify that the cask has been assembled in accordance with the requirements of the Certificate of Compliance.



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

## 7.2 Preparing Universal Transport Cask for Transport Following Loading

The assumptions underlying this procedure are as follows:

- The Universal Transport Cask has been loaded and decontaminated.
- The containment boundary has been leak tested.
- The cask is in the vertical position ready for loading on the transport vehicle.

If redundant lifting must be used to move the cask prior to cask placement on the transport vehicle, the redundant lifting yoke system must be installed on the crane, and the bolt torque of the secondary trunnions must be verified to meet the requirement in Table 7-1. The cask cannot be installed on the transport vehicle using the redundant lifting system.

The procedures for preparing the cask for transport following loading are as follows:

1. Attach the cask lifting yoke to a crane hook with the appropriate load rating.
2. Engage the yoke with the primary (welded) lifting trunnions on the cask.  
**Note:** Verify engagement with primary trunnions  prior to lifting.
3. Lift and move the cask over the transport vehicle so that the rotation pockets are aligned with the rear supports on the transport vehicle.
4. Load the cask onto the transport vehicle by gently lowering the cask until the rear support is fully engaged in the cask rotation pockets.
5. Rotate the cask to the horizontal position by moving the overhead crane in the direction of the front support while keeping the crane cables vertically aligned over the lifting yoke.
6. Using a lifting sling, place the tiedown assembly over the cask upper forging between the neutron shield top plate and the lifting trunnions.
7. Install the front tiedown pins and retaining pins to each side of the front support.
8. Install the lower impact limiter positioner.
9. Perform a contamination survey of the cask and document the results to ensure compliance with 49 CFR 173.443 [3].
10. Using the designated lifting slings and a crane of appropriate capacity, install the upper impact limiter.
11. Install and torque the impact limiter retaining rods .

12. Install and torque the impact limiter attachment nuts and the impact limiter jam nuts to the torque values specified in Table 7-1.
13. Install the impact limiter lock wires.
14. Repeat Steps 10 through 13 for the lower impact limiter.
15. Install tamper indicating seals through holes provided in the upper impact limiter and one of the lifting trunnions.
16. Install tamper indicating seals through holes provided in the lower impact limiter and on the shipping frame assembly.
17. Record the serial number of the seals in the cask-loading checklist.
18. Apply labels to the cask in accordance with 49 CFR 172.200 [6].
19. Install the personnel protection barrier and torque all attachment bolts to the torque values specified in Table 7-1.
20. Install padlocks on any personnel barrier access portal.
21. Perform a radiation survey of the cask and document the results to ensure compliance with 49 CFR 173.441 [3].
22. Perform a contamination survey of the transport vehicle and document results to ensure compliance with 49 CFR 173.443 [3].
23. Complete all shipping documentation in accordance with 49 CFR 172 Subchapter C [6].
24. Apply placards to the transport vehicle in accordance with 49 CFR 172.500 [6].
25. Provide special instruction for Exclusive Use Shipment to the carrier.

### 7.3 Receiving Universal Transport Cask and Unloading Transportable Storage Canister from Universal Transport Cask


These procedures cover inspecting the cask upon receipt, preparing the cask for removal from its conveyance, and unloading the canister to a transfer cask. Following unloading of the canister to a transfer cask, appropriate    procedures should be followed to place the canister into dry storage in a vertical concrete cask or an equivalent, approved, storage configuration.

#### 7.3.1 Conducting Receiving Inspection


1. Perform radiation and contamination surveys on the transport vehicle and personnel barrier in accordance with 10 CFR 20.1906 [1] and document the results on the Universal Transport Cask survey forms.
2. Remove the personnel barrier.
3. Complete the radiation and contamination surveys at the cask surfaces.
4. While the cask is in the horizontal position on the transport vehicle, visually inspect the cask for any physical damage that may have been incurred during transport and record any damage in the cask unloading report.
5. Verify that the tamper indicating seals are in place, and verify their numbers.
6. Move the transport vehicle to the cask receiving area.
7. Secure the vehicle by applying the brake and placing rail car or truck wheel chocks, as applicable.
8. Attach slings to the upper impact limiter lifting lugs.
9. Remove the tamper indicating seal.
10. Remove the impact limiter lock wires, jam nuts, attachment nuts, and retaining rods.
11. Remove the impact limiter and store in an upright transport position within the storage support frame.
12. Repeat the operation in Steps 8 through 11 for the lower impact limiter.
13. Remove the lower impact limiter positioner.
14. Complete radiation and contamination surveys for exposed cask surfaces.
15. Release the tiedown assembly from the front support by removing the front tiedown pins and retaining pins.
16. Attach a sling to the tiedown assembly lifting lugs and remove the tiedown assembly from the transport vehicle.


17. Attach the cask lifting yoke to a crane hook with the appropriate load rating.
18. Engage the two yoke arms with the primary lifting trunnions at the top of the cask.
19. Rotate/lift the cask to the vertical position and raise the cask off the pillow blocks of the transport vehicle rear support structure.
20. Place the cask in the vertical position in a decontamination area or other location identified by the user.
21. Wash any dust and dirt off the cask and decontaminate cask exterior, as required by contamination survey results.


### 7.3.2 Preparing to Unload Transportable Storage Canister from Universal Transport Cask

The assumptions underlying this procedure are :

- The Universal Transport Cask is resting in a vertical position (in the designated spent fuel building work area or in the cask unloading area adjacent to the ISFSI)
- The top of the cask is accessible.

The procedures for preparing to unload the canister from the Universal Transport Cask are :

1. Loosen and remove the vent port coverplate bolts and place the coverplate and bolts in a designated storage area.
2. Attach a pressure test fixture to the vent port to measure the pressure in the cask .
3. Using a vacuum bottle attached to the pressure test fixture, sample the gas in the cask cavity.  
**Caution:** Use caution in opening the cask if the sample activity and/or cask pressure are higher than expected based on the canister contents configuration.
4. Vent the cask cavity gas to the gaseous waste handling system or through an appropriate HEPA filter system.
5. Disconnect the pressure test fixture from the vent port.
6. Remove the Universal Transport Cask lid bolts by following the reverse of the torquing sequence.
7. Install the two closure lid alignment pins.

8. Remove the threaded plugs and attach the lifting eyes in the cask lid.
9. Attach the lid-lifting device to the cask lid and to the overhead crane.
10. Remove the cask lid and place the lid in a designated area.
11. Ensure that the O-ring grooves in the lid are protected so that they will not be damaged during handling.
12. Decontaminate the lid as necessary.
13. Remove the two alignment pins.
14. Install the cask adapter ring to protect the sealing surfaces of the cask.
15. Install the adapter plate guide pins.
16. Install the transfer cask adapter plate to protect the sealing surfaces of the transport cask and to provide a seating surface for the Transfer Cask.
17. Install ~~the four~~ adapter plate bolts. 
18. Install the transfer cask alignment pins in the adapter plate.

### 7.3.3 Unloading Transportable Storage Canister from Universal Transport Cask

A transfer cask is used to unload the Transportable Storage Canister. The transfer cask could be used to transfer the loaded canister to the spent fuel building for subsequent storage in the spent fuel pool or to transfer it to another storage or disposal overpack. Prior to beginning operation of the transfer cask doors and the hydraulic system should be checked. The transfer cask retaining ring should be installed.

1. Remove threaded plugs from structural lid.
2. Install the swivel hoist rings in the canister structural lid.  
**CAUTION:** The structural lid may be thermally hot.
3. Install the transport cask adapter ring to protect the sealing surfaces of the transport cask.
4. Install the transfer cask adapter plate on the transport cask.
5. Attach the canister lifting sling to the hoist rings in the structural lid. Position the sling so that the free end of the sling can be engaged by the cask-handling crane hook.
6. Attach the transfer cask lifting yoke to the cask-handling crane hook.
7. Engage the yoke to the lifting trunnions of the transfer cask.
8. Lift the transfer cask and move it above the Universal Transport Cask.
9. Lower the transfer cask to engage the alignment pins of the transfer cask adapter plate.
10. Once the transfer cask is fully seated, remove the transfer cask lifting yoke and store it in the designated location.

11. Install the transfer cask bottom door hydraulic operating system.
12. Open the transfer cask bottom doors.
13. Lower the cask-handling crane hook through the transfer cask and engage the canister lifting sling.
- CAUTION:** When raising the canister in Step 14, be careful to minimize any contact between the canister and the cavity wall of the Universal Transport Cask and between the canister and the cavity wall of the transfer cask.
14. Raise the canister into the transfer cask just far enough to allow the transfer cask bottom doors to close.
15. Close the transfer cask bottom doors and install the door locking pins.
16. Carefully lower the canister until it rests on the transfer cask bottom doors.
17. Disengage the canister lifting sling from the crane hook.
18. Retrieve the transfer cask lifting yoke and engage it with the transfer cask trunnions.
19. Lift the transfer cask from the transport cask and move it to the designated location.
20. Attach the adapter plate lifting fixture.
21. Remove the four bolts securing the adapter plate to the Universal Transport Cask.
22. Using the auxiliary crane, lift the adapter plate from the top of the cask and move the adapter plate to the designated storage location.
23. Remove cask adapter ring.
24. Install the vent port coverplate over the vent port in the cask lid.
25. Install/torque the coverplate bolts to the values specified in Table 7-1.
26. Install the cask lid alignment pins.
27. With the lid-lifting device, install the cask lid by using the alignment pins to assist in proper seating.
28. Remove the lid-lifting device, lid lift hoist rings, and the lid alignment pins.
29. Install the lid bolts and torque them to the value specified in Table 7-1.
30. Using a pressure test fixture, pressurize the o-ring annulus of the cask lid to 15 psig and hold for 10 minutes. There should be no loss of pressure during the test period.
31. Install the plug in the Seal Test port, verifying that the test plug o-ring is in place, and torque the plug to the value specified in Table 7-2.
32. Using a pressure test fixture, pressurize the vent coverplate o-ring annulus to 15 psig and hold for 10 minutes. There should be no loss of pressure during the test period.
33. Install the plug in the seal test port, verifying that the test plug o-ring is in place, and torque the plug to the value specified in Table 7-2.
34. Repeat Steps 32 and 33 for the drain port, if the drain port was used.

#### 7.4 Preparing Empty Universal Transport Cask for Transport

The assumption underlying this procedure is that the Universal Transport Cask is in a decontamination area after unloading of the Transportable Storage Canister [1].

