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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 % ^{235}U or 56 intact BWR fuel assemblies 4.0 wt % ^{235}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 ^{10}B/cm^2. 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 g ^{10}B/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_{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) 9×9 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)**	
	$k_{eff} \pm \sigma$	**k_s**	**$k_{eff} \pm \sigma$**	**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}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(5)	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(1)
4	GE	8 X 8	GE-10	0.1730	60	0.640	0.484	0.032	0.410	145.2(1,2)
5(6)	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(1)
5	GE	8 X 8	GE-6 (prep)	0.1847	62	0.640	0.483	0.032	0.410	150(1)
5	GE	8 X 8	GE-7 (barr)	0.1847	62	0.640	0.483	0.032	0.410	150(1)
5	GE	8 X 8	GE-10	0.1787	60	0.640	0.484	0.032	0.410	150(1,2)
5	GE	9 X 9	GE-11	0.1854	74	0.566	0.441	0.028	0.376	150(1,3,4)
5	GE	9 X 9	GE-11	0.1979	79	0.566	0.441	0.028	0.376	150(1,3,4)

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_{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_{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_{eff} and k_s (the bias adjusted k_{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 (0.95×10.96 gm/cm^2 = 10.412 g/cm^2).

- Baseline enrichment for the PWR fuel assembly is 4.2 wt% ^{235}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}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_{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_{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^3).

- Fuel, cladding, and structural materials are at 293°K.
- ^{10}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 toleranced 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}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}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 neutronically 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_2	10.412 (95% theoretical)
Zircaloy	6.56
H_2O	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_2 (4.2 wt % ^{235}U)	^{235}U	9.877×10^{-4}
	^{238}U	2.224×10^{-2}
	O	4.646×10^{-2}
UO_2 (4.0 wt % ^{235}U)	^{235}U	9.406×10^{-4}
	^{238}U	2.229×10^{-2}
	O	4.646×10^{-2}
Zircaloy	Zr	4.331×10^{-2}
H_2O	H	6.677×10^{-2}
	O	3.338×10^{-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	^{10}B	8.880×10^{-3} (75% of Nominal)
(0.025 g $^{10}B/cm^2$)	^{11}B	4.906×10^{-2}
	C	1.522×10^{-3}
	Al	2.694×10^{-2}
Boral core	^{10}B	2.212×10^{-3} (75% of Nominal)
(0.011 g $^{10}B/cm^2$)	^{11}B	1.219×10^{-2}
	C	3.786×10^{-3}
	Al	5.217×10^{-2}
Aluminum	Al	6.031×10^{-2}
Steel 304	Cr	1.743×10^{-2}
	Fe	5.936×10^{-2}
	Ni	7.721×10^{-3}
	Mn	1.736×10^{-3}
Carbon steel	C	3.925×10^{-3}
	Fe	8.350×10^{-2}
Lead	Pb	3.297×10^{-2}
NS4FR	H	5.854×10^{-2}
	O	2.609×10^{-2}
	C	2.264×10^{-2}
	N	1.394×10^{-3}
	Al	7.763×10^{-3}
	^{11}B	3.422×10^{-4}
	^{10}B	8.553×10^{-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.