- Assume the cask is closed with lid bolts and coverplate bolts torqued properly
1. Decontaminate all surfaces of the cask to acceptable release limits as defined in 49 CFR 173 [3].
  2. Attach the transport cask lifting yoke to a crane hook and engage the yoke arms with the primary lifting trunnions of the transport cask.
  3. Lift the cask onto the transport vehicle and lower it to the horizontal position.
  4. Using a lifting sling, place the tiedown assembly over the cask upper forging between the neutron shield top plate and the lifting trunnions.
  5. Install the front tiedown pins and retaining pins to each side of the front support.
  6. Install lower impact limiter positioner.
  7. Initiate Health Physics radiation and removable contamination surveys to ensure compliance with 49 CFR 173.441 and 173.443 [3].
  8. Using the designated lifting slings and a crane of appropriate capacity, install the upper impact limiter.
  9. Install the impact limiter retaining rods into each hole and torque to the value specified in Table 7-1.
  10. Install the impact limiter attachment nuts and the jam nuts and torque to the values specified in Table 7-1.
  11. Install the impact limiter lock wires.
  12. Repeat the operations in Steps 8 through 11 for the lower impact limiter installation.
  13. Install tamper indicating seals through appropriate holes and record serial numbers of the seals in the cask loading checklist.
  14. Apply labels to the package in accordance with 49 CFR 172.200 [6].
  15. Install the personnel barrier and torque all attachment bolts to the prescribed torque values in Table 7-1.
  16. Install padlocks on all personnel barrier accesses.
  17. Complete the Health Physics radiation and removable contamination surveys to ensure compliance with 49 CFR 173 requirements [3].
  18. Complete all shipping documents.
  19. Apply placards, if required, to the transport vehicle in accordance with 49 CFR 172.500 [6].



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## 7.5 Loading and Closing the Transportable Storage Canister

The Transportable Storage Canister (Canister) may be loaded with spent fuel or with Greater Than Class C (GTCC) waste. The appropriate contents are loaded into a basket specially designed for these contents and installed in the Canister prior to the loading operation. Either spent fuel or GTCC waste is loaded into the Canister under water while the Canister is installed in the transfer cask.

The transfer cask is a component of the UMS® Universal Storage System. The controls and limitations that apply to the loading of the Transportable Storage Canister, while it is in the transfer cask, are described in the Safety Analysis Report for the UMS® Universal Storage System, Docket No. 72-1015.

This procedure describes the underwater (wet) loading of the Transportable Storage Canister (canister) installed in the transfer cask. The canister is assumed to hold an empty basket designed to hold either spent fuel or GTCC waste.

The spent fuel loaded into the canister will generally consist of spent fuel in the standard fuel assembly configuration provided to the reactor. This spent fuel must be one of those shown in Table 1.2-4 (PWR fuel) or Table 1.2-5 (BWR fuel), which presents the principal characteristics of the evaluated fuel types. In addition to these standard fuel types, site specific spent fuels and GTCC waste may also be loaded into the canister.

### Site Specific Spent Fuel

Certain spent fuel assemblies that have been changed from the original configuration, or that have components added to the assemblies, may be designated for loading into the Transportable Storage Canister. These assemblies are referred to as site specific fuel. Site specific fuel configurations result from conditions that occurred during reactor operations, participation in research and development programs, testing programs intended to improve reactor operations, from decommissioning activities, and from the placement of control components or other items within the fuel assembly.

Approved site specific fuel may be required to be loaded into specified positions within the canister basket. This preferential loading requires that the user administratively control the fuel assembly loading positions to ensure that designated fuel assemblies are installed in the assigned positions within the basket. Preferential loading patterns shall be procedurally supported during loading by a canister map showing the position assignment of individual fuel assemblies by assembly serial number. Correct preferential loading shall be independently confirmed prior to the installation of the canister shield lid.

#### Site Specific Greater Than Class C (GTCC) Waste

GTCC waste results from the activation of reactor core components during reactor operation. Decommissioning of the reactor requires the packaging of these activated components for disposal. The GTCC basket design is based on the configuration of the GTCC waste. The basket may provide additional shielding, contain specific waste loading positions similar to the PWR or BWR basket configuration, provide an undivided open space into which GTCC waste can be placed, may have provision for vertical separation so that layers of waste material are established, and may require the use of "shoring" (non-radioactive bracing material) within the canister to prevent movement of the waste during handling and transport operations. Regardless of the configuration of the GTCC basket, the loaded canister is closed and sealed in the same way as a canister containing spent fuel.

#### 7.5.1 Loading and Closing the Transportable Storage Canister Containing Spent Fuel

This section presents the generic procedure for loading and closing the transportable storage canister in the transfer cask. The procedure is taken from the Safety Analysis Report for the UMS® Universal Storage System, Docket 72-1015, with references to Limiting Conditions of Operation (LCOs) and other conditions removed. LCOs describe limitations that are applied in the canister spent fuel loading and closing operational sequence, and are defined in the Storage System Safety Analysis Report. This procedure is provided for information only since the loading and closing of the canister is not directly associated with handling the UMS® Transport Cask. Note that this procedure, without the LCOs, would be used for loading GTCC waste.

1. Visually inspect the basket fuel tubes to ensure that the tubes are unobstructed and free of debris. Ensure that the welding zones on the canister, shield, and structural lids, and the

port covers are prepared for welding. Ensure transfer cask door lock bolts are installed and secure.

2. Fill the canister with clean or filtered pool water until the water is about 4 inches from the top of the canister.

**Note:** Do not fill the canister completely in order to avoid spilling water during the transfer to the spent fuel pool.

3. Attach clean or filtered pool water lines to the transfer cask.

4. If it is not already attached, attach the transfer cask lifting yoke to the cask handling crane, and engage the transfer cask lifting trunnions.

**Note:** The minimum temperature of the transfer cask (i.e., surrounding air temperature) must be verified to be higher than 0°F prior to lifting.

5. Raise the transfer cask and move it over the pool, following the prescribed travel path.

6. Lower the transfer cask to the pool surface and turn on the clean or filtered pool water line to fill the canister and the annulus between the transfer cask and canister.

7. Lower the transfer cask as the annulus fills with clean or filtered pool water until the trunnions are at the surface, and hold that position until the clean or filtered pool water fills the remainder of the canister and overflows the sides of the transfer cask. Then lower the transfer cask to the bottom of the pool cask loading area.

**Note:** If an intermediate shelf is used to avoid wetting the cask handling crane hook, follow the plant procedure for use of the crane lift extension piece.

8. Disengage the transfer cask lifting yoke to provide clear access to the canister.

9. Load the previously designated fuel assemblies into the canister.

**Note:** Contents must be in accordance with the Certificate of Compliance.

**Note:** Contents may be administratively controlled to ensure that fuel assemblies with certain characteristics are preferentially loaded in specified positions in the basket.

10. Attach a three-legged sling to the shield lid using the swivel hoist rings. Attach the suction pump fitting to the vent port.

**Caution:** Verify that the hoist rings are fully seated against the shield lid.

**Note:** Ensure that the shield lid key slot aligns with the key welded to the canister shell.

11. Using the cask handling crane, or auxiliary hook, lower the shield lid until it rests in the top of the canister.

12. Raise the transfer cask until its top just clears the pool surface. Hold at that position, and using a suction pump, drain the pool water from above the shield lid. After the water is removed, continue to raise the cask.

13. As the cask is raised, spray the transfer cask outer surface with clean or filtered pool water to wash off any gross contamination.
14. When the transfer cask is clear of the pool surface, but still over the pool, turn off the clean or filtered pool water flow to the annulus, remove hoses and allow the annulus water to drain to the pool. Move the transfer cask to the decontamination area or other suitable work station.  
**Note:** Access to the top of the transfer cask is required. A suitable work platform may need to be erected.
15. Verify that the shield lid is level and centered.
16. Attach the suction pump to the suction pump fitting on the vent port. Operate the suction pump to remove free water from the shield lid surface. Disconnect the suction pump and suction pump fitting. Remove any free standing water from the shield lid surface and from the vent and drain ports.
17. Decontaminate the top of the transfer cask and shield lid as required to allow welding and inspection activities.  
**Note:** Supplemental shielding may be used for activities around the shield lid.
18. Insert the drain tube assembly through the drain port of the shield lid into the basket drain tube sleeve. Torque the drain tube assembly to  $125 \pm 5$  ft-lbs. Install a mating quick-disconnect fitting in the vent line to open the vent.
19. Connect the suction pump to the drain port. Verify that the vent port is open. Remove approximately 50 gallons of water from the canister. Disconnect and remove the pump.  
**Caution:** Radiation level may increase as water is removed from the canister.
20. Install the automatic welding equipment.
21. Attach the hydrogen gas detector to the vent port. Verify that the concentration of any detectable hydrogen gas is below 2.4%.  
**Note:** If the concentration exceeds 2.4%, operate the vacuum system to remove gases from the underside of the shield lid and re-verify the hydrogen gas concentration. Disconnect and remove vacuum system.
22. Operate the welding equipment to complete the root weld joining the shield lid to the canister shell following approved procedures to minimize canister shell and weld stress.
23. Examine the root weld using liquid penetrant and record the results.
24. Complete welding of the shield lid to the canister shell. Remove the weld equipment and the hydrogen gas detector.
25. Liquid penetrant examine the final weld surface and record the results.

26. Attach a regulated gas (nitrogen, helium or air) supply line to the vent port. Install a valved fitting on the drain port and ensure the valve is closed. Pressurize the canister to 35 psia (approximately 20.5 psig) and hold the pressure. There must be no loss of pressure for 10 minutes.
27. Release the pressure. Visually examine the shield lid to canister shell weld for indications of defects. Perform a liquid penetrant examination of the final weld surface. Record the results of the examinations.
28. Attach the suction pump to the drain line. Ensure that the vent line is open. Using the pump, remove the remaining free water from the canister cavity. Note the time that the last free water is removed from the canister cavity.  
**Caution:** Radiation levels at the top and sides of the transfer cask may rise as water is removed.  
**Note:** A pressure regulated gas (nitrogen, helium or air) attached to the vent valve may be used to assist water removal from the canister cavity. The pressure must be less than 20 psig.
29. Attach the vacuum equipment to the vent and drain ports. Dry any free standing water in the vent and drain port recesses.
30. Operate the vacuum equipment until a vacuum of 3 mm of mercury exists in the canister.
31. Verify that no water remains in the canister by holding the vacuum for 30 minutes. If water is present in the cavity, the pressure will rise as the water vaporizes.
32. Backfill the canister cavity with helium having a minimum purity of 99.9% to a pressure of one atmosphere (0 psig).  
**Note:** As an option, an informational helium leak test may be conducted at this point of the procedure using the following steps (the record leak test is performed at Step 49):
  - 32a. Backfill the canister cavity with helium having a minimum purity of 99.9% to a pressure of 15 psig.
  - 32b. Using a helium leak detector ("sniffer" detector) with a test sensitivity of  $5 \times 10^{-5}$  cm<sup>3</sup>/sec (helium), survey the weld joining the shield lid and canister shell.
  - 32c. At the completion of the survey, vent the canister helium pressure to one atmosphere (0 psig).
33. Restart the vacuum equipment and operate until a vacuum of 3 mm of mercury exists in the canister.
34. Backfill the canister with helium having a minimum purity of 99.9% to a pressure of one atmosphere (0 psig).



35. Disconnect the vacuum and helium supply lines from the vent and drain ports. Dry any residual water that may be present in the vent and drain port cavities.
36. Install the vent and drain port covers.
37. Complete the root pass weld of the drain port cover to the shield lid.
38. Prepare the weld and perform a liquid penetrant examination of the root pass. Record the results.
39. Complete welding of the drain port cover to the shield lid.
40. Prepare the weld and perform a liquid penetrant examination of the drain port cover weld final pass. Record the results.
41. Complete the root pass weld of the vent port cover to the shield lid.
42. Prepare the weld and perform a liquid penetrant examination of the root pass. Record the results.
43. Complete welding of the vent port cover to the shield lid.
44. Prepare the weld and perform a liquid penetrant examination of the weld final surface. Record the results.
45. Remove any supplemental shielding used during shield lid closure activities.
46. Install the helium leak test fixture.
47. Attach the vacuum line and leak detector to the leak test fixture fitting.
48. Operate the vacuum system to establish a vacuum in the leak test fixture.
49. Operate the helium leak detector for 15 minutes to verify that there is no indication of a helium leak exceeding  $2 \times 10^{-7}$  cm<sup>3</sup>/second.
50. Release the vacuum and disconnect the vacuum and leak detector line from the fixture.
51. Remove the leak test fixture.
52. Attach a three-legged sling to the structural lid using the swivel hoist rings.  
Caution: Ensure that the hoist rings are fully seated against the structural lid. Verify that the backing ring is in place on the structural lid.  
Note: Verify that the structural lid is stamped or otherwise marked to provide traceability of the canister contents.
53. Using the cask handling crane or the auxiliary hook, install the structural lid in the top of the canister. Verify that the structural lid does not protrude above the canister shell. If so, remove the lid and inspect the surface of the shield lid for the cause of the interference. Verify that the gap in the backing ring is not aligned with the shield lid alignment key. Remove the hoist rings.
54. Install the automatic welding equipment on the structural lid.

55. Operate the welding equipment to complete the root weld joining the structural lid to the canister shell, following approved procedures to minimize canister shell and weld stress.
56. Prepare the weld and perform a liquid penetrant examination of the weld root pass. Record the results.
57. Continue with the welding procedure, examining the weld at 3/8-inch intervals using liquid penetrant. Record the results of each intermediate examination.  
**Note:** If ultrasonic testing of the weld is used, testing is performed after the weld is completed.
58. Remove the weld equipment.
59. Perform a smear survey of the accessible area at the top of the canister to ensure that the surface contamination is less than the limits established for the site.
60. Install the transfer cask retaining ring. Torque bolts to  $155 \pm 10$  ft-lbs.
61. Decontaminate the external surface of the transfer cask to the limits established for the site.

#### 7.5.2 Loading and Closing the Transportable Storage Canister Containing Greater Than Class C Waste

Greater Than Class C (GTCC) waste is defined in 10 CFR 61.55(a)(3) and (4) by the concentration of long-lived radionuclides, i.e.,  $^{14}\text{C}$ ,  $^{59}\text{Ni}$ , and  $^{94}\text{Nb}$ , and/or short-lived radionuclides, i.e.,  $^3\text{H}$ ,  $^{60}\text{Co}$ , and  $^{63}\text{Ni}$  [7]. The disposal of GTCC waste is controlled by 10 CFR 61, which among other conditions, prohibits its disposal in shallow land fills.

GTCC waste consists of radiation activated and surface contaminated steel. Stainless steel core baffle structure, which is located adjacent to the reactor vessel in a high neutron flux field, is the major component of GTCC waste. The core baffle structure is typically cut underwater into pieces of a size that are loaded into a waste basket. The basket has the same external dimensions as the spent fuel basket that is installed in the transportable storage canister.

The GTCC waste basket design is based on the configuration of the GTCC waste. The basket may provide additional shielding, contain specific waste loading positions similar to the PWR or BWR basket configuration, provide an undivided open space into which GTCC waste can be placed, may have provision for vertical separation so that layers of waste material are established,



and may require the use of shoring or internal bracing to ensure that there is no movement of the waste in handling operations or storage.

Regardless of the configuration of the GTCC waste basket, the loaded transportable storage canister is closed and sealed in the same way as a canister containing spent fuel using the procedure provided in Section 7.5.1.

The Maine Yankee GTCC waste basket and canister are shown in Drawings 790-611 and 790-612, respectively. The Maine Yankee GTCC waste is loaded into a specially designed basket that fits the UMS Class 1 transportable storage canister. The canister uses a "Support Weldment," to separate upper and lower waste loading areas in the canister. These two separate sections within the basket accommodate GTCC waste sections cut from the reactor core barrel. After loading the lower section of the basket, the "Support Weldment," is installed to establish the upper section. Non-radioactive stainless steel internal bracing or shoring is installed as necessary to prevent the GTCC waste from moving during canister handling and transport. After the upper section is filled, the canister is handled, loaded and closed using the same steps specified for loading and closing the canister containing spent fuel, which are provided in Section 7.5.1. Steps 1 and 2 are revised to address GTCC waste.

The GTCC waste, and shoring (if necessary), are loaded into the basket sections using the spent fuel pool bridge crane, or other suitable crane.

Using the procedure provided in Section 7.5.1, Step 1 and Step 9 are modified for GTCC waste loading as:

1. Visually inspect the GTCC waste basket to ensure that it is free of debris, that the intermediate support ring is installed and free of debris. Verify that the Support Weldment is available and free of debris;
9. Load GTCC waste sections in the lower section of the GTCC waste basket. Install shoring if necessary. When the lower section is filled, install the Support Weldment in the canister using the cask handling crane auxiliary hook. Load GTCC waste into the Support Weldment and install shoring as necessary.

**Caution:** Verify that the Support Weldment hook tabs are correctly seated against the top of the basket to prevent interference with the installation of the shield lid.

### 7.5.3 Unloading the Transportable Storage Canister

This section presents the generic procedure for opening the sealed transportable storage canister, if circumstances arise that dictate the opening of a previously loaded canister and the removal of the stored spent fuel or GTCC waste. The procedure is taken from the Safety Analysis Report for the UMS® Universal Storage System®, Docket 72-1015, with references to Limiting Conditions of Operation (LCOs) and other conditions removed. LCOs describe limitations that are applied in the canister loading and closing operational sequence, and are defined in the Storage System Safety Analysis Report. This procedure is provided for information only since the loading and closing of the canister is not directly associated with handling the UMS® Transport Cask.

The procedure assumes that the canister is positioned in the transfer cask and that the transfer cask is in the decontamination station or other suitable work station in the facility. The principal mechanical operations are the cutting of the closure welds, filling the canister with water, cooling the fuel contents, and removing the spent fuel or GTCC waste. Supplemental shielding is used as required.

1. Remove the transfer cask retaining ring.
2. Survey the top of the canister to establish the radiation level and contamination level at the structural lid.
3. Set up the weld cutting equipment to cut the structural lid weld (Abrasive grinding, hydrolaser, or similar cutting equipment).
4. Enclose the top of the transfer cask in a radioactive material retention tent, as required.  
**Caution:** Monitor for any out-gassing. Wear respiratory protection as required.
5. Operate the cutting equipment to cut the structural lid weld.
6. After proper monitoring, remove the retention tent. Remove the cutting equipment and attach a three-legged sling to the structural lid.
7. Using an appropriate crane, lift the structural lid out of the transfer cask.
8. Survey the top of the shield lid to determine radiation and contamination levels. Use supplemental shielding as necessary. Decontaminate the top of the shield lid, if necessary. Reinstall the retention tent. Using an abrasive grinder or hydrolaser, and wearing suitable respiratory protection, cut the welds joining the vent and drain port covers to the shield lid.  
**Caution:** The canister could be pressurized.

9. Remove the port covers. Monitor for any out-gassing and survey the radiation level at the quick-disconnect fittings.
10. Attach a manually valved line with a vacuum bottle to the vent port quick-disconnect. Open the valve to the vacuum bottle to obtain a gas sample from the vent line. Analyze the gas sample to determine the make up of the canister atmosphere. The presence of fission gases indicates failed fuel and the possible need to handle ruptured fuel.
11. Attach a nitrogen gas line to the drain port quick-disconnect and a discharge line from the vent port quick-disconnect to an off-gas handling system. Set up the vent line with appropriate instruments so that the pressure in the discharge line and the temperature of the discharge gas are indicated. Continuously monitor the radiation level of the discharge line.  
**Caution:** The discharge gas temperature could initially be above 400°F. The discharge line and fittings may be very hot.  
**Note:** Any significant radiation level in the discharge gas indicates the presence of fission gas products. The temperature of the gas indicates the thermal conditions in the canister.
12. Start the flow of nitrogen through the line until there is no evidence of fission gas activity in the discharge line. Continue to monitor the gas discharge temperature. When there is no additional evidence of fission gas, stop the nitrogen flow and disconnect the drain and vent port line connections.
13. Perform canister refill and fuel cooldown operations. Attach a source of clean or filtered pool water with a minimum temperature of 70°F and a maximum supply pressure of 35 psig to the drain port quick-disconnect. Attach a steam rated discharge line to the vent port quick-disconnect and route it to the spent fuel pool, a fuel pool cooler or an in-pool steam condensing unit. Slowly start the flow of clean or filtered pool water to establish a flow rate at 5 (+3, -0) gpm. Monitor the discharge line pressure gage during canister flooding. Stop filling the canister if the canister vent line pressure exceeds 50 psig. Re-establish water flow when the canister pressure is below 30 psig. The discharge line will initially discharge hot gas or steam. After the canister fills, it will discharge hot water.  
**Caution:** Relatively cool water may flash to steam as it encounters hot surfaces within the canister.  
**Caution:** If there are grossly failed or ruptured fuel rods within the canister, very high levels of radiation could rapidly appear at the discharge line. The radiation level of the discharge gas or water should be continuously monitored.