Material	Element	Density (atoms/barn-cm)
H_2O	H	6.677×10^{-2}
	O	3.338×10^{-2}

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

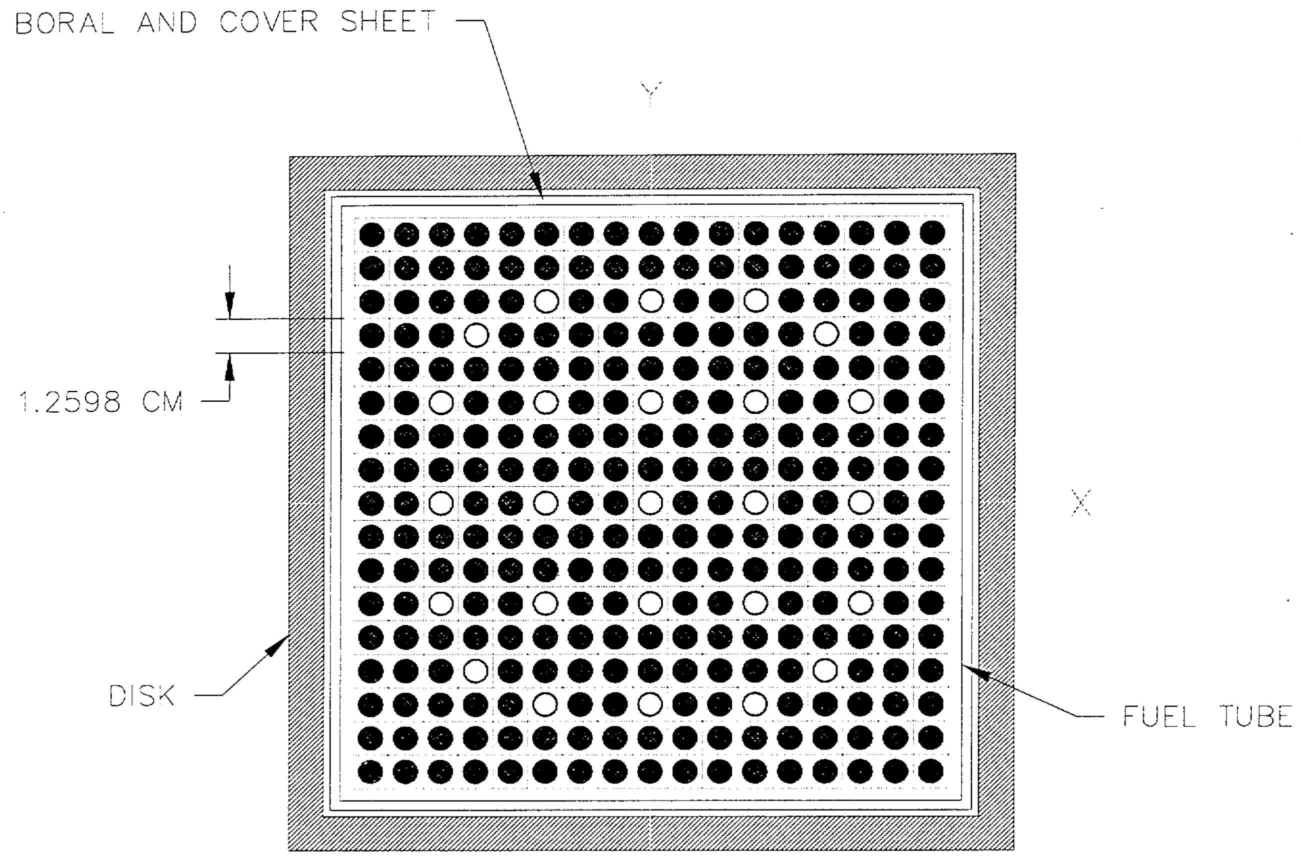


Figure 6.3-2 Universal Transport Cask KENO-Va BWR Basket Cell Model

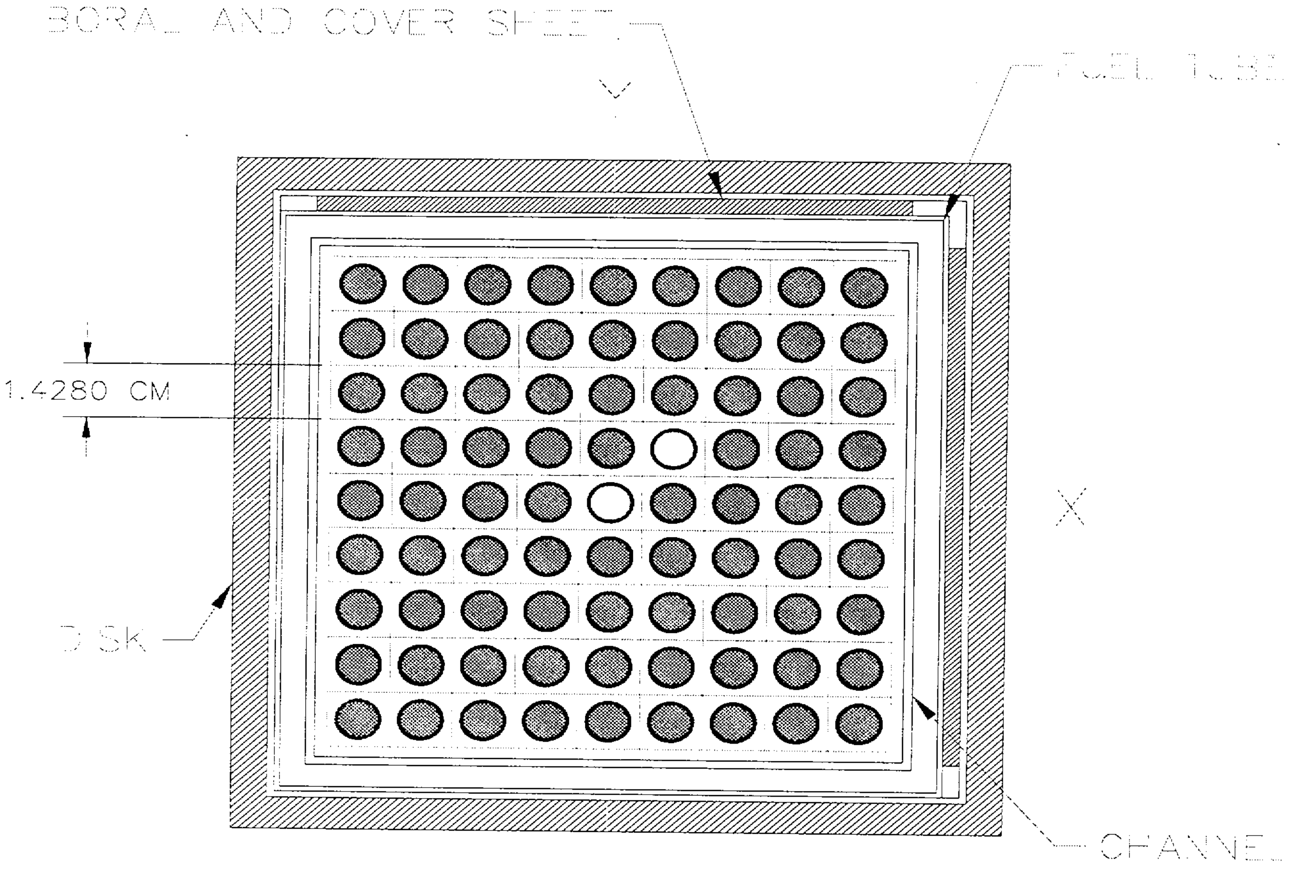


Figure 6.3-3 Universal Transport Cask PWR KENO-Va Cask Model

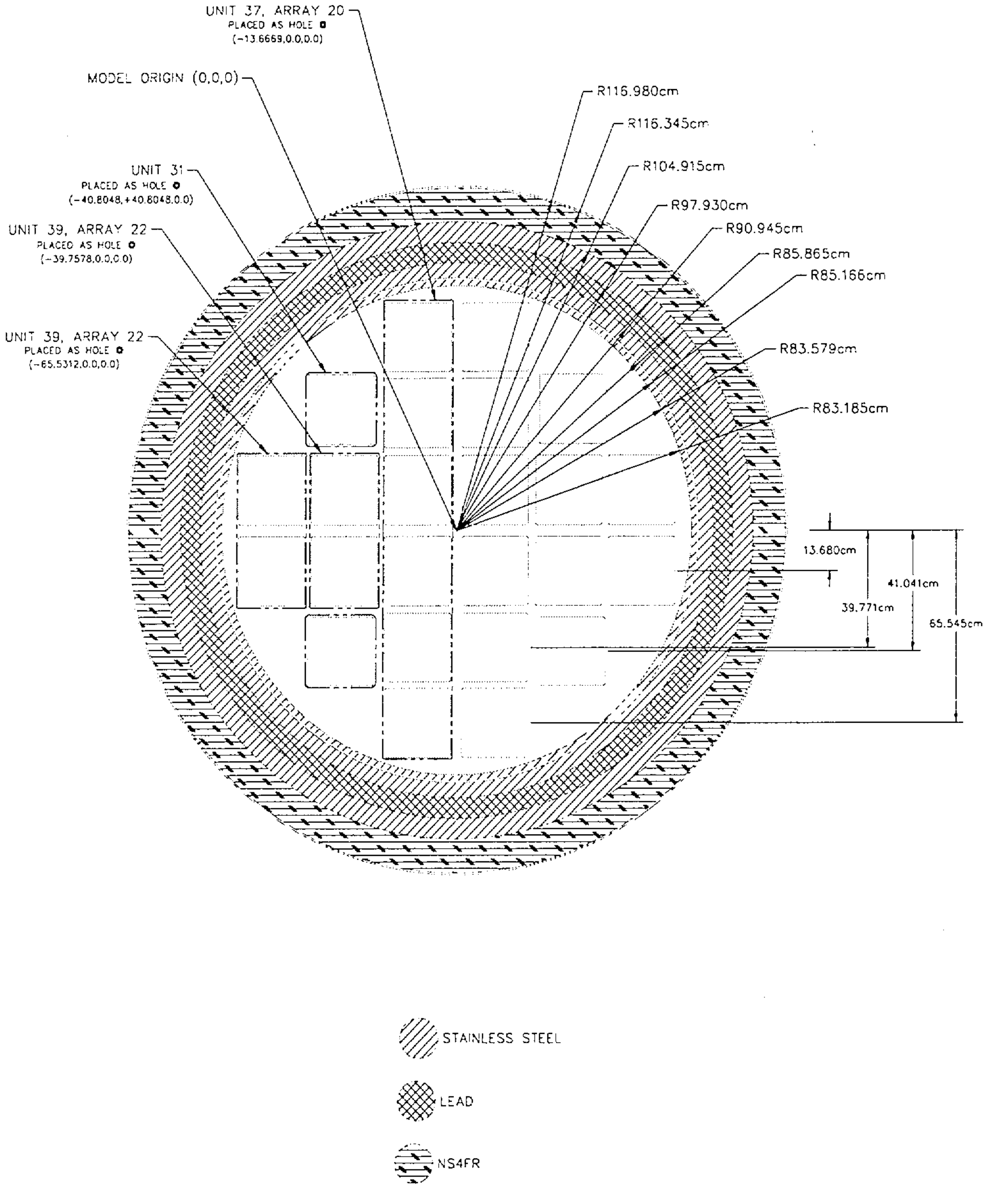


Figure 6.3-4 Universal Transport Cask BWR KENO-Va Cask Model

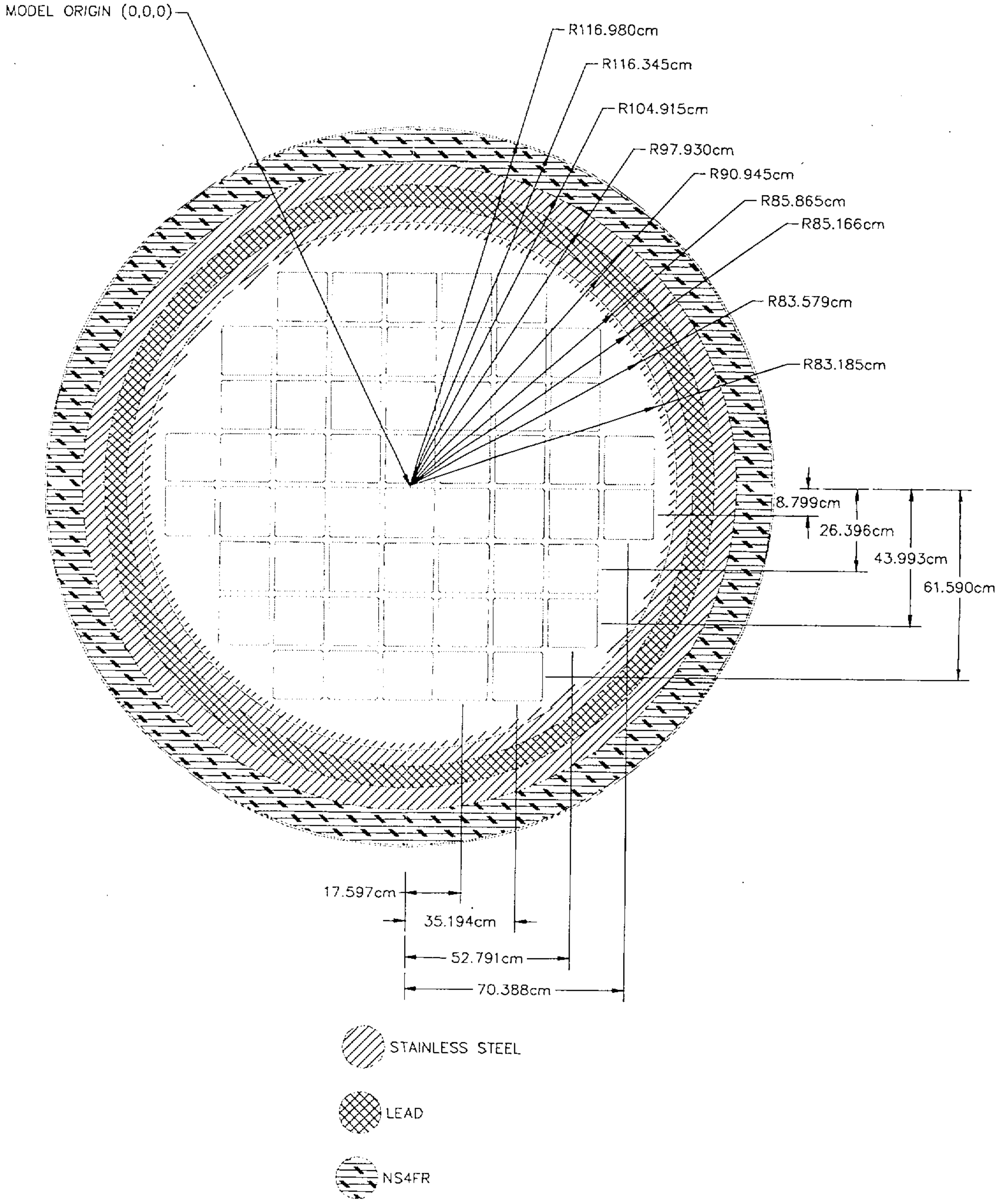


Figure 6.3-5 PWR Basket Criticality Control Design

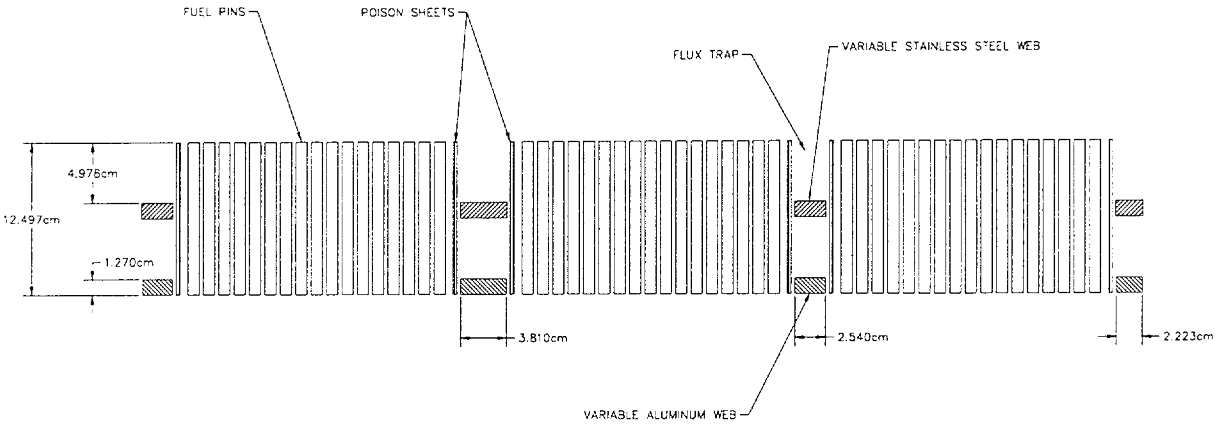
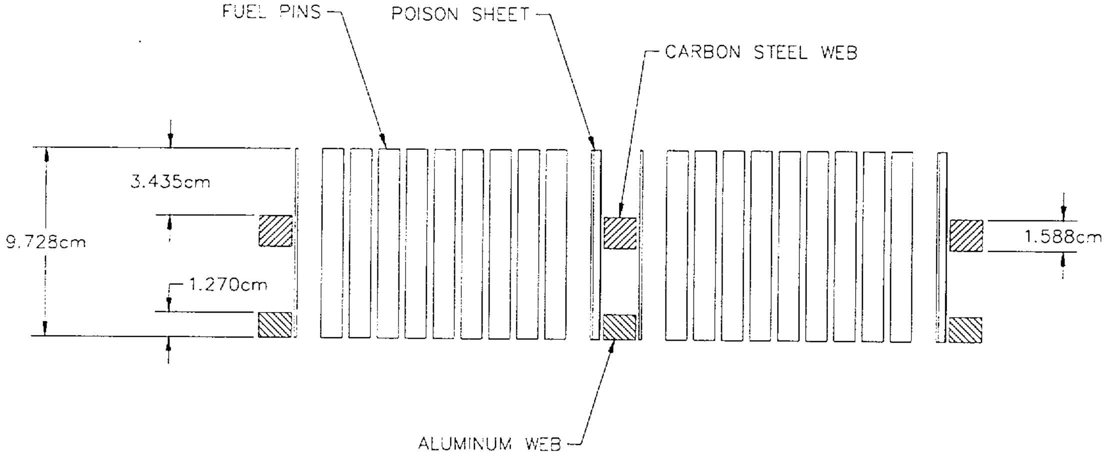


Figure 6.3-6 BWR Basket Criticality Control Design



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
- B&W 15x15 Mark BZ
- B&W 17x17 Mark C
- CE 14x14 Standard
- CE 14x14 Ft. Calhoun
- CE 14x14 Palisades
- CE 14 x14 Lucie 2
- CE 16x16 System 80
- CE 16x16 San Onofre 2&3
- CE 16x16 ANO2
- Westinghouse 14x14 Std/ZCA
- Westinghouse 14x14 Std/ZCB
- Westinghouse 14x14 OFA
- Westinghouse 14x14 (CE)
- Westinghouse 15x15 Std
- Westinghouse 15x15 Std/ZC
- Westinghouse 15x15 OFA
- Westinghouse 17x17
- Westinghouse 17x17 Vant5
- Westinghouse 17x17 OFA
- Ex/ANF 14x14 (CE)
- Ex/ANF 14x14 (WE)
- Ex/ANF 14x14 (Praire Isl.)
- Ex/ANF 15x15 (WE)
- Ex/ANF 15x15 (Palisades)
- 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 Δk between the dry and wet cases. k_{eff} values in Table 6.4-1 are for a representative 1.0" flux trap, a ^{10}B areal density of 0.02 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 Δk_{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.

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 ± 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 ± 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 boundarsy 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 ± 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 ± 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 Δk_{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 Δk_{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_{eff} and k_s (the bias adjusted k_{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_{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.

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

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

where:

k_s = the calculated allowable maximum multiplication factor, k_{eff}, of system being evaluated for all normal or credible abnormal conditions or events.
k_{eff} = the KENO - Va calculated k_{eff}
σ_{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 ± 0.231 in. (0.587cm). The maximum movement of the tube in the disk opening is ± 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 ± 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 ± 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_{eff} for the Universal Transport Cask loaded with 4.00 wt % ^{235}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_{eff} of 0.91032. The change in reactivity, a Δk_{eff} of +0.00105, is within 2σ 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_{eff} and k_s (the bias adjusted K_{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_{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.

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

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

where:

k_s = calculated allowable maximum multiplication factor, k_{eff}, of the system being evaluated for all normal or credible abnormal conditions or events
k_{eff} = KENO - Va calculated k_{eff}
σ_{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}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_{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_∞ for the GE8x8-62 fuel rod assembly was calculated. The in-core k_∞ 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_s, 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}U (most reactive PWR fuel assembly type) or 56 Ex/ANF 9x9-79 rod fuel assemblies at 4.0 wt % ^{235}U (most reactive BWR fuel assembly type)
- No fuel burnup
- 75% of the minimum ^{10}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}U and the cask filled with maximum reactivity BWR fuel enriched to 4.00 wt % ^{235}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 Δk penalty associated with BORAL plates. A Δk 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 ± 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 ± 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_{eff} is calculated to be 0.9320 ± 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 Δk 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_{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 0.4005 ± 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_{eff} for this condition is calculated to be 0.9086 ± 0.0008. For conditions where the inside of the cask is wet but the outside is at optimum moderation, the maximum k_{eff} is calculated to be 0.9108 ± 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 Δk_{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 ration in the undermoderated fuel lattice.

A slight increase in reactivity, 0.004 Δk, 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 ≥ Nominal Dimension
b) Clad Thickness ≥ Nominal Dimension
c) Fuel Rod Pitch ≤ Nominal Dimension
d) Guide Tube (Instrument Tube) Thickness ≥ Nominal Dimension
e) Pellet Diameter ≤ Nominal Dimension

BWR

a) Fuel Rod Diameter ≥ Nominal Dimension
b) Clad Thickness ≥ Nominal Dimension
c) Fuel Rod Pitch ≤ Nominal Dimension
d) Pellet Diameter ≤ 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, $k_{eff} \pm 2\sigma$, of 0.9340 ± 0.0005 and a base BWR system reactivity, $k_{eff} \pm 2\sigma$, of 0.9116 ± 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, $k_{eff} \pm 2\sigma$, of 0.9335 ± 0.005 reflects a change in reactivity, k_{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, $k_{eff} \pm 2\sigma$, of 0.9365 ± 0.005 reflects a change in reactivity, Δk_{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 $k_{eff} \pm 2\sigma$ of 0.9108 as determined in Section 6.4.3.3, to establish a maximum BWR system reactivity, $k_{eff} \pm 2\sigma$, of 0.9357 ± 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}B from 100 to 75 percent and water in the pellet-to-cladding gap.

Undamaged Cask

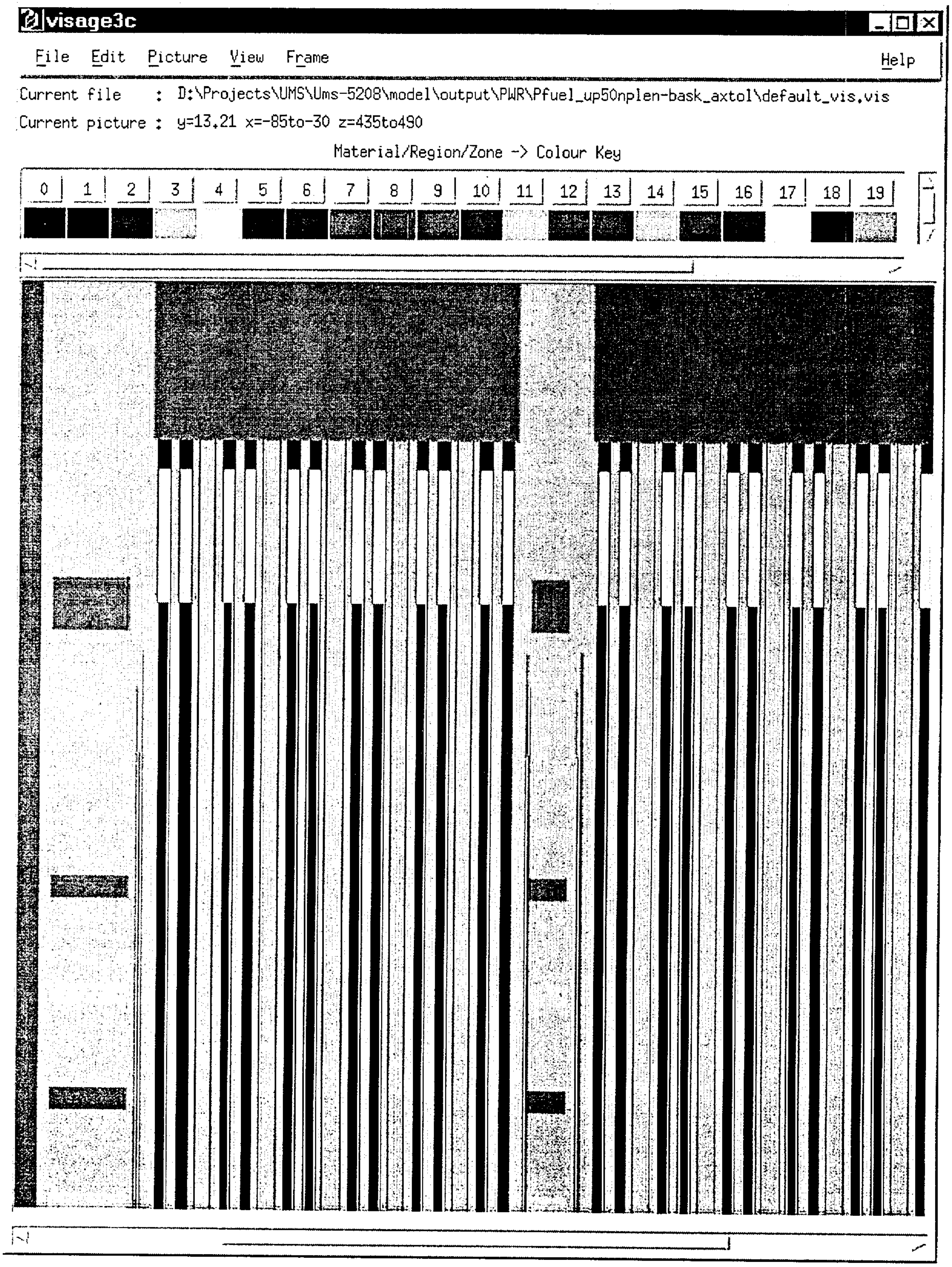
Compliance with the requirements of paragraphs (b) and (d) of 10 CFR 71.55 is shown by modeling an undamaged cask surrounded by water. Requirements of paragraphs (a) through (c) of 10 CFR 71.59 are satisfied by providing a value of "N" equal to infinity and a criticality transport index of 0 by imposing 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.

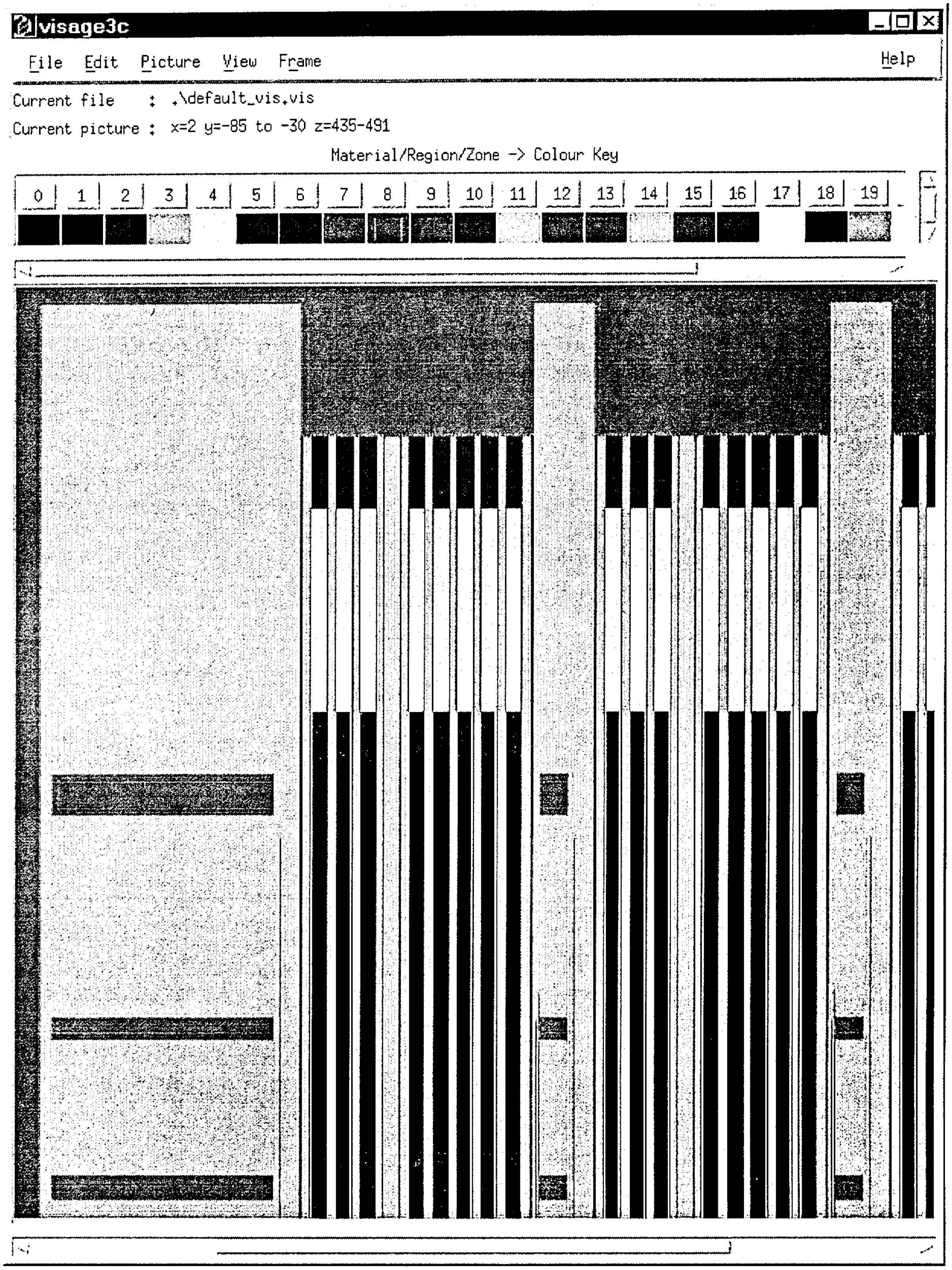
Figure 6.4-1 Visage Slice - Hypothetical Shifting of PWR Fuel



Current file : D:\Projects\UMS\Ums-5208\model\output\PWR\Pfuel_up50nplen-bask_axtol\default_vis.vis

Current picture : y=13.21 x=-85to-30 z=435to490

Figure 6.4-2 Visage Slice - Hypothetical Shifting of BWR Fuel



Current file : .\default_vis.vis
Current picture : x=2 y=-85 to -30 z=435-491

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

Assembly Type	Dry Gap		Wet Gap		Δk_{eff} Wet - Dry
	k_{eff}	σ	k_{eff}	σ	
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}	σ
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}	σ	
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(2)	2 mm	0.8778	0.0011	-9.558
GE 9x9	74	2(2)	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(2)	80 mil	0.8862	0.0012	-2.034

Note:

(1) $\Delta k_{eff} = k_{eff} - k_{eff}$(Ex/ANF 9x9 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}	σ	Δk_{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}	σ	Δk_{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_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
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^3)		Neutron Shield	Water in Gap	^{10}B	k_{eff}	σ	k_s
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^3)		Neutron Shield	Water in Gap	^{10}B	k_{eff}	σ	k_s
	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/cm³) Inside	Water Density (g/cm³) Outside	Neutron Shield	Water in Gap	^{10}B	k_{eff}	σ	k_s
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/cm³) Inside	Water Density (g/cm³) Outside	Neutron Shield	Water in Gap	^{10}B	k_{eff}	σ	k_s
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^3)		Neutron	Water in				
Inside	Outside	Shield	Gap	^{10}B	k_{eff}	σ	k_s
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	Water Density (gm/cm^3)		Neutron	Water in				
Pitch	Inside	Outside	Shield	Gap	^{10}B	k_{eff}	σ	k_s
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^3) Inside	Water Density (gm/cm^3) Outside	Neutron Shield	Water in Gap	^{10}B	k_{eff}	σ	k_s
Touching	1.0	1.0	No	Yes	75%	0.9086	0.0008	0.9226
270 cm	1.0	1.0	No	Yes	75%	0.9084	0.0008	0.9224
300 cm	1.0	1.0	No	Yes	75%	0.9075	0.0008	0.9215
Touching	0.8	0.8	No	Yes	75%	0.8810	0.0008	0.8950
270 cm	0.8	0.8	No	Yes	75%	0.8785	0.0008	0.8926
300 cm	0.8	0.8	No	Yes	75%	0.8779	0.0008	0.8919
Touching	0.6	0.6	No	Yes	75%	0.8370	0.0011	0.8511
270 cm	0.6	0.6	No	Yes	75%	0.8366	0.0012	0.8508
300 cm	0.6	0.6	No	Yes	75%	0.8378	0.0011	0.8519
Touching	0.4	0.4	No	Yes	75%	0.7653	0.0015	0.7797
270 cm	0.4	0.4	No	Yes	75%	0.7698	0.0014	0.7842
300 cm	0.4	0.4	No	Yes	75%	0.7680	0.0014	0.7824
Touching	0.2	0.2	No	Yes	75%	0.6524	0.0012	0.6666
270 cm	0.2	0.2	No	Yes	75%	0.6562	0.0012	0.6704
300 cm	0.2	0.2	No	Yes	75%	0.6560	0.0012	0.6702
Touching	0.1	0.1	No	Yes	75%	0.5662	0.0013	0.5805
270 cm	0.1	0.1	No	Yes	75%	0.5708	0.0014	0.5851
300 cm	0.1	0.1	No	Yes	75%	0.5668	0.0013	0.5810

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

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

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

Cask Pitch	Water Density (g/cm^3) Inside	Water Density (g/cm^3) Outside	Neutron Shield	Water in Gap	^{10}B	k_{eff}	σ	k_s
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 (% ^{235}U)			Loading Pattern				
Array	Fuel Rods	Average	Min	Max	Heterog.	Homog.	k_{eff}	σ	$\Delta k/\sigma$
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(1)	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(1)	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(2)	74	4.000	N/A	N/A		X	0.8890	0.0012	N/A
9x9(2)	74	4.000	1.96	4.80	X		0.8805	0.0012	-7.08
9x9(3)	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% ^{235}U enriched rods near center of assembly

Table 6.4-17 PWR Lattice Parameter Study Criticality Analysis Results

Description	k_{eff}	**σ**	**Δ k**	**2 σ**	**Δ k / 2 σ**
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}	σ	Δk	2σ	$\Delta k / 2\sigma$
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:

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

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.

Δk_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.

Δk_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.

Δk_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:

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

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:

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

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:

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

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 β and $\Delta\beta$ are evaluated below for KENO-Va with the 27-group ENDF/B-IV library.

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}U fuel storage (Baldwin et al. , July 1979) [10], 10 PNL 4.31 wt% ^{235}U lattice (Bierman and Clayton, July 1980) [12], 21 PNL 2.35 and 4.31 wt% ^{235}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}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 ±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}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}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}U and results indicate confidence well above 5 wt % ^{235}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±0.0044. The average Monte Carlo error (statistical convergence) is ±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}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 ±0.001. Criticality can then be represented as 1.000±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 $\Delta\beta= 2.012\text{x}0.0043=0.0087$. Equation 3 now becomes:

$$k_{eff} + \Delta k_s + 0.0052 + 0.0087 \leq 0.95 \tag{5}$$

where Δk_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 Δk_s becomes 0.0 and the Monte Carlo error, σ_{mc}, can be combined statistically, because it is independent, with the uncertainty in the bias as:

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

6.5.3 Trends

Scatter plots of k_{eff} versus wt % ^{235}U, rod pitch, H/U volume ratio, average neutron group causing fission, ^{10}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_{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_{eff} versus enrichment) and the lowest is 0.0048 (k_{eff} versus ^{10}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}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_{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_{eff} was evaluated for the following independent variables: wt % ^{235}U, rod pitch, H/U volume ratio, average neutron group causing fission, ^{10}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:

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

where:

k_s = calculated allowable maximum multiplication factor, k_{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.

Δk_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.

Δk_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.

Δk_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:

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

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

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

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:

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

where:

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

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:

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

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}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 β. 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 ± 1. Thus a constant bias with a 95/95 confidence factor is applied to the system k_{eff}. NAC's statistical analysis of the k_{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_{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_{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}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_{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}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_{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_{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

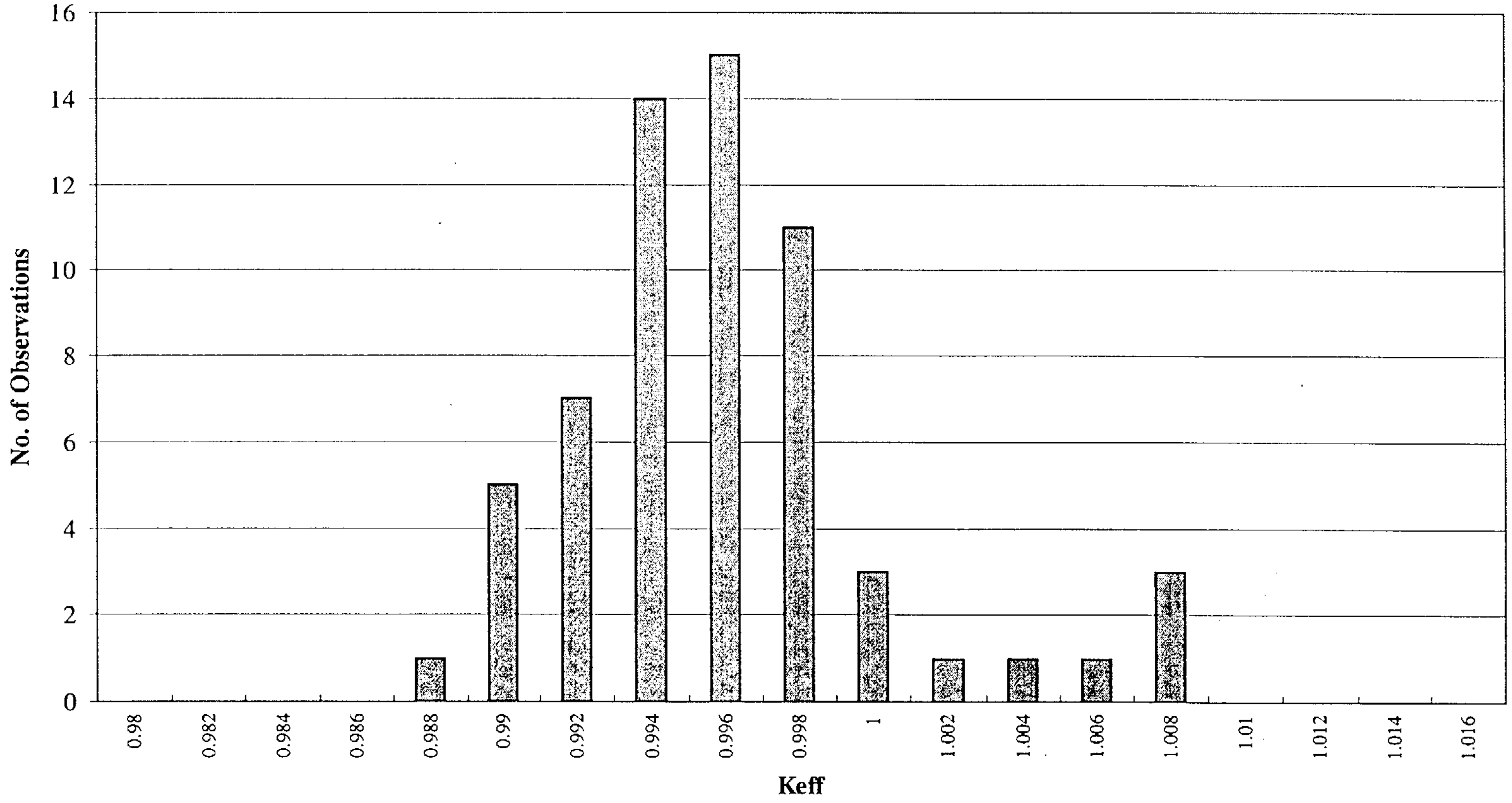


Figure 6.5-2 KENO-Va Validation - 27-Group Library Results: k_{eff} versus Enrichment

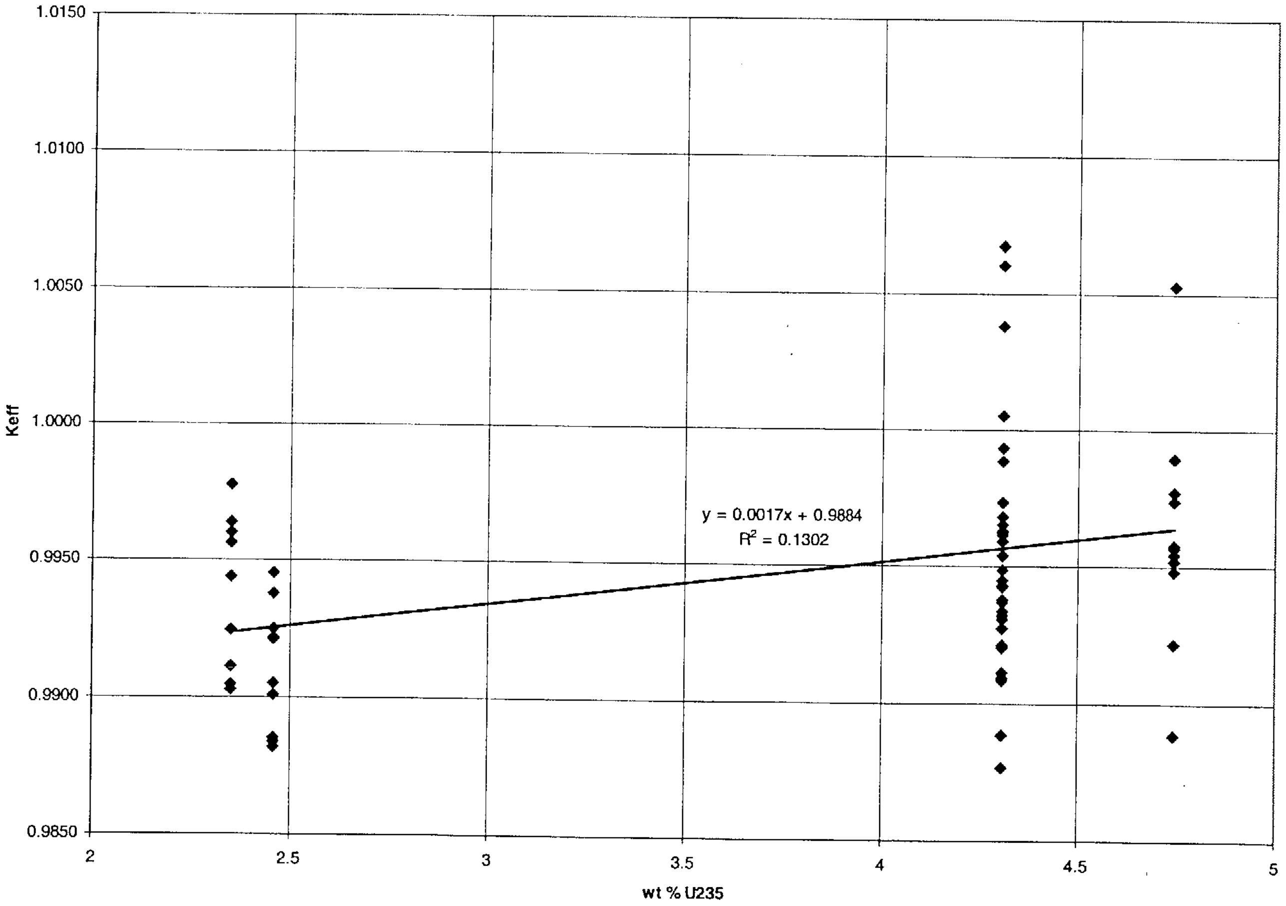


Figure 6.5-3 KENO-Va Validation - 27-Group Library Results: k_{eff} versus Rod Pitch