14. Monitor water flow through the canister until the water discharge temperature is below 200°F. Stop the flow of water and remove the connection to the drain line.  
**Note:** Monitor canister water temperature and reinitiate cooldown operations if temperature exceeds 200°F.
15. Connect a suction pump to the drain port and remove approximately 50 gallons of water. Disconnect and remove the pump.  
**Note:** Air pressure may be used to force water out of the canister by connecting the air line to the vent port and a drain line to the drain port. Air pressure must be regulated to not exceed 50 psig.
16. Set up the weld cutting equipment to cut the shield lid weld (Abrasive grinding, hydrolaser, or similar cutting equipment.). Route the vent line to avoid interference with the weld cutting operation.
17. Tent the top of the transfer cask and wear respiratory protection equipment as required. Attach a hydrogen gas detector to the vent port. Verify that the concentration of hydrogen gas is less than 2.4%.
18. Operate the cutting equipment to cut the shield lid weld.  
**Note:** Stop the cutting operation if the hydrogen gas detector indicates a concentration of hydrogen gas above 2.4%. Clear the gas before proceeding with the cutting operation.
19. Remove the cutting equipment. Remove supplemental shielding if used. Install the shield lid lifting hoist rings, verifying that the hoist rings are fully seated against the shield lid, and attach a three-legged sling. Attach a tag line to the sling master link to aid in attaching the sling to the auxiliary crane hook (at Step 24).
20. Attach the clean or filtered pool water line to the transfer cask.
21. Retrieve the transfer cask lifting yoke and engage the transfer cask lifting trunnions.
22. Move the transfer cask over the pool and lower the bottom of the transfer cask to the surface. Start the flow of clean or filtered pool water to the transfer cask annulus. Continue to lower the transfer cask, as the annulus fills with water, until the top of the transfer cask is about 4 inches above the pool surface. Hold this position until clean or filtered pool water fills to the top of the transfer cask.
23. Lower the transfer cask to the bottom of the cask loading area and remove the lifting yoke.

24. Attach the shield lid lifting sling to the crane hook.  
**Caution:** The drain line tube is suspended from the under side of the shield lid. The lid should be raised as straight as possible until the drain tube clears the canister basket. The under side of the shield lid could be highly contaminated.
25. Slowly lift the shield lid. Move the shield lid to one side after it is raised clear of the transfer cask.
26. Visually inspect the fuel for damage.

At this point, the spent fuel could be transferred from the canister to the fuel racks. If the fuel is damaged, special rigging could be required to remove the fuel. In addition, the bottom of the canister could be highly contaminated. GTCC waste could be transferred to a suitable storage area or bin in the spent fuel pool. Care must be exercised in the handling of the transfer cask when it is removed from the pool. Highly radioactive particles could rest on flat surfaces of the transfer cask resulting in high dose rates.

7.6            Appendix

7.6.1          References

1. Code of Federal Regulations Title 10, Part 20 (10CFR20), "Standards for Protection Against Radiation," April 1996.
2. Code of Federal Regulations Title 10, Part 71 (10CFR71), "Packaging and Transportation of Radioactive Materials," April 1996.
3. Code of Federal Regulations Title 49, Part 173 (49CFR173), "Shippers - General Requirements for Shipments and Packaging," October 1995.
4. IAEA Safety Series No. 6, "Regulations for the Safe Transport of Radioactive Materials," International Atomic Energy Agency, Vienna, Austria, 1985 Edition, as amended 1990.
5. Peckner, D., and Bernstein, R.M., Handbook of Stainless Steels, McGraw-Hill Book Company, 1977.
6. Code of Federal Regulations Title 49, Part 172 (49CFR172), "Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements," October 1995.
7. Title 10 of the Code of Federal Regulations, Part 61 (10 CFR 61), "Licensing Requirements for Land Disposal of Radioactive Waste," January, 1996.

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## **8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM**

This chapter describes the acceptance tests and maintenance program to be used to assure compliance of the Universal Transport Cask with 10 CFR 71 [1] and IAEA Safety Series No. 6 [2] acceptance testing and maintenance criteria. The appendix to this chapter includes information on the general steps in the fabrication of the cask including major weld location, inspection technique and acceptance criteria. The general requirements and procedures for the pouring of NS-4-FR and chemical copper lead in the annulus between the inner and outer shells of the cask body is also explained.

Specific approved procedures for inspection, special processes, and testing are developed, as required. The entire manufacturing process is completed under a quality assurance program that has been approved as being in accordance with 10 CFR 71, Subpart H, and IAEA Safety Series No. 6.

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## 8.1 Fabrication Requirements and Acceptance Tests

Prior to first use of the Universal Transport Cask, the inspections and tests that must be performed on the cask are visual inspection, structural and pressure tests, leakage tests, component tests, tests for shielding integrity, and a thermal acceptance test. These inspections and tests are described in the following sections.

### 8.1.1 Visual Inspection

Prior to construction, all cask materials are visually examined by qualified personnel in accordance with the License Drawings (Section 1.3.4) and in accordance with approved written procedures (fabrication specifications). The purpose of the examination is to verify that the materials used in the fabrication of the cask are as specified on the License Drawings.

The finished surfaces of all welds on the cask are visually examined in accordance with ASME Code, Section V, Article 9 [3]. The purpose of the examination is to verify that the cask components are assembled in accordance with the License Drawings and that the components are free of nicks, gouges, or other damage. The acceptance criteria for the visually examined welds are in accordance with ASME Code, Section VIII, Division 1, UW-35 and UW-36 [4]. Unacceptable welds are repaired as required and reexamined in accordance with the original acceptance criteria.

All weld inspections are performed by qualified personnel in accordance with written procedures. The inspection personnel are qualified in accordance with SNT-TC-1A, "Personnel Qualifications and Certification in Nondestructive Testing" [5], as specified by the ASME Code, Section III, Division 1, Subsection NB, Paragraph NB-5520 [6].

### 8.1.2 Structural and Pressure Tests

These structural tests include load testing of the lifting trunnions, load testing of the rotation pockets, and pressure testing of the containment boundary.

#### 8.1.2.1 Lifting Trunnion Load Testing

Each pair of the Universal Transport Cask lifting trunnions is designed and load tested in accordance with the requirements of ANSI N14.6, "Special Lifting Devices for Shipping Containers Weighing 10,000 lb (4500 kg) or More for Nuclear Materials" [7]. A primary pair of diametrically opposed trunnions is welded to the upper forging of the cask. A secondary pair of trunnions can be bolted to the upper forging for redundant lifts. The primary trunnions are designed to satisfy the critical load (non-redundant) lifting requirements of ANSI N14.6. The secondary trunnions are designed to satisfy the redundant lifting requirements of ANSI N14.6. Load tests of both pairs of trunnions are performed in accordance with ANSI N14.6 and approved written procedures.

Each primary and secondary trunnion pair is separately tested. A load of 780,000 lb, which is 300% of the maximum service load (combined weight of the heaviest, loaded transport cask), is applied to the primary trunnion pair. A load of 390,000 lb, which is 150% of the maximum service load, is applied to the secondary trunnion pair. In each test, the load is applied in a vertical direction, equally distributed between the two trunnions. Trunnions have a "land" width of 3.0 in. The cask lid is bolted in place for the test. The test may be carried out by attaching to the trunnion pair either calibrated hydraulic rams (combined with a load-spreading beam) or the cask-lifting yoke. The load is held for a minimum of 10 minutes.

Following completion of the lifting trunnion load tests, all trunnion welds, trunnion bolt load-bearing surfaces, and welds that are part of the load path are visually inspected for permanent deformation, galling, or cracking. Liquid penetrant examinations are performed in accordance with the ASME Boiler and Pressure Vessel Code, Section V, Article 6 [3]. Liquid penetrant acceptance standards are those of Paragraph NF-5350 of the ASME Boiler and Pressure Vessel Code, Section III, Division 1 [9].

Any evidence of permanent deformation, cracking, galling of the load-bearing surfaces, or unacceptable dye penetrant results is cause for rejection of the trunnion or related welds. Any identified defects must be repaired and the load test repeated prior to final acceptance.

### 8.1.2.2      Rotation Pocket Load Testing

There are two rotation pockets, located on opposite sides of the bottom of the cask, which are simultaneously load tested prior to cask acceptance. The rotation pockets are designed and analyzed to satisfy the more restrictive of 10 CFR 71.45(b) [1] or AAR Field Manual [8] load conditions for nuclear waste transport. The rotation pockets are not used to lift the cask at any time. During intermodal transport, the loaded cask with the top and bottom impact limiters attached, the cask is horizontally mounted on a tiedown structure/personnel barrier. The tiedown structure is designed with four pick-up points specifically for moving the loaded cask.

The rotation pocket recesses at the lower end of the cask shall be load tested. The load test shall be performed in accordance with approved written procedures.

The load test for recesses shall consist of applying a vertical load of 390,000 lb, + 5/-0 percent, to the rotation pocket pair. The load will be applied in a vertical direction and equally distributed between the two rotation trunnion recesses by the use of hydraulic rams combined with a load spreading beam.

Following completion of the rotation pocket load test, all trunnion recess welds and load bearing surfaces shall be visually inspected for permanent deformation, galling or cracking. Inspections utilizing liquid penetrant examination shall be performed in accordance with the "ASME Boiler and Pressure Vessel Code," Section V, Article 6 [3]. Liquid penetrant acceptance standards shall be as indicated in paragraph NF-5350 of the "ASME Boiler and Pressure Vessel Code," Section III, Division 1 [9].

Any evidence of permanent deformation, cracking, galling of the load bearing surfaces or unacceptable dye penetrant results shall be cause for rejection of the rotation pocket recesses or related welds.

### 8.1.2.3      Hydrostatic Pressure Testing of the Containment Boundary

The Universal Transport Cask primary containment boundary components, described in detail in Section 4.1, include the bottom forging, inner shell, top forging, and cask lid. The cask containment boundary is hydrostatically pressure tested to 125% of the design pressure in



accordance with ASME Boiler and pressure Vessel Code Section III, Paragraph NB-6220 [6]. This test is in lieu of the 10 CFR 71.85(b) requirement that the cask containment be tested at an internal pressure at least 50% higher than the maximum normal operating pressure. The transport cask containment is hydrostatic tested to 85 psig for a minimum of 30 minutes during which time a visual inspection is conducted to detect any evidence of leakage. The containment maximum normal operating pressure (MNOP) is calculated to be 7.3 psig (Table 3.4-4).