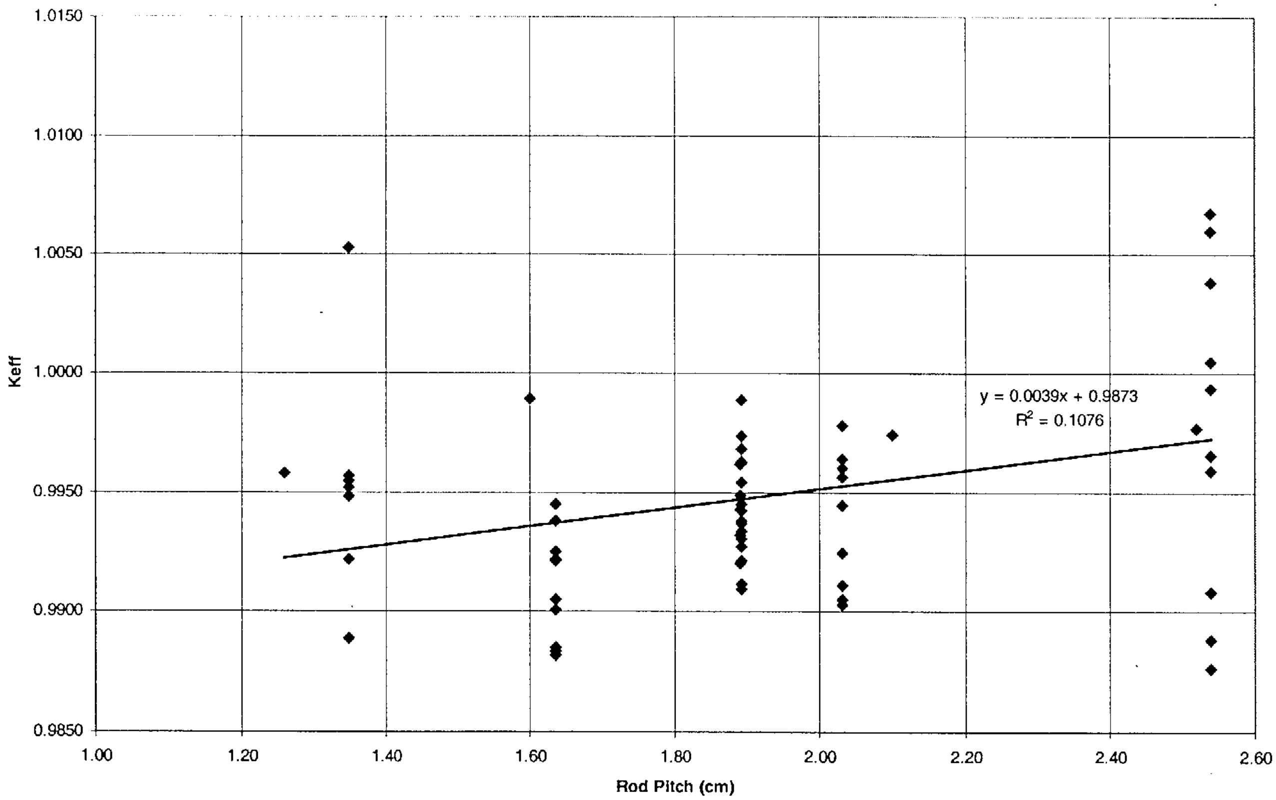


Figure 6.5-4 KENO-Va Validation - 27-Group Library Results: k_{eff} versus H/U Volume Ratio

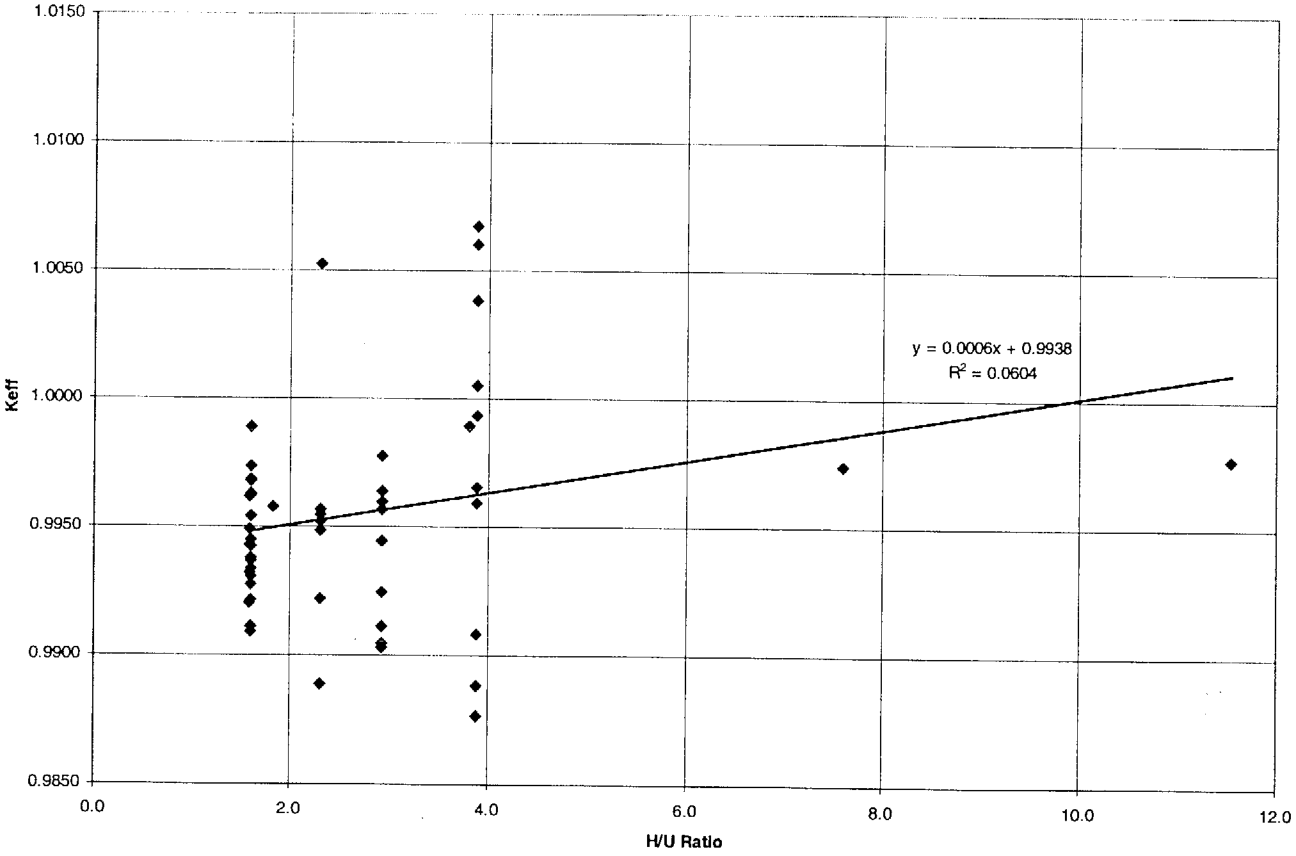


Figure 6.5-5 KENO-Va Validation - 27-Group Library Results: k_{eff} versus Average Group of Fission

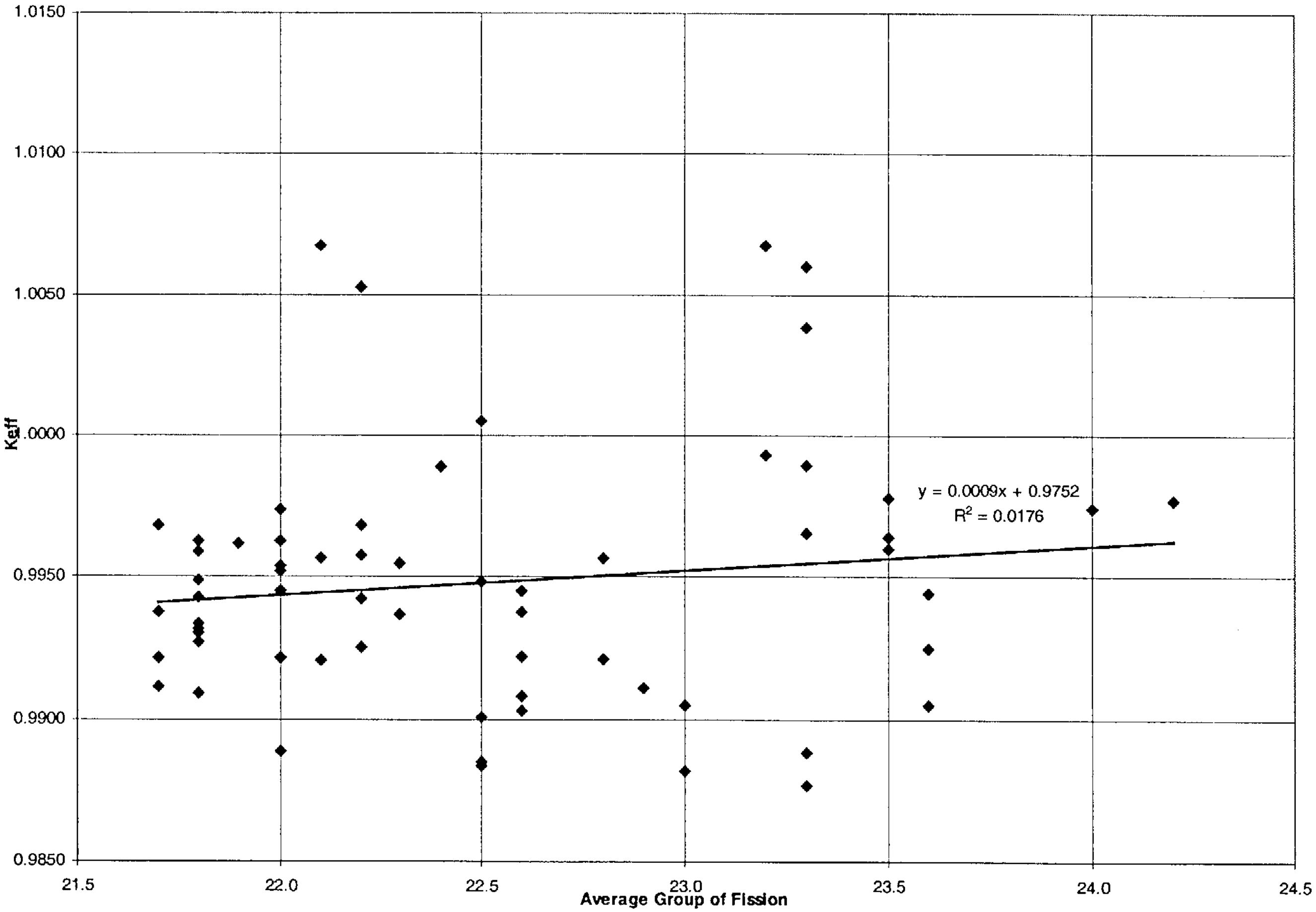


Figure 6.5-6 KENO-Va Validation - 27-Group Library Results: k_{eff} versus ^{10}B Loading for Flux Trap Criticals

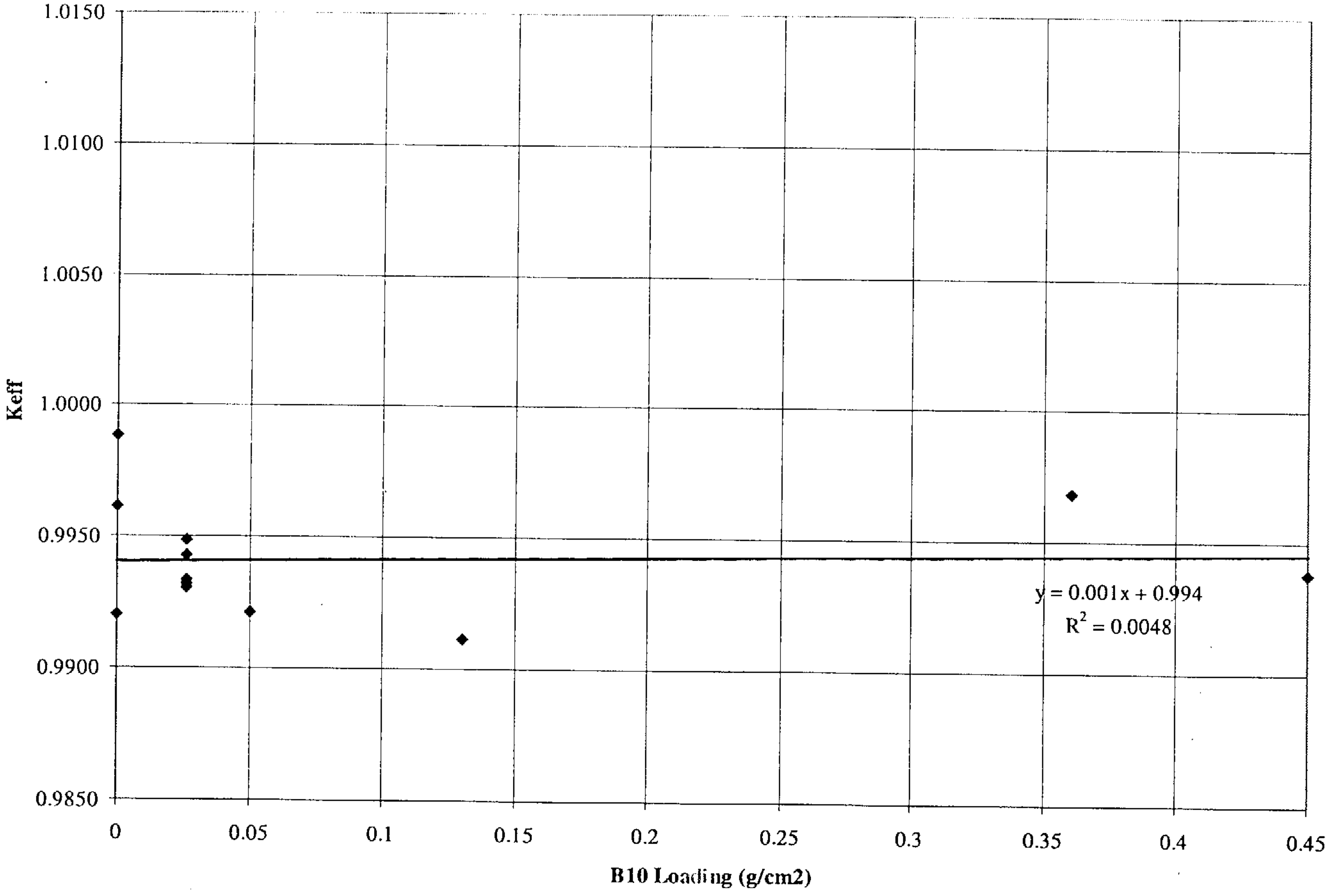


Figure 6.5-7 KENO-Va Validation - 27-Group Library Results: k_{eff} versus Flux Trap Critical Gap Thickness

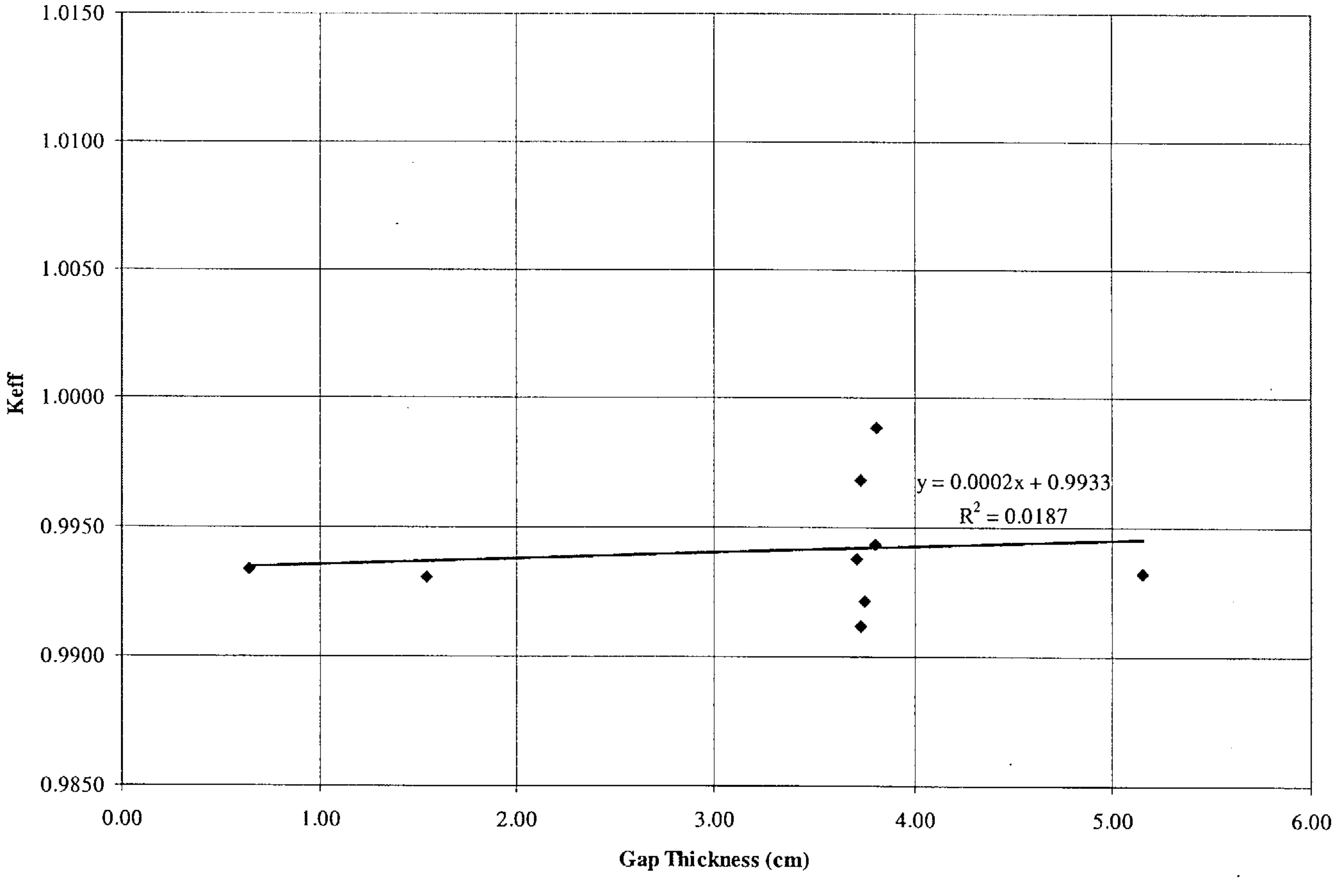


Figure 6.5-8 USLSTATS Output for Fuel Enrichment Study

```
uslstats: a utility to calculate upper subcritical
limits for criticality safety applications

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

Input to statistical treatment from file:EN_KEFF.TXT

Title: 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      deviation          independent    dependent      deviation
variable - x   variable - y    in y              variable - x   variable - y    in y

2.35000E+00    9.96400E-01    1.00000E-03        4.31000E+00    9.96500E-01    1.10000E-03
2.35000E+00    9.94400E-01    1.00000E-03        4.31000E+00    1.00680E+00    2.10000E-03
2.35000E+00    9.90500E-01    1.00000E-03        4.31000E+00    1.00380E+00    1.20000E-03
2.35000E+00    9.96000E-01    1.10000E-03        4.31000E+00    9.88900E-01    1.10000E-03
2.35000E+00    9.97800E-01    1.00000E-03        4.31000E+00    9.95900E-01    1.10000E-03
2.35000E+00    9.92500E-01    1.00000E-03        4.31000E+00    1.00670E+00    1.00000E-03
2.35000E+00    9.90300E-01    9.00000E-04        4.31000E+00    1.00050E+00    1.10000E-03
2.35000E+00    9.95700E-01    1.00000E-03        4.31000E+00    9.90800E-01    1.10000E-03
2.35000E+00    9.91100E-01    1.00000E-03        4.31000E+00    9.98900E-01    1.20000E-03
2.46000E+00    9.92100E-01    1.10000E-03        4.31000E+00    9.92100E-01    1.20000E-03
2.46000E+00    9.92500E-01    9.00000E-04        4.31000E+00    9.91100E-01    1.20000E-03
2.46000E+00    9.93800E-01    9.00000E-04        4.31000E+00    9.96800E-01    1.30000E-03
2.46000E+00    9.90500E-01    1.00000E-03        4.31000E+00    9.93800E-01    1.20000E-03
2.46000E+00    9.88200E-01    1.00000E-03        4.31000E+00    9.93400E-01    1.00000E-03
2.46000E+00    9.94500E-01    1.00000E-03        4.31000E+00    9.93100E-01    1.00000E-03
2.46000E+00    9.92200E-01    1.00000E-03        4.31000E+00    9.94300E-01    1.00000E-03
2.46000E+00    9.88500E-01    1.00000E-03        4.31000E+00    9.93200E-01    1.00000E-03
2.46000E+00    9.88400E-01    1.00000E-03        4.31000E+00    9.94900E-01    1.00000E-03
2.46000E+00    9.90100E-01    9.00000E-04        4.31000E+00    9.92000E-01    1.00000E-03
4.31000E+00    9.95400E-01    1.40000E-03        4.31000E+00    9.96200E-01    1.00000E-03
4.31000E+00    9.94500E-01    1.30000E-03        4.74000E+00    9.92200E-01    1.30000E-03
4.31000E+00    9.97400E-01    1.30000E-03        4.74000E+00    9.88900E-01    1.30000E-03
4.31000E+00    9.96300E-01    1.30000E-03        4.74000E+00    9.95700E-01    1.30000E-03
4.31000E+00    9.92700E-01    1.20000E-03        4.74000E+00    1.00530E+00    1.10000E-03
4.31000E+00    9.90900E-01    1.20000E-03        4.74000E+00    9.95500E-01    1.20000E-03
4.31000E+00    9.96200E-01    1.20000E-03        4.74000E+00    9.94800E-01    1.30000E-03
4.31000E+00    9.93700E-01    1.30000E-03        4.74000E+00    9.95800E-01    1.20000E-03
4.31000E+00    9.94200E-01    1.20000E-03        4.74000E+00    9.95200E-01    1.20000E-03
4.31000E+00    9.96800E-01    1.20000E-03        4.74000E+00    9.98900E-01    1.30000E-03
4.31000E+00    9.87700E-01    2.30000E-03        4.74000E+00    9.97400E-01    1.20000E-03
4.31000E+00    9.99300E-01    1.20000E-03        4.74000E+00    9.97700E-01    1.10000E-03
4.31000E+00    1.00600E+00    2.20000E-03

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

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