Following the hydrostatic pressure test, all containment boundary components weld joints, connections and regions of high stress are visually examined to verify that no permanent deformation or breach of the containment boundary resulted from the hydrostatic test. All accessible containment boundary welds shall be liquid penetrant inspected for ASME Code Section V, Article 6 [3], with acceptance per ASME Code Section III, NB-5350 [6].

#### 8.1.2.4 Pneumatic Bubble Testing of the Neutron Shield Shell

A pneumatic bubble test of the neutron shield tank will be performed in accordance with Section V, Article 10, Appendix I, of the ASME Code following final closure welding of the bottom closure plates. The bubble test pressure shall be 5 (+1/-0) psig. The test shall be performed in accordance with approved written procedures.

During the test, the two relief valves on the neutron shield tank will be removed. One of the relief valve threaded connections will be used for connection of the air pressure line and test pressure gauge. The other relief valve connection will be plugged with a threaded plug.

Following introduction of pressurized air into the neutron shield, a 15 minute minimum soak time will be required. Following completion of the soak time, approved soap bubble solution will be applied to all heat transfer fins to neutron shield shell, and neutron shield shell to end plate welds. The acceptance criteria for the bubble test will be no air leakage from any tested weld as indicated by continuous bubbling of the solution. If air leakage is indicated, the weld shall be repaired in accordance with approved weld repair procedures and the pneumatic bubble test shall be repeated until no unacceptable air leakage is observed.

### 8.1.3 Leak Tests

Acceptance leak testing is performed on the containment weldment during fabrication and on the containment boundary having replaceable components, when fabrication is complete. The purpose of this leak testing is to confirm that the leak rate from any sealed containment penetration does not exceed the allowable leak rates, calculated in Chapter 4.0, and to confirm that the 10 CFR 71.85(a) [1] requirements are satisfied. Leak tests are performed in accordance with the methodologies and requirements of ANSI N14.5-1997 [11], using approved written procedures.

#### Containment Weldment Testing

Following the hydrostatic testing of the containment weldment in accordance with Section 8.1.2.3, the containment cavity is drained and cleaned. A helium leak test of the containment weldment is performed in accordance with the requirements of Section V, Article 10 of the ASME Code. The containment weldment shall be leak tested to demonstrate a leak rate of  $2 \times 10^{-7}$  std cm<sup>3</sup>/sec (helium), or less, using a minimum detector sensitivity of  $1 \times 10^{-7}$  std cm<sup>3</sup>/sec (helium), to qualify the weldment as leak tight as defined in ANSI N14.5-1997.

If a leak is detected exceeding the acceptance criteria, the affected weld shall be rejected. Rejected welds shall be repaired in accordance with the requirements of Article NB-4450 of the ASME Code. The repaired weld area shall be retested and reinspected using the same procedure and acceptance criteria.

#### Containment Fabrication Acceptance Testing

Once cask fabrication is complete, helium leak tests are performed on the o-rings sealing the mechanical joints at the containment boundary.

Containment fabrication acceptance testing is performed with the cask assembled in accordance with the cask handling procedure except that the quick disconnects at the vent and drain ports are not installed. This ensures that when the cask cavity is backfilled with helium, helium is present on the containment side of the port coverplate containment o-rings. The leak test is then conducted by establishing a vacuum in the o-ring annulus of the lid and port coverplates using the seal test ports and testing for helium.

Leak tests are performed on the cask lid and the vent and drain port coverplate o-rings. Containment o-ring testing is performed to demonstrate a leak rate of  $3.3 \times 10^{-5}$  std cm<sup>3</sup>/sec (helium), or less. The helium leak detector sensitivity shall be  $1.6 \times 10^{-5}$  std cm<sup>3</sup>/sec or less. The allowable leak rate is based on the calculated allowable leak rate for BWR fuel (Table 4.2-4).

A leak rate that exceeds the allowable leak rate limit is cause for rejection of the component being tested. Seal replacement or other corrective actions are taken to correct any leak. The component is then retested and inspected in accordance with the test requirements and acceptance criteria. On successful completion of the leak tests, the quick disconnects are re-installed in the vent and drain ports.

#### 8.1.4 Component Tests

Individual cask components are tested as applicable to ensure that the component meets the design requirements for its intended function during operation of the cask system. Test acceptance criteria are established on the basis of the component function, the corresponding graded quality category and design requirements of the component being tested.

##### 8.1.4.1 Transportable Storage Canister

The Transportable Storage Canister is not considered to be a containment boundary when transported in the Universal Transport Cask. However, all of the longitudinal and girth welds are radiographically inspected in accordance with ASME [ ] Code, Section V, Article 2 [ ]. Radiographic acceptance is in accordance with ASME Code Section III, NB-5320 [ ]. The weld between the canister bottom and the canister shell is ultrasonically examined in accordance with ASME [ ] Code Section V, Article 5. Acceptance criteria are in accordance with ASME [ ] Code Section III, NB-5330.

The welds made in the field to attach the shield lid [ ] to the canister shell are subjected to dye-penetrant testing on the root weld and final weld surface in accordance with the requirements of the ASME [ ] Code, Section V, Article 6. Following welding of the shield lid, a helium leak test is performed as described in the operating procedures. The root weld, intermediate, and final weld surface of the structural lid weld to the canister shell are also dye penetrant examined in accordance with ASME Code, Section V, Article 6 to ensure the quality of the weld. The liquid penetrant test acceptance criteria are as described in ASME Code Section III, Article NB-5350.

The finished surfaces of all welds on the canister are visually examined in accordance with ASME Code, Section V, Article 9, to verify that the components are assembled in accordance with the License Drawings (Section 1.3.4) and that the components are free of nicks, gouges, or other surface damage. The acceptance criteria for the visually examined welds are in accordance with ASME Code, Section III, NB-4424 and NB-4427.

Each fabricator of the canister will be required to establish a detailed written weld inspection plan, in accordance with an approved quality assurance program, of visual (VT), dye-penetrant (PT), ultrasonic (UT), and radiographic (RT) weld examinations to be performed during fabrication and prior to acceptance of the canister. The weld inspection plan identifies the welds to be examined, the sequence of the examinations, the type of examination method to be used, and the criteria for acceptance of the weld in accordance with the applicable sections of the ASME Boiler and Pressure Vessel Code.

The canister is pressure tested after completion of the weld between the canister shell and shield lid. The canister is conservatively pressure tested to 20.5 psig for 10 minutes. This pressure is higher than the required test pressure of 1.2 times the 7.3 psig maximum normal operating pressure (MNOP), or 8.8 psig. Upon completion of the test, the weld surface is visually examined for evidence of failure. The finished weld surface is visually examined in accordance with ASME Code, Section V, Article 9. The acceptance criteria is in accordance with ASME Code, Section III, NB-4424 and NB-4427.

#### 8.1.4.2 Valves, Rupture Disks, and Fluid Transport Devices

No valves are part of the Universal Transport Cask containment boundary. Access to the cask cavity during operations and the capability to isolate the cavity are provided by quick disconnects. No credit is taken for any containment function provided by the quick disconnects.

The quick disconnects serve as valves when the mating parts are connected and are used to connect ancillary equipment to the cask cavity for filling, draining, drying, backfilling, gas-sampling, and leak-testing operations. The design and selection of the quick disconnects are based on the design and selection of similar equipment used with other NRC-approved storage

and transport casks. Prior to transport, the quick disconnects are sealed by using a bolted coverplate fitted with O-rings. These O-rings are helium leak tested prior to each shipment.

No rupture disks are present on the Universal Transport Cask.

Two self-actuating pressure relief valves installed on the bottom of the external shell of the neutron shield provide for venting of vapor from the shielding material that results from the neutron shield material being exposed to transport thermal accident conditions. The neutron shield shell and end plates are welded to the cask body outer shell. There is no penetration between the neutron shield and the containment boundary; therefore, there can be no release of containment gas via the pressure relief valve, even during the fire accident. The relief valves do not provide a safety function with respect to the cask contents in transport. They are designed to minimize recovery efforts by allowing the neutron shield shell to remain intact in the unlikely event of a neutron shield overpressure condition.

#### 8.1.4.3 Gaskets

The cask lid, drain port coverplate, and vent port coverplate, are sealed using concentric sets of two o-rings. The inner o-ring of each of these sets forms part of the primary containment boundary. The outer o-ring of each set is used to form an annulus, which is used to test the containment boundary seal at the inner o-ring. The outer o-rings also provide an additional barrier to the potential release of the cask contents, but no credit is taken in the containment analysis for the presence of the outer o-rings.

The inner o-rings, which are part of the primary containment boundary are tested in accordance with the requirements of ANSI N14.5-1997. Each o-ring is replaced either annually, or as needed, based on operating procedure (Chapter 7) or maintenance (Sections 8.2.2 and 8.2.4) requirements.

#### 8.1.4.4 Miscellaneous

The Universal Transport Cask impact limiters consist of redwood and balsa wood completely enclosed in a stainless steel shell. Following final closure welding of the impact limiter stainless steel shell, the shell welds are vacuum leak tested to verify weld integrity. If leakage exceeding

the criteria limit is detected, the cause of the leak is determined and repaired. The leak test is then re-performed.

#### 8.1.5 Tests for Shielding Integrity

Lead is poured in the annulus between the inner and outer shells of the cask body, and layers of stainless steel provide the primary radial gamma shielding in the Universal Transport Cask body. The general lead pour procedures are described in Section 8.3.3. A solid layer of NS-4-FR located in the cask bottom and in the annulus formed by the outer shell and the neutron shield shell provides neutron shielding of the cask. Testing of the gamma and neutron shielding material for effectiveness is discussed in the following paragraphs.

##### 8.1.5.1 Gamma Shielding Test

To verify the integrity, a gamma scan test of the steel and lead shielding of the cask body is performed prior to installation of the neutron shield shell. The test is performed in accordance with approved written procedures. The test involves using a detector and a Co<sup>60</sup> source to continuously scan or probe over 100% of all accessible cask surfaces. The source strength is sufficiently intense to produce a count rate that equals or exceeds three times the background count rate on the external surfaces of the cask. The maximum scan path spacing is 2.5 in. and the scanning speed is 4.5 ft/min or less. All probing is on a 2-in. grid pattern (when using a 3-in. detector) and the specified count time is greater than 1 min.

The acceptance criterion for the test is that the shield effectiveness of the cask body and lid be equal to or greater than the shield effectiveness of a lead and steel mock-up, where the steel thickness is equivalent to the minimum thickness specified on the License Drawings and the lead thickness is equivalent to the minimum thickness specified in the License Drawings less 3%. The shielding mock-up is produced by using the approved fabrication techniques for the cask.

Components for which measured count rates exceed those established by the test mock-up are rejected. The rejected areas or components are evaluated to determine the corrective action to be taken. Any repaired areas are retested to the original acceptance criteria prior to final acceptance.