```
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.
```

Figure 6.5-9 MONK8A – JEF 2.2 Library Validation Statistics – k_{eff} versus Fuel Enrichment

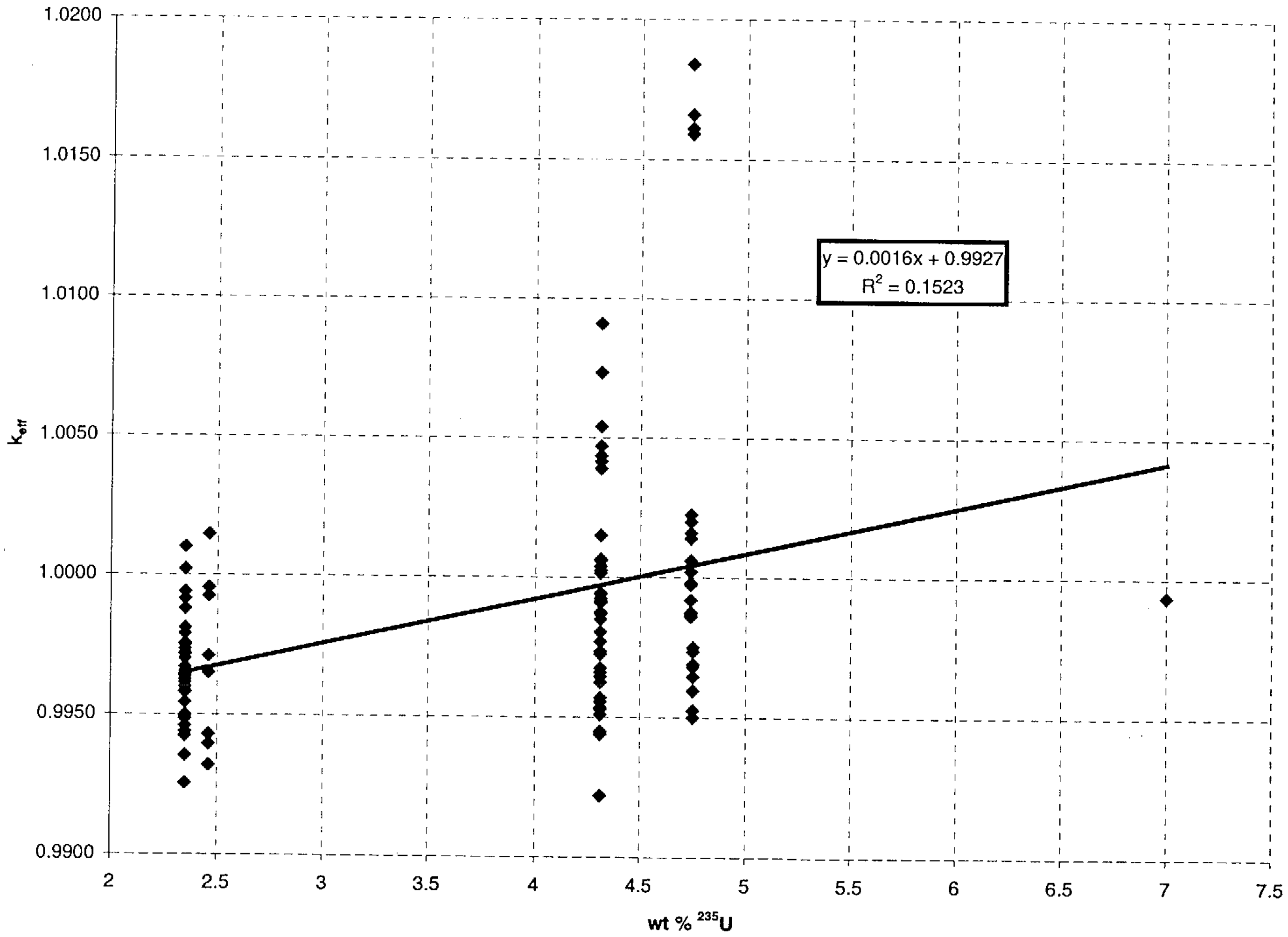


Figure 6.5-10 MONK8A – JEF 2.2 Library – k_{eff} versus Rod Pitch

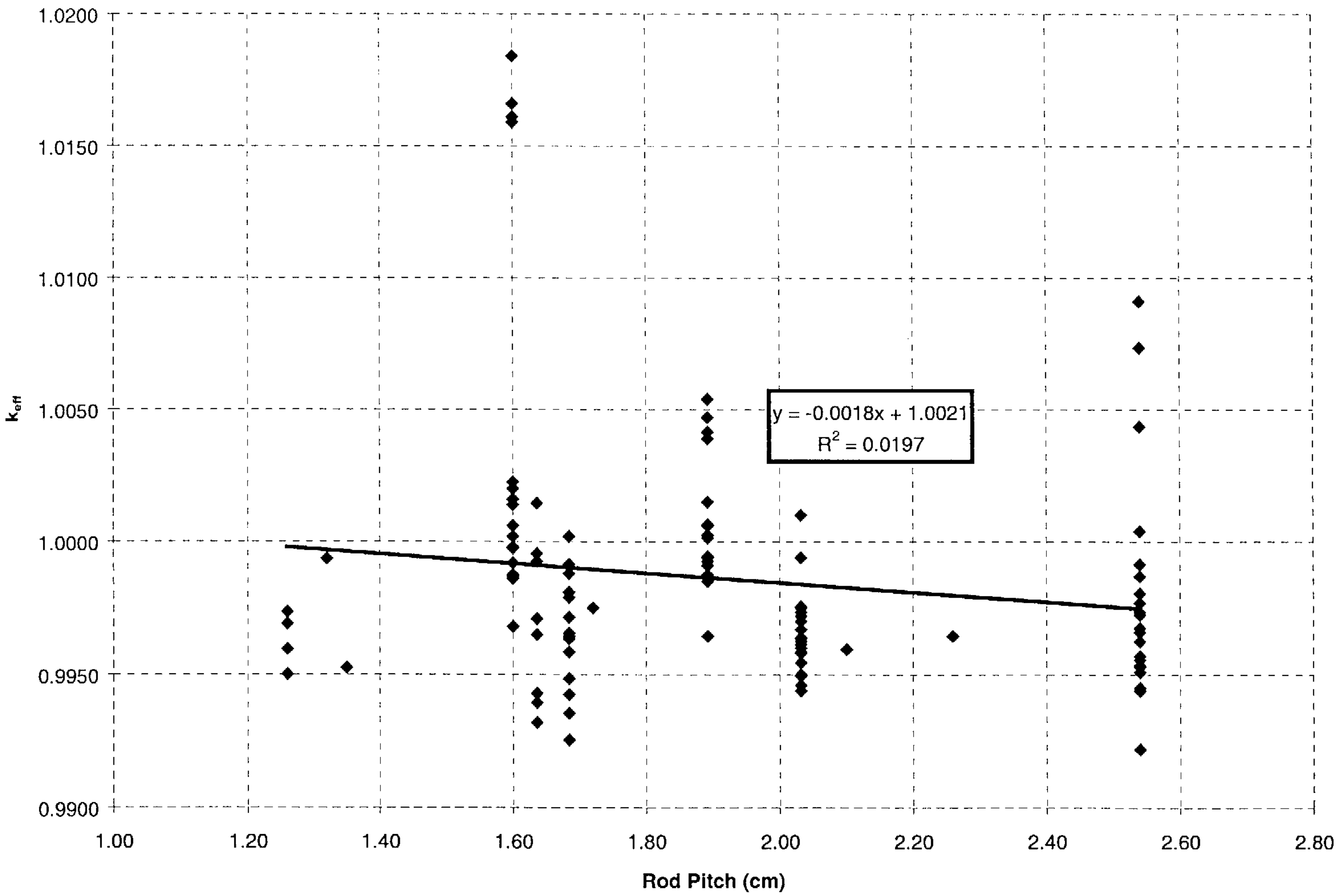


Figure 6.5-11 MONK8A – JEF 2.2 Library - k_{eff} versus H/U (fissile) Atom Ratio

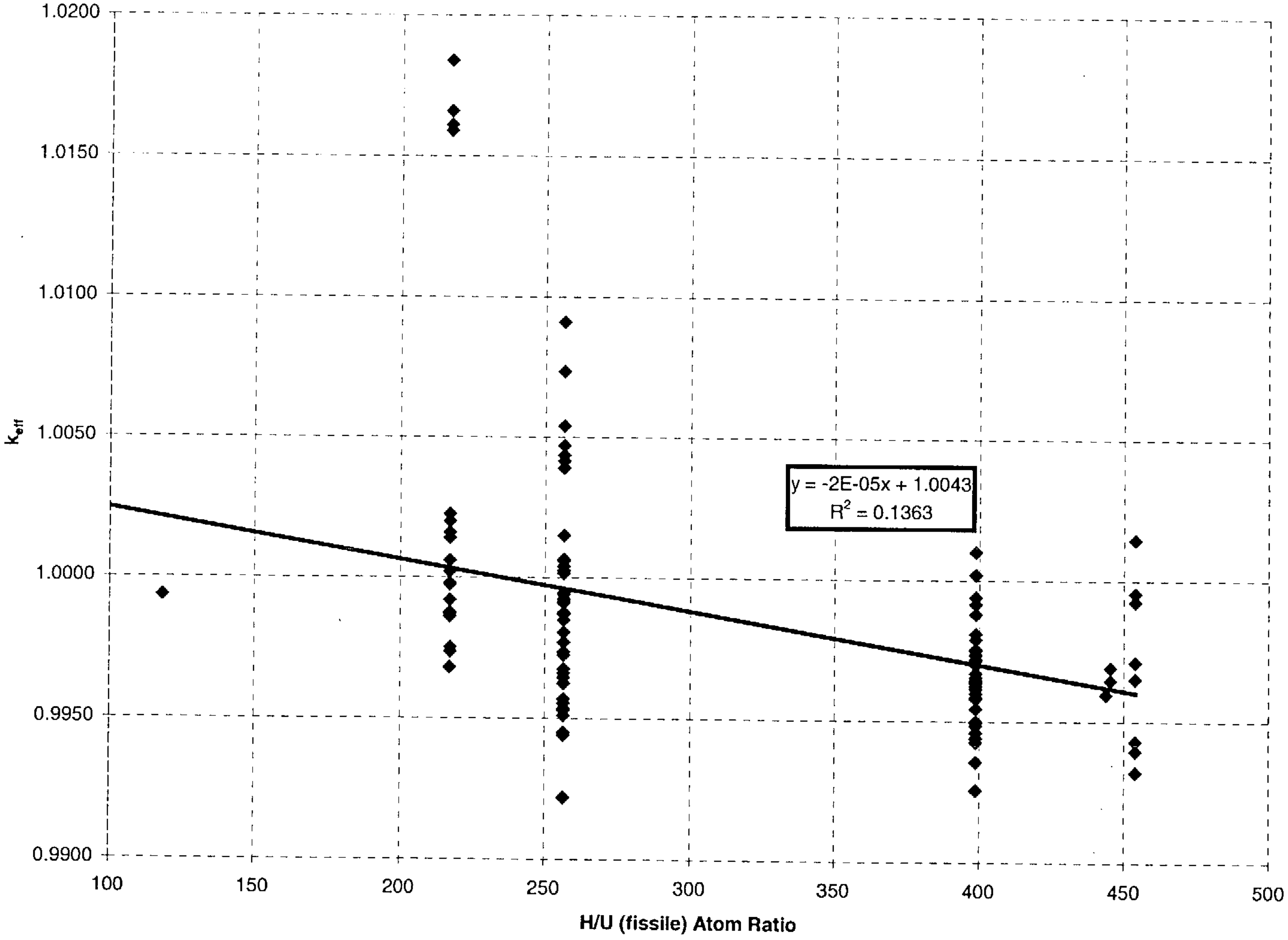


Figure 6.5-12 MONK8A – JEF 2.2 Library - k_{eff} versus ^{10}B Loading

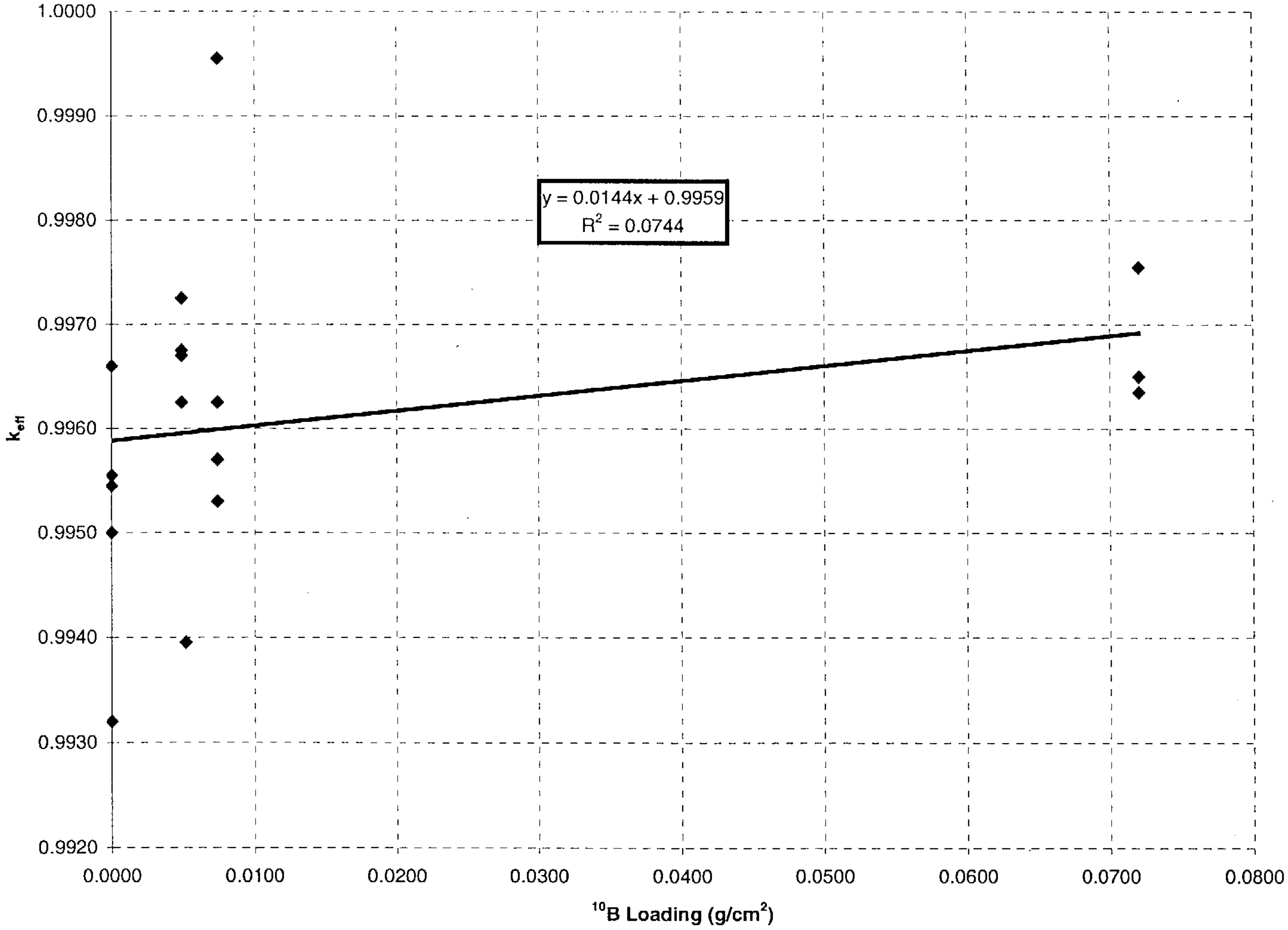


Figure 6.5-13 MONK8A – JEF 2.2 Library - k_{eff} versus Mean Neutron Log(E) Causing Fission

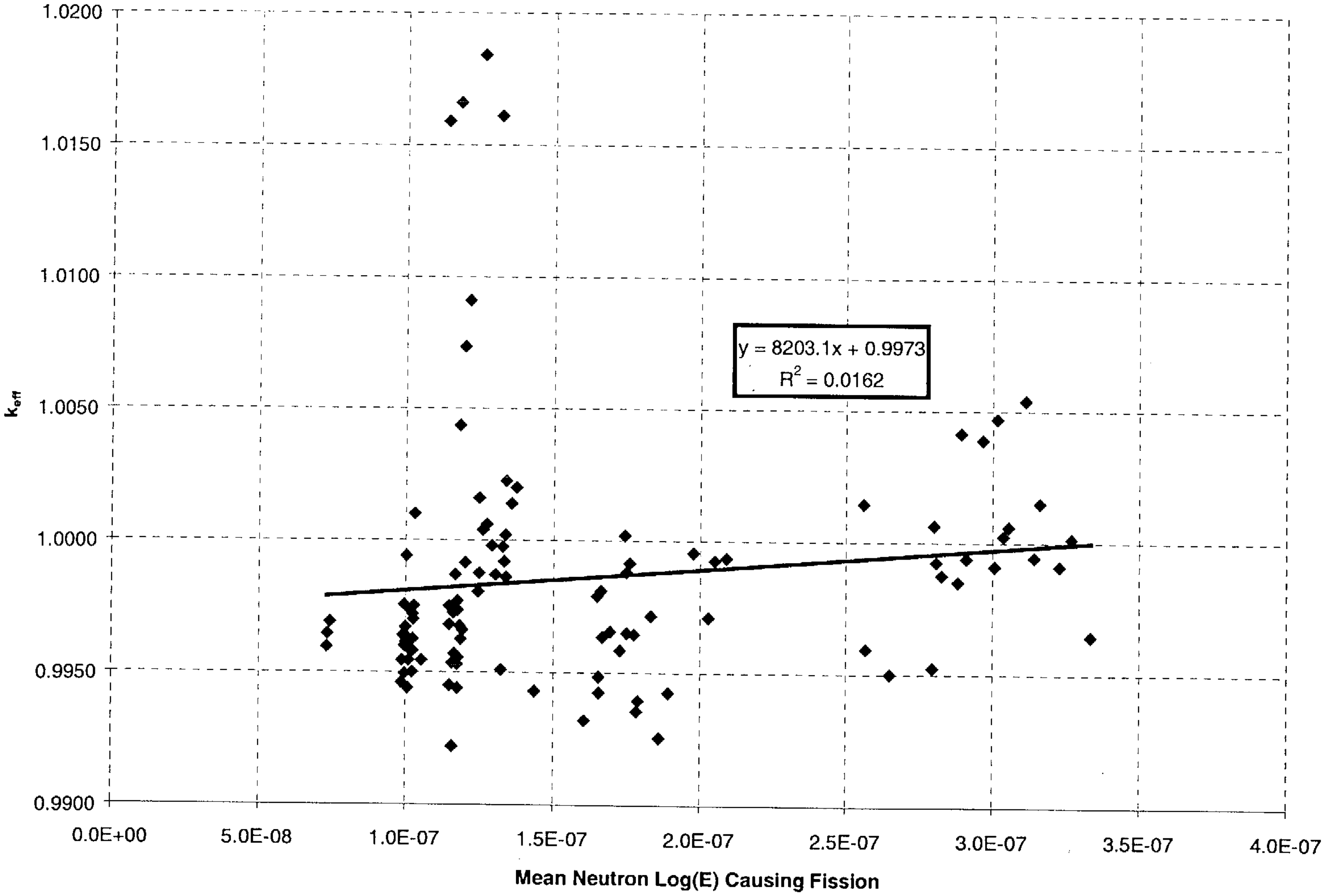


Figure 6.5-14 MONK8A – JEF 2.2 Library - k_{eff} versus Cluster Gap Thickness

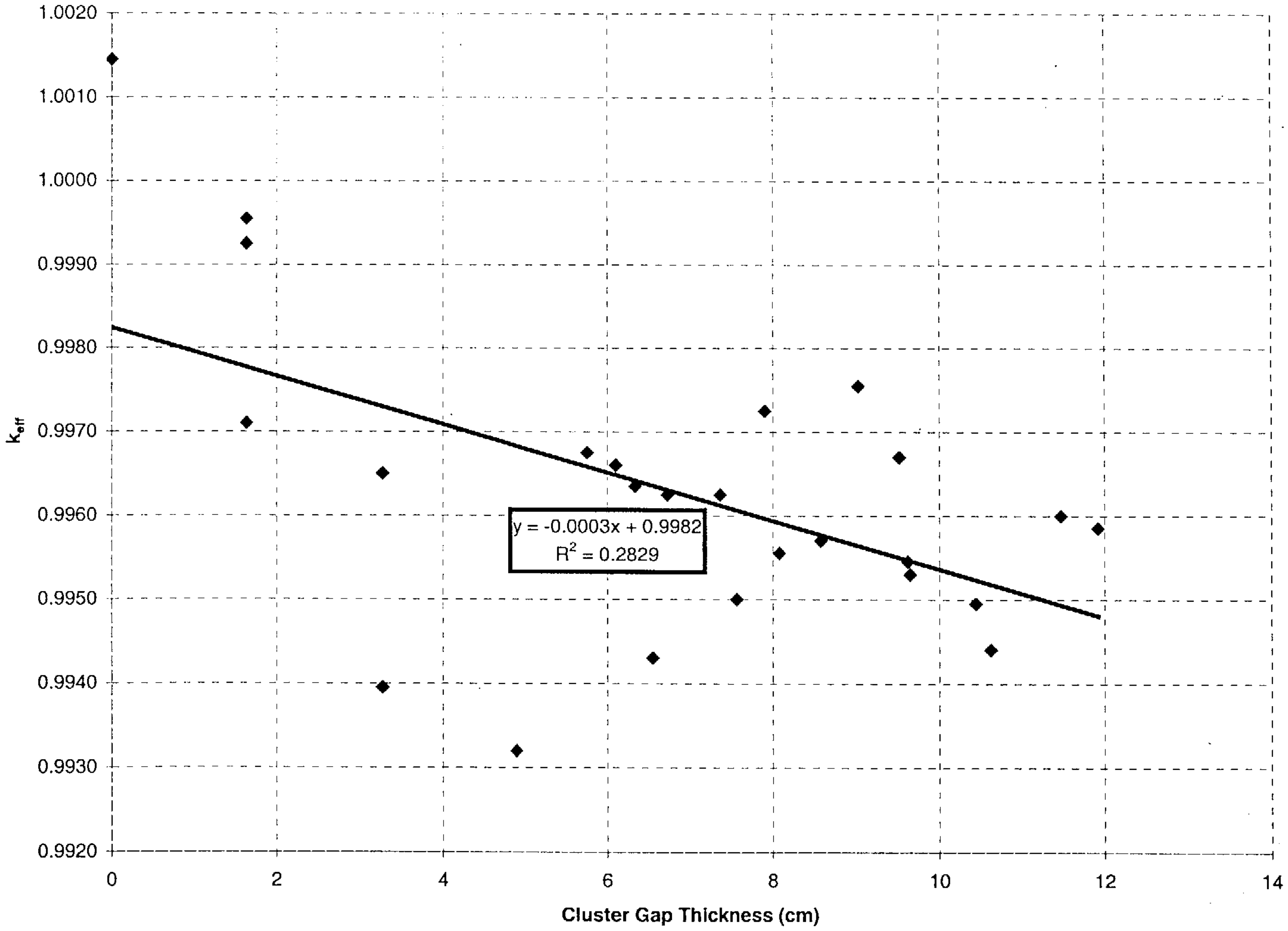


Figure 6.5-15 MONK8A – JEF 2.2 Library - k_{eff} versus Fuel Pellet Outside Diameter

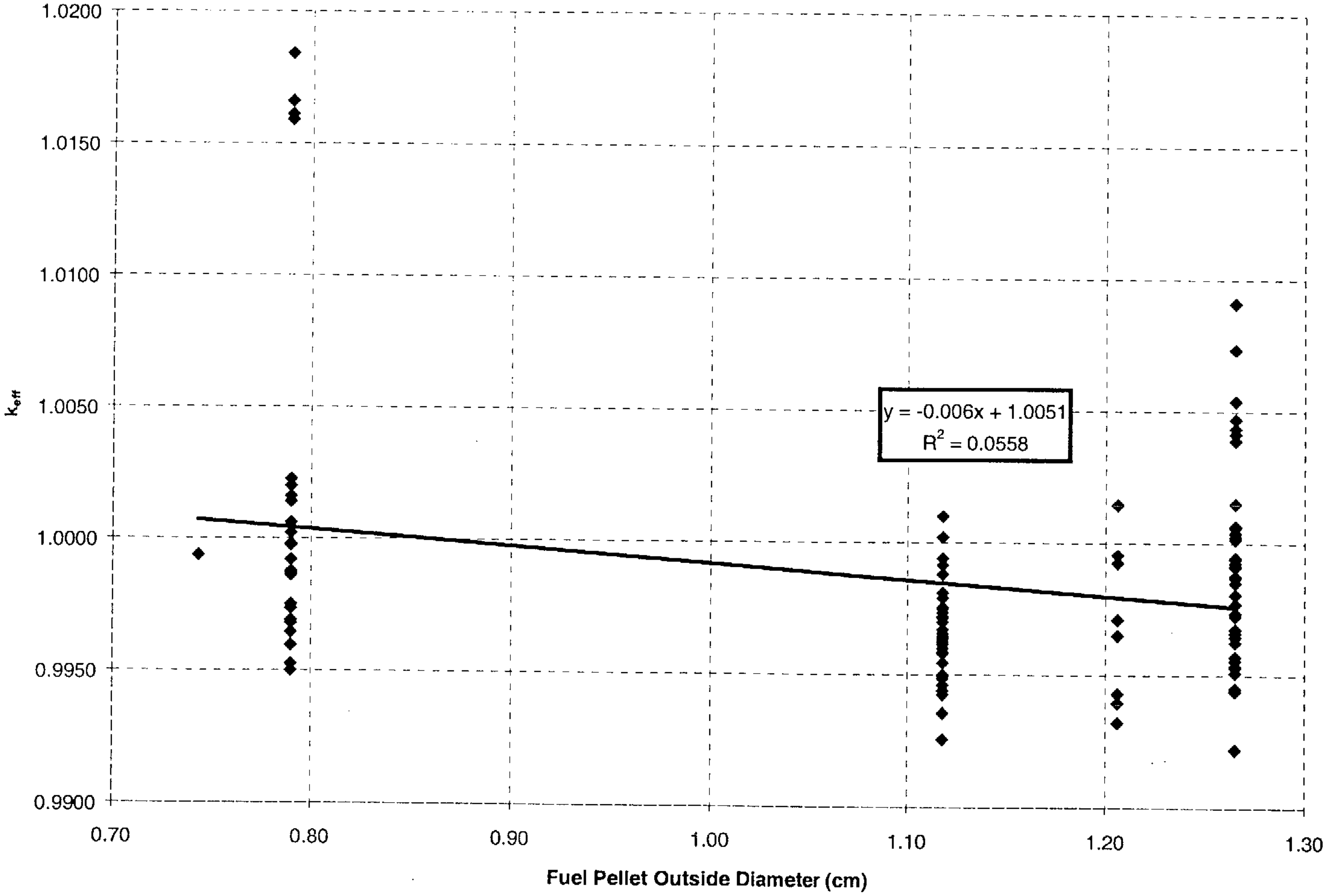


Figure 6.5-16 MONK8A – JEF 2.2 Library - k_{eff} versus Fuel Rod Outside Diameter

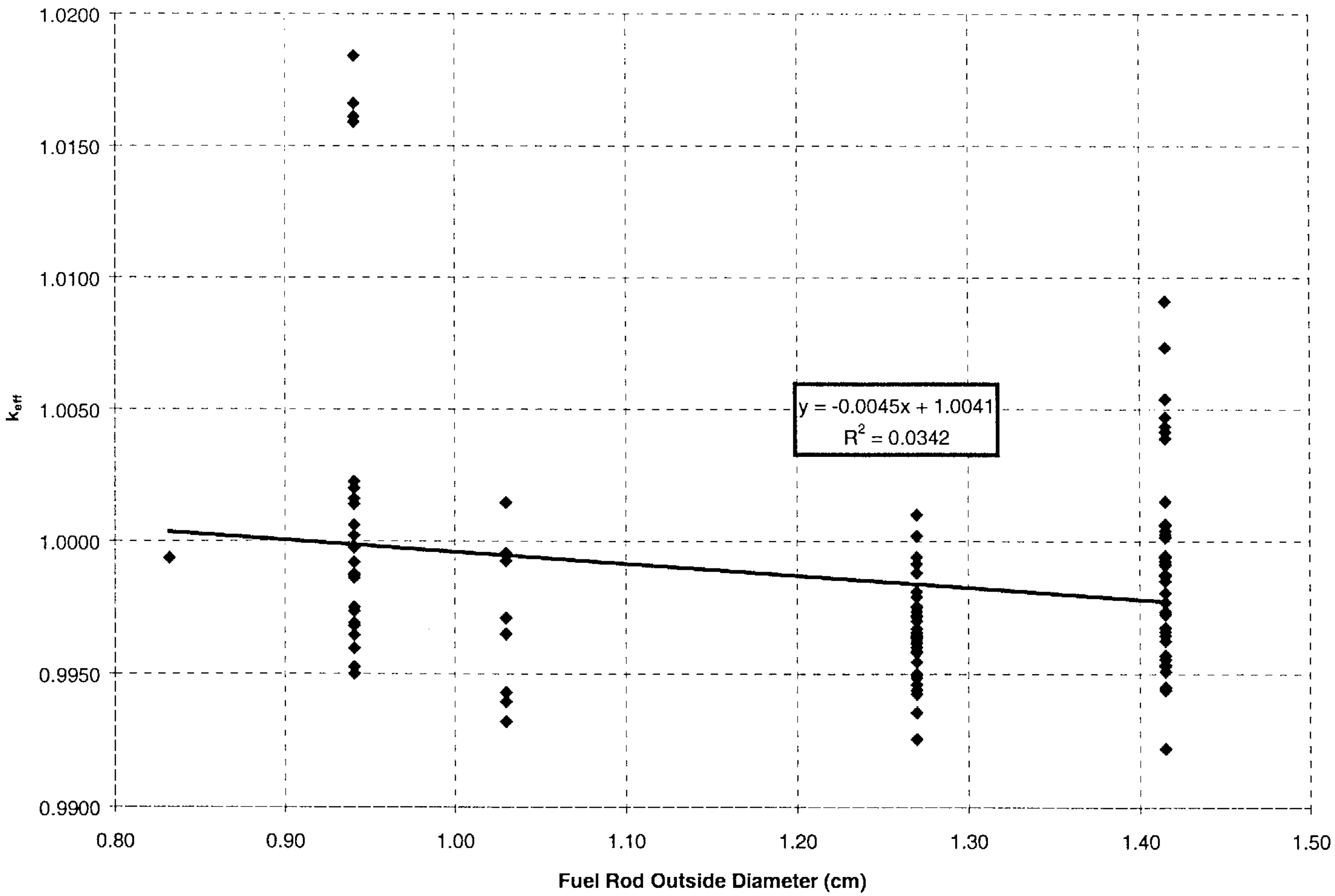


Figure 6.5-17 USLSTATS Output - k_{eff} versus Gap Thickness

```
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      independent  dependent   deviation
variable - x variable - y  in y         variable - x variable - y  in y

6.33000E+00  9.96400E-01  1.00000E-03    1.05100E+01  9.96200E-01  1.00000E-03
9.03000E+00  9.97600E-01  1.00000E-03    1.10900E+01  9.95500E-01  1.00000E-03
1.04400E+01  9.95000E-01  1.00000E-03    1.31900E+01  9.97200E-01  1.00000E-03
1.14700E+01  9.96000E-01  1.00000E-03    1.33700E+01  9.97400E-01  1.00000E-03
7.56000E+00  9.95000E-01  1.00000E-03    1.29600E+01  9.96700E-01  1.00000E-03
9.62000E+00  9.95500E-01  1.00000E-03    9.95000E+00  9.94400E-01  1.00000E-03
7.36000E+00  9.96300E-01  1.00000E-03    7.82000E+00  9.94600E-01  1.00000E-03
9.52000E+00  9.96700E-01  1.00000E-03    9.88800E+00  9.97500E-01  1.00000E-03
1.19200E+01  9.95900E-01  1.00000E-03    1.04380E+01  9.97000E-01  1.00000E-03
1.06200E+01  9.94400E-01  1.00000E-03    1.04380E+01  9.95800E-01  1.00000E-03
8.58000E+00  9.95700E-01  1.00000E-03    9.59800E+00  9.96400E-01  1.00000E-03
9.65000E+00  9.95300E-01  1.00000E-03    8.74800E+00  9.95500E-01  1.00000E-03
6.10000E+00  9.96600E-01  1.00000E-03    8.56600E+00  9.94300E-01  1.00000E-03
8.08000E+00  9.95600E-01  1.00000E-03    9.16600E+00  9.97200E-01  1.00000E-03
5.76000E+00  9.96800E-01  1.00000E-03    9.09600E+00  9.98800E-01  1.00000E-03
7.90000E+00  9.97300E-01  1.00000E-03    9.24600E+00  9.96500E-01  1.00000E-03
6.72000E+00  9.96300E-01  1.00000E-03    8.86600E+00  9.96600E-01  1.00000E-03
0.00000E+00  1.00150E+00  1.00000E-03    8.64600E+00  9.95900E-01  1.00000E-03
1.64000E+00  9.99300E-01  1.00000E-03    8.12600E+00  9.94300E-01  1.00000E-03
1.64000E+00  9.97100E-01  1.00000E-03    7.25600E+00  9.94900E-01  1.00000E-03
1.64000E+00  9.99600E-01  1.00000E-03    9.64600E+00  9.99200E-01  1.00000E-03
3.27000E+00  9.96500E-01  1.00000E-03    9.69600E+00  1.00020E+00  1.00000E-03
3.27000E+00  9.94000E-01  1.00000E-03    8.08600E+00  9.97900E-01  1.00000E-03
4.91000E+00  9.93200E-01  1.00000E-03    7.64600E+00  9.92600E-01  1.00000E-03
6.54000E+00  9.94300E-01  1.00000E-03    9.08600E+00  9.93600E-01  1.00000E-03
1.31000E+01  1.00100E+00  1.00000E-03    9.41600E+00  9.98100E-01  1.00000E-03
1.29800E+01  9.99400E-01  1.00000E-03    9.77600E+00  9.96400E-01  1.00000E-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
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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^2	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^2	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. B (ppm)	Poison	g B10/cm²	Gap(cm)	Gap Den.	Ave. Gfis	Keff	s
Set 4														
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
Set 5										**Gap(cm)**	**Gap Den.**			
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_{eff} versus enrichment	0.361
k_{eff} versus rod pitch	0.328
k_{eff} versus H/U volume ratio	0.246
k_{eff} versus ^{10}B loading	0.069
k_{eff} versus average group causing fission	0.133
k_{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}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}B areal density (g/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}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}B loading (g/cm^2)	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_{eff} versus enrichment	0.390
k_{eff} versus rod pitch	0.140
k_{eff} versus H/U (fissile) atomic ratio	0.369
k_{eff} versus ^{10}B loading	0.273
k_{eff} versus log energy causing fission	0.127
k_{eff} versus cluster gap thickness	0.532
k_{eff} versus fuel diameter	0.236
k_{eff} versus clad diameter	0.185

Table 6.5-6 MONK8A – JEF 2.2 Library Validation Statistics

Case	Configuration	wt % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (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 % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (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

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

Case	Configuration	wt % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (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 % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (JEF2.2)	σ
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_4C 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 % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G $^{10}B/cm^2$	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (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 % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (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 % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (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 % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (JEF2.2)	σ
17.25	18x23(center), 18x20(two outer)	2.35	1.684	1.1176	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	1.1176	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	1.1176	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	1.1176	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	1.1176	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 % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k$_{eff}$ (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 % ^{235}U	Pitch (cm)	Fuel OD (cm)	Clad OD (cm)	Clad Mat'l.	H/U (fissile)	Sol. B (ppm)	Poison Type/Absorber	G ^{10}B/cm^2	Cluster Gap (cm)	Wall/ Cluster (cm)	Reflector	Mean Log(E) Neutrons Causing Fission	k_{eff} (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_{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® 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 $k_{eff} + 2\sigma$ of 0.91014. This is less reactive than the accident condition for the transport cask loaded with the Westinghouse 17 x 17 OFA assemblies ($k_{eff} + 2\sigma$ 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® 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 $k_{eff} + 2\sigma = 0.96268$. This is less reactive than the same array of Westinghouse 17x17 OFA assemblies ($k_{eff} + 2\sigma = 0.9751$ 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 Δk_{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 % ^{235}U and 3.5 wt % ^{235}U. The maximum planar average enrichment of this batch is 3.99 wt % ^{235}U. In the other batch, the fuel rod enrichments are 4.0 wt % ^{235}U and 3.4 wt % ^{235}U. The maximum planar average enrichment of this batch is 3.92 wt % ^{235}U. Loading 24 variably enriched fuel assemblies having both a maximum fuel rod enrichment of 4.21 wt % ^{235}U and a maximum planar average enrichment of 3.99 wt % ^{235}U results in a $k_{eff} + 2\sigma$ of 0.89940. Using a planar fuel rod enrichment of 4.2 wt % ^{235}U results in a $k_{eff} + 2\sigma$ of 0.91014. Therefore, all of the fuel rods are conservatively modeled as if enriched to 4.2 wt % ^{235}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}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}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}U.
- Variably enriched fuel with a maximum fuel rod enrichment of 4.21 wt % ^{235}U with a maximum planar average enrichment of 3.99 wt % ^{235}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}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

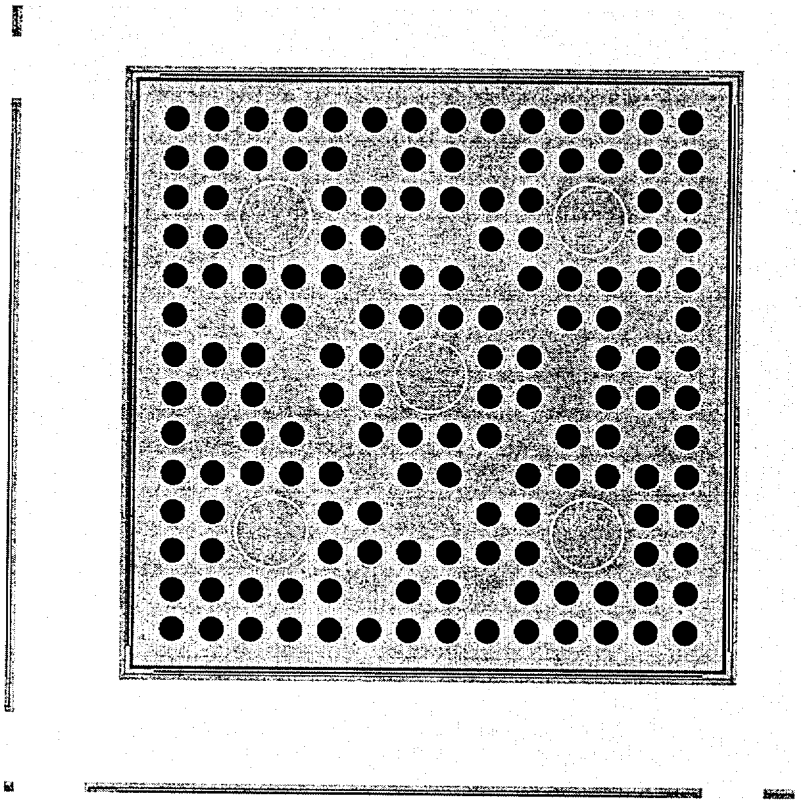

Figure 6.6.1.1-2 Consolidated Fuel Geometry, 113 Empty Fuel Rod Positions, Maine Yankee Site Specific Fuel

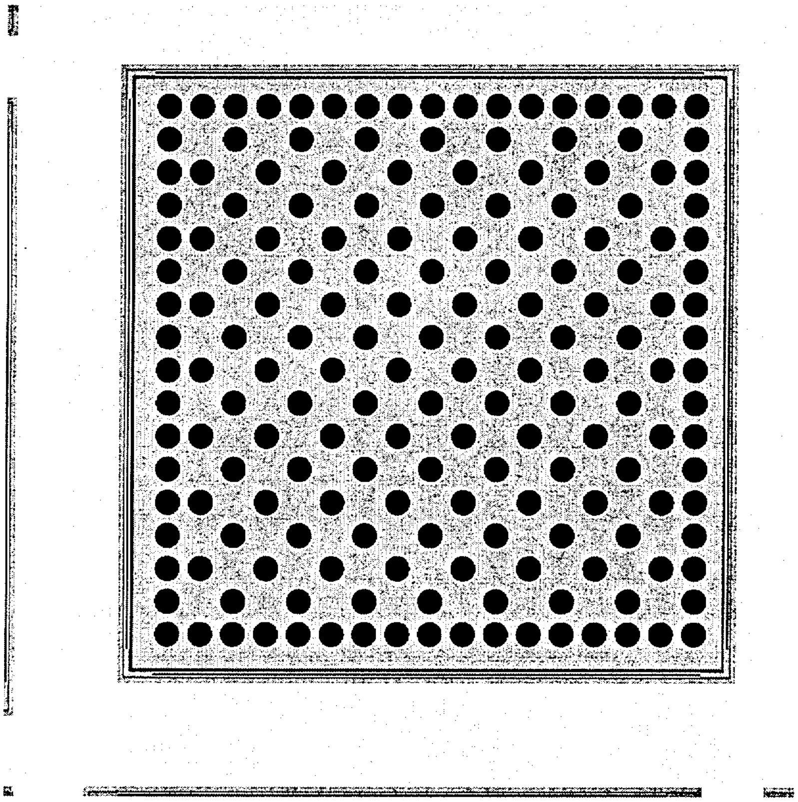

Table 6.6.1.1-1 Maine Yankee Standard Fuel Characteristics

Fuel Class[1]	Vendor	Array	Version	Number of Fuel Rods	Pitch (in.)	Rod Diameter (in.)	Clad ID (in.)	Clad Thickness (in.)	Pellet Diameter (in.)	GT[2] Thickness (in.)
1	CE	14x14	Std.	160[3]-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[4]-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[1]	4.2 wt % ^{235}U
Maximum Number of Fuel Rods[2]	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 % ^{235}U with a maximum planar average enrichment of 3.99 wt % ^{235}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	σ	k-eff +2σ
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_{eff}	σ	$k_{eff} + 2\sigma$
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}	σ	$k_{eff} + 2\sigma$
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}	σ	$k_{eff} + 2\sigma$
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}	σ	$k_{eff} + 2\sigma$
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}	σ	$k_{eff} + 2\sigma$
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 TRANPORT 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 TRANPORT 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 TRANPORT 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 ZFC=PER YXF=MIRROR END BOUNDS
   END DATA

SECONDARY MODULE 000008    HAS BEEN CALLED.