An additional gamma shielding effectiveness test is performed on each cask following first fuel loading. Details on the gamma shielding effectiveness test procedures and acceptance criteria are provided in Section 8.1.5.3.

#### 8.1.5.2 Neutron Shielding Material Testing

The neutron shield properties of NS-4-FR are provided in Chapters 1 and 3. Each lot (mixed batch) of neutron shield material shall be tested to verify that the material composition (aluminum and hydrogen), boron concentration, and neutron shield density meet the requirements specified in Chapters 1 and 3 and the License Drawings. Testing shall be performed by qualified laboratories in accordance with written and approved procedures. Material composition, boron concentration, and density data for each lot of neutron shield material shall become part of the quality record documentation package.

Dimensional inspection of the cavities containing the neutron shielding material shall assure that the required thickness specified in the License Drawings is incorporated into the cask.

The installation of the neutron shielding material shall be performed in accordance with written, approved, and qualified procedures. The procedures shall ensure that mix ratios and mixing methods are controlled in order to achieve proper material composition, boron concentration and distribution, and that pours are controlled in order to prevent gaps or unacceptable voids from occurring in the material. Procedures shall be qualified by the use of mock-ups to ensure that the NS-4-FR installation does not result in the creation of unacceptable voids. Samples of each lot of neutron shield material shall be maintained as part of the quality record documentation package.

#### 8.1.5.3 Neutron and Gamma Shielding Effectiveness Tests

Following first fuel loading and prior to transport, a neutron and gamma shielding effectiveness test is performed for each cask in accordance with approved written procedures. The purpose of the test is to document the effectiveness of the neutron and gamma shielding materials. For this test, the cask is loaded with the canister (containing fuel) that is drained, vacuum dried, and backfilled with helium.

Calibrated neutron and gamma dose rate meters are used to measure the neutron and gamma dose rate at contact with the outer shell of the neutron shield and at 2.3 m from the surface (equivalent to 2 m from the sides of the railcar). Dose measurement points are established on the external surface of the shell at 30° intervals and at five points along the height of the shield (a total of 60 measuring points). In addition, neutron and gamma dose rate measurements are made at the trunnion areas above the neutron shield, at four points below the neutron shield, and at the edges and center of the cask top and bottom surfaces. Dose rates at the top and bottom of the cask are measured with the impact limiters installed. The dose rates measured at contact and at 2.3 m are recorded on the test data sheet, along with the total power of the loaded fuel assemblies; date, time and location of test; identification and calibration of instrumentation; and identification of test engineer and operators. To enable the measured dose rates to be evaluated, the burnup and cool time for the actual fuel assemblies loaded into the cask are determined and recorded. From this fuel history data, the total actual neutron and gamma source terms are estimated by using ORIGEN or similar calculations.

If the measured dose rates exceed the applicable regulatory limits, the cask User must notify the NRC. Appropriate corrective measures are taken, including fuel unloading and correction of the shielding deficiency. Following corrective actions, the test is reperformed to the original acceptance criteria prior to final acceptance.

#### 8.1.6 Thermal Acceptance Test

Prior to acceptance of the cask body at the fabrication facility, a thermal test using dry steam shall be performed on each fabricated packaging to confirm and verify that the fabricated and assembled cask possesses the heat rejection capabilities calculated in the thermal analyses. The thermal test shall be performed in accordance with approved written procedures.

##### 8.1.6.1 Thermal Test Setup

The thermal test set-up is shown in Figure 8.1-1. As depicted, the thermal test shall be performed with the cask positioned horizontally on a test frame. The transport impact limiter or equivalent insulating material shall be installed on each end of the cask to simulate the transport configuration. The cask will be located in a covered building in a still environment.



Twelve (12) calibrated thermocouples shall be installed on the external walls of the transport cask as shown in Figure 8.1-1. Three (3) calibrated thermocouples shall be installed on the cavity shell in locations to be determined by procedure, but shall include the top, mid-point and bottom of the cask cavity with the cask horizontal. Additional thermocouples or temperature sensors shall be used to monitor ambient temperature, steam supply temperature, and condensate drain temperature. The thermocouples shall be attached to strip chart recorders, which may have multiple input channels, or other similar device to allow for continuous monitoring and recording of temperatures during the test. Cask cavity pressure shall be monitored during the test.

Following thermocouples installation, dry steam is introduced through a penetration in the cask test lid, which is designed to accommodate the cask cavity thermocouple leads, and the test is initiated. Air will be purged from the cask cavity by venting during the heat up cycle. If not recorded continuously, temperatures of thermocouples, other temperature monitoring devices, and pressure, shall be recorded hourly, until temperature equilibrium is reached. The time to equilibrium will be calculated for a number of potential ambient temperature test conditions and incorporated into the test procedure. During the test, the steam condensate flowing out of the cask drain shall be collected and the mass of the condensate measured with a precision scale.

After thermal equilibrium is established, the ambient, steam supply, condensate drain and thermocouple temperatures shall be recorded or marked on the recorder strip chart, as appropriate. These records shall be part of the quality assurance acceptance records for the cask under test.

The heat rejection capability of the cask at the test conditions shall be computed as:

$$Q = (h_i - h_o)m_c$$

Where:

$Q$  = Heat rejection rate of the cask (Btu/hr)

$h_i$  = Enthalpy of steam entering the cask cavity (Btu/lbm)

$h_o$  = Enthalpy of condensate leaving the cask cavity (Btu/lbm)

$m_c$  = Average rate of condensate flow measured at thermal equilibrium conditions (lbm/hr)

Based on the cask thermal model, the design basis heat rejection rate shall be computed and compared to the test condition heat rejection rate ( $Q$ ). The thermal test shall be considered

acceptable if the measured heat rejection rate is equal to, or greater than, the design basis heat rejection rate.

The nominal test conditions are 70°F ambient and initial cask body temperature, no solar insolation, still air, no external radiant heat sources, and dry steam at 212°F. At these test conditions, the neutron shield shell temperature is within 2°F of the calculated steady state equilibrium temperature of 174°F within 48 hours. The thermal test procedure shall provide a thermal transient heatup curve to show the time at which equilibrium is expected to be established, and a table or set of curves which correlate equilibrium neutron shield shell temperature with a range of ambient temperatures. For purposes of the thermal test, equilibrium temperature is assumed to be established when the change in neutron shell temperature no longer exceeds 2°F in a two (2) hour period.

#### 8.1.6.2 Thermal Test Acceptance Criteria

The purpose of the thermal test is to confirm that the heat rejection capabilities of the as-built Universal Transport Cask are acceptable by showing that the measured temperature gradients correspond to those calculated in the thermal analyses.

Cask thermal test acceptance is based on demonstration that the measured temperature gradients are less than, or equal to, the thermal gradients calculated in the thermal analyses and that the total heat rejection rate is equal to, or greater than, the cask design basis heat rejection rate.

#### 8.1.7 Neutron Absorber Verification Tests

Neutron-absorbing material, BORAL®, is used as a poison in the BWR and PWR fuel tubes. BORAL is manufactured by AAR Manufacturing, Inc. (AAR) of Livonia, Michigan, under a Quality Assurance/Quality Control program in conformance with the requirements of 10 CFR 50, Appendix B. The computer-aided manufacturing process consists of several steps - the first being the mixing of the aluminum and boron-carbide powders that form the core of the finished material, with the amount of each powder a function of the desired <sup>10</sup>B areal density. The methods used to control the weight and blend the powders are patented and proprietary processes of AAR.

After manufacturing, test samples from each batch of BORAL neutron absorber (poison) sheets shall be tested using wet chemistry techniques to verify the presence, proper distribution, and minimum weight percent of  $^{10}\text{B}$ . The tests shall be performed in accordance with approved written procedures.

#### Preparation of Samples

Detailed written procedures to perform wet chemistry tests of each batch of BORAL sheets shall be established by the manufacturer (AAR) and approved by NAC. For each batch of BORAL sheets, a sample shall be taken from each end of randomly selected sheets. The samples shall be indelibly marked and recorded for identification. At least 2 percent of the sheets in a batch shall be fully tested as described, with the remaining sheets to be tested at one location to ensure the presence of boron in those sheets.

#### Wet Chemistry Test Performance

An approved facility with chemical analysis capability shall be selected to perform the wet chemistry tests. The tests will ensure the presence of boron and enable the calculation of the  $^{10}\text{B}$  areal density.

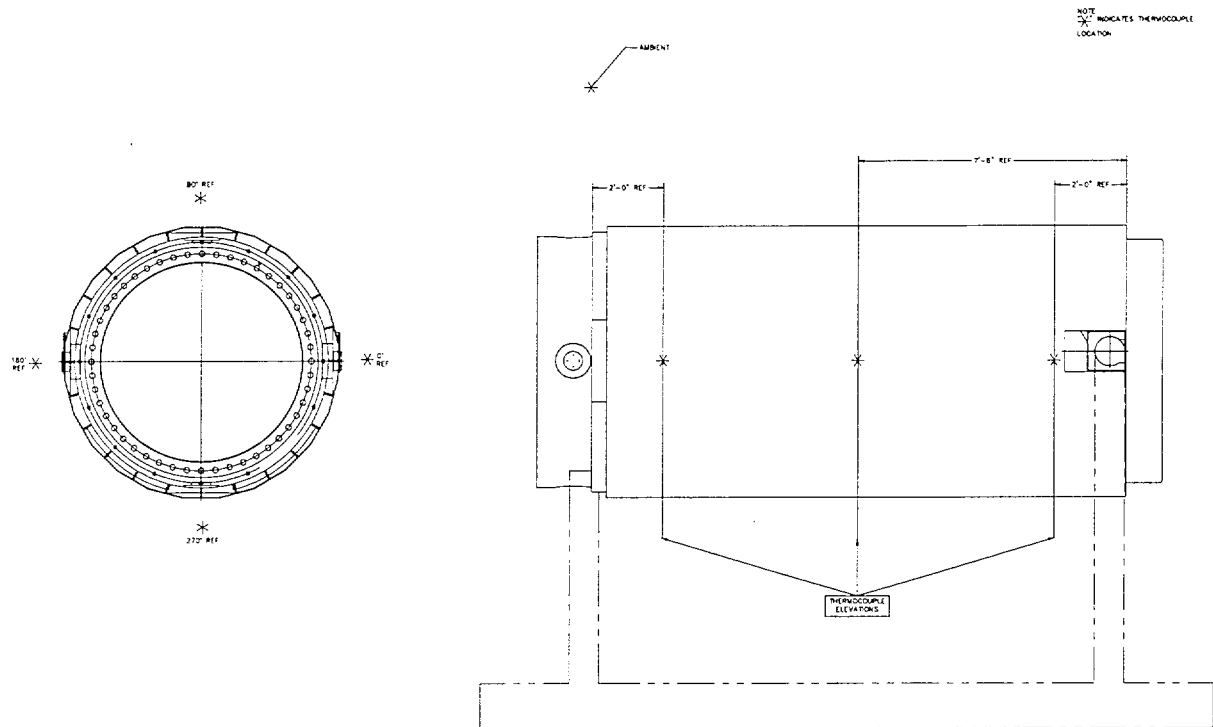
The most common method of verifying the acceptability of neutron absorber material is the wet chemistry method—a chemical analysis where the aluminum is separated from a sample with known thickness and volume. The remaining boron-carbide material is weighed and the areal density of  $^{10}\text{B}$  is computed. A statistical conclusion about the BORAL sheet from which the sample was taken and that batch of BORAL sheets may then be drawn based on the test results and the established manufacturing processes previously noted.

#### Acceptance Criteria

The wet chemistry test results shall be considered acceptable if the minimum  $^{10}\text{B}$  areal density is determined to be equal to, or greater than,  $0.011 \text{ g/cm}^2$  for the BORAL sheets used in BWR fuel tubes and  $0.025 \text{ g/cm}^2$  for the BORAL sheets used in PWR fuel tubes.

Any specimen not meeting the acceptance criteria shall be rejected and all of the sheets from that batch shall be similarly rejected.

Figure 8.1-1 Thermal Test Arrangement



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## 8.2 Maintenance Program

A maintenance program for the Universal Transport Cask is established to ensure continued performance and use of the package. The cask maintenance program specifies the inspections, tests, and replacement of components to be performed and the frequency and schedule for these activities. This section describes the overall requirements of the maintenance program and establishes the frequency and schedule for the maintenance activities. The detailed, written inspection, test, component replacement, and repair procedures will be included in the Universal Transport Cask Operations Manual. The Operations Manual is issued to users of the packaging prior to their use of the cask.

The welded Transportable Storage Canister containing fuel does not require any maintenance.

### 8.2.1 Structural and Pressure Tests

The four lifting trunnions or two trunnions if the secondary trunnions are not attached and the two rotation pockets are visually inspected prior to each shipment. The visual inspections are performed in accordance with approved written procedures, and the results are evaluated against established acceptance criteria.

Evidence of cracking on the load-bearing surfaces is cause for rejection of the affected trunnion until an approved repair is completed and the surfaces are reinspected and accepted. Such repairs are implemented and documented in accordance with an approved quality assurance program. Any identified damage to the bolted trunnions and the rotation pockets, such as cracking and wear, must be evaluated to determine if replacement of the affected components is necessary.

The lifting trunnions are also inspected annually in accordance with Paragraph 6.3.1(b) of ANSI N14.6 [7]. All trunnion welds, trunnion bolts, trunnion bolt load-bearing surfaces, and welds that are part of the load path are visually inspected for permanent deformation, galling, or cracking. Liquid penetrant examinations of welds and load bearing surfaces are performed in accordance with the ASME Code, Section V, Articles 6 [3]. Liquid penetrant acceptance standards are those of Paragraph NF-5350 of the ASME Boiler and Pressure Vessel Code, Section III, Division 1 [9].

During periods of nonuse of the transport cask, the inspection of the trunnions may be omitted provided that the trunnions are inspected in accordance with this section prior to the next use.

## 8.2.2 Leak Tests

### 8.2.2.1 Containment Periodic Verification Leak Testing

As shown in Table 8.2-1, the periodic verification leak test is performed in accordance with approved written test procedures and the test requirements and acceptance criteria established in Section 8.1.3 for the containment fabrication verification leak test.

The periodic verification leak test is performed on each cask after the third use (prior to fourth cask loading sequence), and every 12 months thereafter to verify the containment capability, and whenever a replaceable containment component (containment o-ring set or port coverplate) is replaced.

When the cask is not in use, the periodic verification leak test need not be performed annually but must be re-performed before returning the cask to service.

Leak tests are performed in accordance with the methodologies and requirements of ANSN14.5-1997, using approved written procedures.

### 8.2.2.2 Periodic Verification Leak Test Acceptance Criteria

The maximum permissible leak rate requirements and the minimum required test sensitivity for the containment fabrication verification and periodic verification leak tests are provided in Section 8.1.3. Unacceptable leak test results are cause for rejection of the component tested. Corrective actions, including repair or replacement of the o-rings or closure component, are taken and documented as appropriate. Before the cask is returned to service, the leak test and corrective actions are repeated until acceptable results are achieved.

## 8.2.3 Subsystems Maintenance

The Universal Transport Cask has no subsystem maintenance requirements.

#### 8.2.4 Valves, Rupture Disks, and Gaskets on the Containment Vessel

No valves providing a containment function are present on the cask packaging. Three quick disconnects, one each on the vent, drain, and lid seal test ports, are provided for ease of cask operation. The Universal Transport Cask containment vessel has no rupture disks.

The quick disconnects are inspected for proper performance and function during each cask loading and unloading operation and replaced as necessary. The quick disconnects are also replaced every 2 years during transport operations.

The closure lid and vent port coverplate o-rings are visually inspected for damage during each cask closure operation. The drain port coverplate o-rings are inspected during each cask closure operation when the drain port is used. Any identified damage is cause for replacement. Containment boundary o-rings are leak tested as specified in Table 7-2. As shown in the table, containment boundary o-rings are replaced as required by inspection or test, but are replaced at least annually during routine use of the cask.

#### 8.2.5 Shielding

The gamma and neutron shields of the Universal Transport Cask do not degrade with time or usage. The radiation surveys performed by the cask user prior to transport and upon receipt of the loaded cask provide continuing validation of the shield effectiveness.

#### 8.2.6 Miscellaneous Inspections

Prior to each shipment, the impact limiters are visually inspected for gross damage or cracking of the stainless steel shells in accordance with 10 CFR 71.87 and approved written procedures and established acceptance criteria. Impact limiters not meeting the established acceptance criteria are removed from service until repairs are performed and the component reinspected and accepted.

The cask cavity is visually inspected prior to each fuel loading. The overall cask exterior and cavity are visually inspected for evidence of foreign material, obstructions or damage prior to the loading of each canister. Foreign material and obstructions shall be discarded or appropriately removed. Damage to any sealing surface between the cask lid or upper forging seal surface or



port cover and corresponding recessed seal surface, shall be assessed and repaired if necessary. Evidence of damage to the inner shell shall be examined, assessed and repaired as necessary. All repairs shall conclude with a re-inspection of the affected area and acceptance to criteria appropriate for the repair made, as described previously.

For each cask loaded for transport, the following information is included in the cask loading report: results of the visual inspections, leak tests, shielding, and radiological contamination surveys; fuel identification information for the package contents; date, time, and location of the cask loading operations; and remarks regarding replaced components. The specific requirements of the cask loading report are detailed in the Universal Transport Cask Operations Manual.

#### 8.2.7 Maintenance Program Schedule

Table 8.2-1 presents the overall maintenance program schedule for the Universal Transport Cask.

Table 8.2-1 Maintenance Program Schedule

Task/Activity	Frequency
Visual inspection of cavity	Prior to loading
Visual inspection of o-rings	Prior to loading
Visual inspection of cask lid and port coverplate bolts	Prior to installation (each use)
Visual and Proper Function Inspection of Cask	Prior to each shipment
Visual inspection of lifting trunnions and rotation pockets	Prior to each shipment
Liquid penetrant inspection of lifting trunnion surfaces	Annually during use
Containment system periodic verification leak test of lid, and port coverplate, o-rings	After the third use of a transport cask. Annually during use. After each o-ring or port coverplate replacement
Containment system leak test of lid and port coverplate o-rings	Prior to each shipment
Visual inspection of impact limiter	Prior to each shipment
Inspection of quick disconnects for proper function	Each cask loading/unloading operation
Replacement of quick disconnects	Every two years of service
Replacement of O-ring	As required by inspection during operations and at each annual maintenance
Replacement of lid bolts	Every 20 years

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### 8.3 Appendices

#### 8.3.1 References

1. Title 10 of the Code of Federal Regulations, Part 71 (10 CFR 71), "Packaging and Transportation of Radioactive Materials," April 1996.
2. IAEA Safety Series No. 6, "Regulations for the Safe Transport of Radioactive Materials," International Atomic Energy Agency, Vienna, Austria, 1985 Edition, as amended 1990.
3. ASME Boiler and Pressure Vessel Code, Section V, "Nondestructive Examination," 1995 Edition with 1995 Addenda.
4. ASME Boiler and Pressure Vessel Code, Section VIII, "Rules for Construction of Pressure Vessels," 1995 Edition with 1995 Addenda.
5. American Society for Nondestructive Testing, SNT-TC-1A, "Recommended Practices, Nondestructive Testing, Personnel Qualifications and Certification, 1984.
6. ASME Boiler and Pressure Vessel Code, Division I, Section III, Subsection NB, "Class 1 Components," 1995 Edition with 1995 Addenda.
7. ANSI N14.6, "American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More for Nuclear Materials," American National Standards Institute, February 1993.
8. Field Manual of the Interchange Rules as Adopted by the Association of American Railroads, Rule 88, "Mechanical Requirements for Acceptance," Washington, D.C., 1986.
9. ASME Boiler and Pressure Vessel Code, Division 1, Section III, Subsection NF, "Component Supports," 1995 Edition with 1995 Addenda.
10. ASTM B-29-92, "Standard Specification for Refined Lead," American Society for Testing and Materials, 1992 (Reapproved 1997).
11. ANSI N14.5-1997, "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials," American National Standards Institute, December 1997.

### 8.3.2 Cask Body Fabrication

The Universal Transport Cask is a welded structure of stainless steel plates and forgings. The major chronological steps involved in the fabrication of the cask body are:

- Welding of plate sections to form the inner shell.
- Welding of inner shell to top and bottom forging to form cask containment.
- **Perform hydrostatic and helium leak testing of the containment weldment.**
- Welding of plate sections to form outer shell.
- Welding of outer shell to cask containment to form cask body.
- Welding of backing bars and supports in preparation for lead pour.
- Lead pour.
- Installation of NS-4-FR shielding material between cask bottom and bottom forging.
- Welding of cask bottom to outer shell.
- Welding of primary trunnions to top forging.
- Installation of NS-4-FR outside cask outer shell.
- **Perform load testing of the primary and secondary lifting trunnions.**
- **Perform containment boundary o-ring leak testing.**

Welding on the cask is performed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code as specified on the cask license drawings (Section 1.3.4). The type and location of the major welds on the cask body and the type of inspection required on the welds are shown in Figure 8.3-1. Pouring of chemical **copper** lead between the cask inner and outer shells to provide gamma shielding is addressed in Section 8.3.3. Installation of the NS-4-FR shielding material between the neutron shield top and bottom plates in the annulus formed by the cask outer shell and the neutron shield shell is discussed in the following paragraphs.

The methods and process for installation of the NS-4-FR shielding material will be qualified by means of a full-scale mockup test prior to actual installation in a cask or by methods and process that have already demonstrated successful and proper installation. The mockup test will establish that appropriate procedures are followed in the NS-4-FR installation process and that critical NS-4-FR material properties and characteristics are in accordance with the manufacturer's specification. The mockup structure will consist of a minimum of two cavities separated by three heat transfer fins. The NS-4-FR will be installed according to an approved procedure into two adjacent cavities of the mockup. After mixing but prior to installation, the wet material density will be measured and compared with the manufacturer's specification. Upon curing, the mockup will undergo destructive examination and testing. The destructive examination and tests will

confirm the NS-4-FR material characteristics through verification of appearance (i.e., color, voids, cracking, disbonding, shrinkage), material density, and chemical composition (i.e., boron, hydrogen). The installation procedure will be considered "qualified" upon acceptance of the results of the destructive examination and test.

Actual installation of the NS-4-FR into the cask will be performed according to the procedure verified by the mockup test or previously used methods. The wet material density of each mix batch will be measured and compared with the manufacturer's specification to verify the material characteristics of the NS-4-FR. Compliance with the wet material density criteria will confirm final acceptance of the mix batch and subsequent installation.

### 8.3.3 Description of Lead Pour Procedures

Molten lead is poured into the annulus between the inner and outer shells of the Universal Transport Cask body to provide the primary radial gamma shielding in the cask body. The lead annulus is subjected to a gamma scan test to verify its shielding integrity. The description that follows includes the prepour preparations, the pouring of the molten lead in the annulus, and the postpour controlled cooldown of the cask.

#### 8.3.3.1 Preparation for Lead Pour

The following activities must be completed in preparation for pouring of the lead in the cask body:

1. Temporary stiffener bars/rings are installed both inside and outside the body weldment at intermittent locations along the cask length. To maintain the specified dimensions of the lead annulus, the stiffeners support the inner and outer shells during the lead pour and cooldown. The stiffeners are removed after the cooldown operation is completed.
2. At least 12 pairs of thermocouples are used to monitor the heating and cooling cycle of the inner and outer shells. Each pair of thermocouples is positioned at approximately the same radial and axial location, one on the inside diameter of the inner shell and one on the outside diameter of the outer shell.

3. Electric heaters are installed in the cask cavity to heat the inner shell.
4. The body weldment (formed by the outer shell weldment welded to the cask cavity weldment at the top forging/outer shell interface) of the cask is inverted and supported in a stable, vertical position in a "pit" or within a windbreak structure to provide a basically draft-free operations area.
5. At least 20 gas heating/water cooling rings are installed around the outside of the body weldment for use in heating, and later in cooling, the outer shell. Gas torches are provided for heating the outside surface of the bottom forging.
6. The body weldment surfaces, especially the lead annulus, are checked for dimensional accuracy and cleanliness.
7. The general arrangement of the equipment for the lead pour operation is shown in Figure 8.3-2.

#### 8.3.3.2 Lead Pour Operations

The requirements and activities that must be completed during pouring of the lead in the Universal Transport Cask body are as follows:

1. The lead material certification is checked to ensure that it conforms to the requirements of ASTM B29-92 for chemical **copper refined lead** [10].
2. Approximately 47,500 pounds of lead is placed in appropriately sized kettles and melted. During the lead pour operations, the temperature of the molten lead is maintained between 650°F (343°C) and 750°F (399°C).
3. At the same time that the lead is being melted, the cask body weldment is simultaneously heated by using both the electric heaters on the interior and the gas heating rings on the exterior. The body weldment is heated steadily and uniformly at a rate not exceeding 125°F/hr (52°C/hr). Gas torches are used to heat the exterior of

the bottom forging. The surface temperature of the body weldment is never permitted to exceed 800°F (427°C). The temperature of the entire body weldment is maintained between 640°F (338°C) and 740°F (393°C) throughout the lead pour operations.

4. The lead pour is initiated immediately after the temperatures of the lead and the body weldment are stabilized in the ranges previously specified. The actual pouring of the lead is completed without interruption and as quickly as possible. During the lead pour, the bottom end of the filler-tube is kept below the surface of the molten lead to keep voids from forming in the lead.
5. The lead is poured to a level that is sufficient to ensure that dross removal and contraction during solidification do not reduce the finished surface below the required level. A long steel rod inserted into the molten lead annulus is used to ensure that no solidification has begun anywhere in the volume of molten lead.

#### 8.3.3.3 Cooldown Following Lead Pour

The procedures and requirements that must be completed during cooldown of the cask body weldment following completion of the lead pour are as follows:

1. Cooldown is initiated by turning off the electrical heater (interior) and the gas heating/water cooling ring (exterior) at the lowest end of the cask (in the as-poured position). The gas heating/water cooling ring is then used to facilitate and control cooling by spraying water on the exterior surface of the cask. As cooldown proceeds, the heaters and rings upward along the cask are successively turned off and the cooling water spray is turned on from each ring.
2. The cooldown process is temperature controlled to maintain approximately uniform solidification conditions across the thickness and around the circumference of the annulus.
3. The cooldown rate is held steady and uniform at a rate not to exceed 125°F/hr (52°C/hr) and the temperature differential between the inside shell and the outside shell is not allowed to exceed 100°F (38°C). Once the inner and outer shell



temperatures have cooled to 150°F (66°C), controlling the cooldown rate is no longer necessary.

4. The solidification level in the lead annulus is checked with the aid of a long steel rod. The maximum difference in the elevation of the solidified lead between the inside surface of the outer shell and the outside surface of the inner shell is not permitted to exceed 2 in. (51 mm).
5. Dross is skimmed off the top of the lead while maintaining the molten head throughout the cooldown process.

#### 8.3.3.4 Lead Pour Documentation

The following data are included in the data package for the lead pour operation:

1. Certificate of chemical analysis of the lead.
2. Heating and cooling charts showing elapsed time and temperatures.
3. Location, time, and temperature for readings taken with a handheld pyrometer or other temperature-reading device.
4. Difference in solidification elevations when checking at the inside surface of the outer shell and the outside surface of the inner shell.

Figure 8.3-1 Cask Body Welds

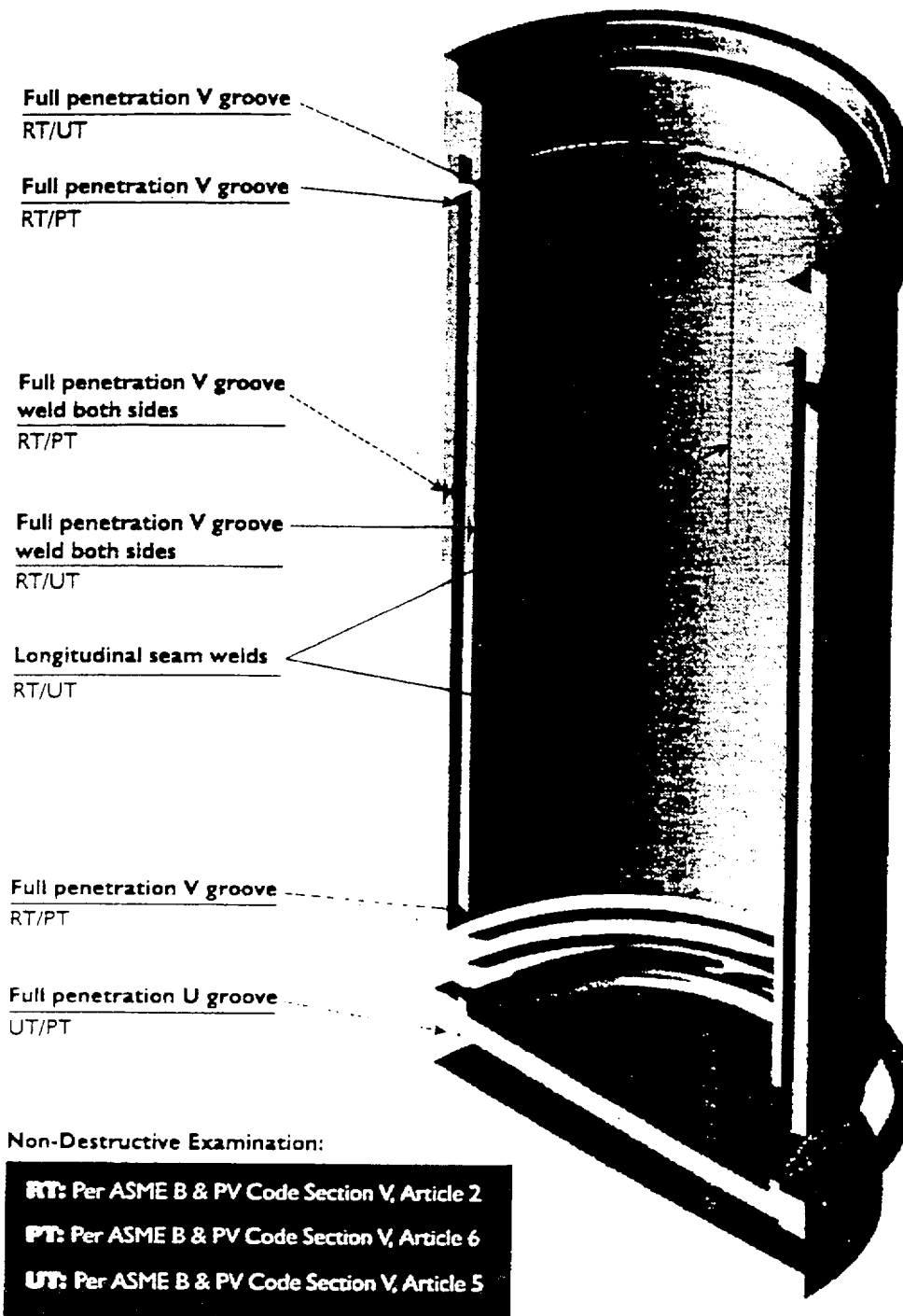


Figure 8.3-2 Arrangement of Lead Pour Equipment