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

```
 CCCCCCCCCCC     SSSSSSSSSSS      AAAAAAAAA      SSSSSSSSSSS     22222222222    5555555555555
CCCCCCCCCCCCC   SSSSSSSSSSSSS    AAAAAAAAAAA    SSSSSSSSSSSSS   2222222222222   5555555555555
CC         CC   SS         SS   AA         AA   SS         SS   22         22   55
CC              SS              AA         AA   SS                         22   55
CC              SS              AA         AA   SS                         22   55
CC              SSSSSSSSSSSS    AAAAAAAAAAAAA   SSSSSSSSSSSS             22     555555555555
CC               SSSSSSSSSSSS   AAAAAAAAAAAAA    SSSSSSSSSSSS          22       5555555555555
CC                         SS   AA         AA              SS        22                    55
CC                         SS   AA         AA              SS      22                      55
CC         CC   SS         SS   AA         AA   SS         SS    22             55         55
CCCCCCCCCCCCC   SSSSSSSSSSSSS   AA         AA   SSSSSSSSSSSSS   2222222222222   5555555555555
 CCCCCCCCCCC     SSSSSSSSSSS    AA         AA    SSSSSSSSSSS    2222222222222    55555555555


 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC


   0000000       88888888888               //    22222222222     33333333333               //    99999999999     666666666666
  000000000     8888888888888             //    2222222222222   3333333333333             //    9999999999999   6666666666666
 00       00    88         88            //     22         22   33         33            //     99         99   66
00         00   88         88           //                 22              33           //      99         99   66
00         00   88         88          //                  22              33          //       99         99   66
00         00    88888888888          //                 22             333          //        9999999999999   666666666666
00         00    88888888888         //                22               333         //          999999999999   6666666666666
00         00   88         88       //               22                    33       //                     99   66         66
00         00   88         88      //              22                      33      //                      99   66         66
 00       00    88         88     //             22             33         33     //                       99   66         66
  000000000     8888888888888    //             2222222222222   3333333333333    //             9999999999999   6666666666666
   0000000       88888888888    //              2222222222222    33333333333    //              999999999999     66666666666


   0000000       666666666666                             44     666666666666                    22222222222     666666666666
  000000000     6666666666666                            444    6666666666666                   2222222222222   6666666666666
 00       00    66                    :::              4444    66                    :::       22         22   66
00         00   66                    :::             44 44    66                    :::                  22   66
00         00   66                    :::            44  44    66                    :::                  22   66
00         00   666666666666                         44   44    666666666666                             22     666666666666
00         00   6666666666666                       44    44    6666666666666                          22       6666666666666
00         00   66         66         :::        444444444444   66         66         :::            22         66         66
00         00   66         66         :::       4444444444444   66         66         :::          22           66         66
 00       00    66         66         :::                 44    66         66         :::        22             66         66
  000000000     6666666666666                             44    6666666666666                   2222222222222   6666666666666
   0000000       66666666666                              44     66666666666                    2222222222222    66666666666


 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC
```

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
MXX             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
 CLADOD    0.9144 CM CLAD OUTER DIAMETER
 MCLAD          2 MIXTURE NO. OF CLAD
 GAPOD     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                                           VOLUME                                  ***
***         NUMBER             DATA SET NAME                 NAME       UNIT FUNCTION               ***
***         ------             -------------                 ----       -------------               ***
***                                                                                                 ***
***           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                                     08/12/94   ***
***                                        L.M.PETRIE    -    ORNL                                  ***
***                                                                                                 ***
***                                                                                                 ***
***                                                                                                 ***
***                                                                                                 ***
*******************************************************************************************************
*******************************************************************************************************
```

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

```
                KK          KK  EEEEEEEEEEEEE   NN          NN   OOOOOOOOOOO                    VV          VV
                KK         KK   EEEEEEEEEEEEE   NNN         NN  OOOOOOOOOOOOO                   VV          VV
                KK        KK    EE              NNNN        NN  OO         OO                   VV          VV
                KK       KK     EE              NN NN       NN  OO         OO                   VV          VV
                KK      KK      EE              NN   NN     NN  OO         OO                   VV          VV
                KKKKKKKK        EEEEEEEEE       NN    NN    NN  OO         OO   -------------   VV          VV
                KKKKKKKK        EEEEEEEEE       NN     NN   NN  OO         OO   -------------    VV        VV
                KK      KK      EE              NN      NN  NN  OO         OO                      VV     VV
                KK       KK     EE              NN       NN NN  OO         OO                       VV   VV
                KK        KK    EE              NN        NNNN  OO         OO                        VV VV
                KK         KK   EEEEEEEEEEEEE   NN         NNN  OOOOOOOOOOOOO                         VVV
                KK          KK  EEEEEEEEEEEEE   NN          NN   OOOOOOOOOOO                           V


 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC


   0000000       88888888888                //    22222222222      33333333333                //    99999999999     666666666666
  000000000     8888888888888              //   2222222222222   3333333333333              //   9999999999999   6666666666666
 00       00    88         88             //    22         22   33         33             //    99         99   66
00         00   88         88            //                22              33            //     99         99   66
00         00   88         88           //                 22              33           //      99         99   66
00         00    88888888888           //                22              333           //       9999999999999   666666666666
00         00    88888888888          //               22                333          //         999999999999   6666666666666
00         00   88         88        //              22                    33        //                    99   66         66
00         00   88         88       //             22                      33       //                     99   66         66
 00       00    88         88      //            22             33         33      //                      99   66         66
  000000000     8888888888888     //            2222222222222   3333333333333     //            9999999999999   6666666666666
   0000000       88888888888     //             2222222222222    33333333333     //             999999999999     66666666666


   0000000       666666666666                            44      666666666666                            44        0000000
  000000000     6666666666666                           444     6666666666666                           444       000000000
 00       00    66                    :::              4444     66                    :::              4444      00       00
00         00   66                    :::             44 44     66                    :::             44 44     00         00
00         00   66                    :::            44  44     66                    :::            44  44     00         00
00         00   666666666666                        44   44     666666666666                        44   44     00         00
00         00   6666666666666                      44    44     6666666666666                      44    44     00         00
00         00   66         66         :::        444444444444   66         66         :::        444444444444   00         00
00         00   66         66         :::       4444444444444   66         66         :::       4444444444444   00         00
 00       00    66         66         :::                44     66         66         :::                44      00       00
  000000000     6666666666666                            44     6666666666666                            44       000000000
   0000000       66666666666                             44      66666666666                             44        0000000


 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC
```

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:  000009                                        *****
*****                                                                      *****
*****        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                       ***
***                                                                                                             ***
***                  NB8        NUMBER OF D.A. BLOCKS ON UNIT  8                      200                       ***
***                                                                                                             ***
***                  NL8        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 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 6.6.2-1 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          ***
***                                                                                                                 ***
***********************************************************************************************************************
***********************************************************************************************************************
***                                                                                                                 ***
***      UNIT                                                    VOLUME                                             ***
***     NUMBER              DATA SET NAME                         NAME        UNIT FUNCTION                         ***
***     ------              -------------                         ----        -------------                         ***
***                                                                                                                 ***
***   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    ........


                          CROSS SECTIONS READ FROM THE AMPX WORKING LIBRARY ON UNIT    4
```

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                                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) = 0.99817E-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) =  2.5549
   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) = 0.99817E-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                     UPDATED
08/12/94
   9008016  3.33846E-03  8.88074E-01     8016     15.9904      OXYGEN-16      ENDF/B-IV MAT 1276                                UPDATED
08/12/94

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                UPDATED
08/12/94
 10008016   3.33846E-06  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       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    ELAPSED TIME      AVERAGE        AVG K-EFF        MATRIX          MATRIX K-EFF
    GENERATION    K-EFFECTIVE      MINUTES       K-EFFECTIVE      DEVIATION      K-EFFECTIVE         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     AVERAGE                          67 PER CENT           95 PER CENT           99 PER CENT       NUMBER OF
   SKIPPED     K-EFFECTIVE      DEVIATION     CONFIDENCE INTERVAL   CONFIDENCE INTERVAL   CONFIDENCE INTERVAL   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.O  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 TRANPORT 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 TRANPORT 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 TRANPORT 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   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 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)

```
 CCCCCCCCCCC     SSSSSSSSSSS      AAAAAAAAA      SSSSSSSSSSS     22222222222    5555555555555
CCCCCCCCCCCCC   SSSSSSSSSSSSS    AAAAAAAAAAA    SSSSSSSSSSSSS   2222222222222   5555555555555
CC         CC   SS         SS   AA         AA   SS         SS   22         22   55
CC              SS              AA         AA   SS                         22   55
CC              SS              AA         AA   SS                         22   55
CC              SSSSSSSSSSSS    AAAAAAAAAAAAA   SSSSSSSSSSSS             22     555555555555
CC               SSSSSSSSSSSS   AAAAAAAAAAAAA    SSSSSSSSSSSS          22       5555555555555
CC                         SS   AA         AA              SS        22                    55
CC                         SS   AA         AA              SS      22                      55
CC         CC   SS         SS   AA         AA   SS         SS    22             55         55
CCCCCCCCCCCCC   SSSSSSSSSSSSS   AA         AA   SSSSSSSSSSSSS   2222222222222   5555555555555
 CCCCCCCCCCC     SSSSSSSSSSS    AA         AA    SSSSSSSSSSS    2222222222222    55555555555


 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC


   0000000       88888888888               //    22222222222     22222222222               //    99999999999     66666666666
  000000000     8888888888888             //    2222222222222   2222222222222             //    9999999999999   6666666666666
 00       00    88         88            //     22         22   22         22            //     99         99   66
00         00   88         88           //                 22              22           //      99         99   66
00         00   88         88          //                  22              22          //       99         99   66
00         00    88888888888          //                 22              22           //        9999999999999   666666666666
00         00    88888888888         //                22              22            //           999999999999   6666666666666
00         00   88         88       //               22              22             //                     99   66         66
00         00   88         88      //              22              22              //                      99   66         66
 00       00    88         88     //             22              22               //                       99   66         66
  000000000     8888888888888    //             2222222222222   2222222222222    //             9999999999999   6666666666666
   0000000       88888888888    //              2222222222222   2222222222222   //              999999999999     66666666666


   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                      11           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        :::           11           00         00
   11              11                :::         00       00     00       00         :::           11            00       00
11111111        11111111                          000000000       000000000                     11111111          000000000
11111111        11111111                           0000000         0000000                      11111111           0000000
```

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

```
 SSSSSSSSSSS     CCCCCCCCCCC       AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC
```

```
********************************************************************************
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                  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
MXX            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
```

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                 ***
***                                                                                                                   ***
*************************************************************************************************************************
*************************************************************************************************************************
***                                                                                                                   ***
***                                   ********** DATA LIBRARY INFORMATION **********                                  ***
***                                                                                                                   ***
***            UNIT                                                     VOLUME                                        ***
***           NUMBER                 DATA SET NAME                       NAME        UNIT FUNCTION                    ***
***           ------                 -------------                       ----        -------------                    ***
***                                                                                                                   ***
***             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\ARAC-                SHORT CROSS SECTION LIBRARY      ***
***                                                                                                                   ***
***             90       C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARAC-                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                                                     08/12/94    ***
***                                         L.M.PETRIE    -    ORNL                                                   ***
***                                                                                                                   ***
***                                                                                                                   ***
***                                                                                                                   ***
***                                                                                                                   ***
*************************************************************************************************************************
*************************************************************************************************************************
```

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

```
                KK         KK   EEEEEEEEEEEEE   NN         NN    OOOOOOOOOOO                    VV         VV
                KK        KK    EEEEEEEEEEEEE   NNN        NN   OOOOOOOOOOOOO                   VV         VV
                KK       KK     EE              NNNN       NN   OO         OO                   VV         VV
                KK      KK      EE              NN NN      NN   OO         OO                   VV         VV
                KK     KK       EE              NN  NN     NN   OO         OO                   VV         VV
                KKKKKKKK        EEEEEEEEE       NN   NN    NN   OO         OO   -------------   VV         VV
                KKKKKKKK        EEEEEEEEE       NN    NN   NN   OO         OO   -------------    VV       VV
                KK     KK       EE              NN     NN  NN   OO         OO                     VV     VV
                KK      KK      EE              NN      NN NN   OO         OO                      VV   VV
                KK       KK     EE              NN       NNNN   OO         OO                       VV VV
                KK        KK    EEEEEEEEEEEEE   NN        NNN   OOOOOOOOOOOOO                        VVV
                KK         KK   EEEEEEEEEEEEE   NN         NN    OOOOOOOOOOO                          V


 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLL    EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLL    EEEEEEEEEEEEE                   PP               CCCCCCCCCCC


   0000000       88888888888               //    22222222222     22222222222               //    99999999999     66666666666
  000000000     8888888888888             //    2222222222222   2222222222222             //    9999999999999   6666666666666
 00       00    88         88            //     22         22   22         22            //     99         99   66
00         00   88         88           //                 22              22           //      99         99   66
00         00   88         88          //                  22              22          //       99         99   66
00         00    88888888888          //                  22              22          //        9999999999999   666666666666
00         00    88888888888         //                 22              22           //          999999999999   6666666666666
00         00   88         88       //                22              22            //                     99   66         66
00         00   88         88      //               22              22             //                      99   66         66
 00       00    88         88     //              22              22              //                       99   66         66
  000000000     8888888888888    //             2222222222222   2222222222222   //             9999999999999   6666666666666
   0000000       88888888888    //              2222222222222   2222222222222   //               99999999999     66666666666


     11              11                            0000000         0000000                       22222222222     99999999999
    111             111                           000000000       000000000                     2222222222222   9999999999999
   1111            1111              :::         00       00     00       00         :::        22         22   99         99
     11              11              :::        00         00   00         00        :::                   22   99         99
     11              11              :::        00         00   00         00        :::                   22   99         99
     11              11                         00         00   00         00                             22    9999999999999
     11              11                         00         00   00         00                           22       999999999999
     11              11              :::        00         00   00         00        :::              22                   99
     11              11              :::        00         00   00         00        :::            22                     99
     11              11              :::         00       00     00       00         :::          22                       99
  11111111        11111111                        000000000       000000000                     2222222222222   9999999999999
  11111111        11111111                         0000000         0000000                      2222222222222    99999999999
```

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

```
 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC
```

```
********************************************************************************
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                  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                                           *****
*****                                                                      *****
*****              JOBNAME:  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              ***
***                                                                                                           ***
***                      NB8          NUMBER OF D.A. BLOCKS ON UNIT  8                       200              ***
***                                                                                                           ***
***                      NL8          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               DATA SET NAME                  NAME      UNIT FUNCTION           ***
***       ------               -------------                  ----      -------------           ***
***                                                                                             ***
***     XSC  14    C:\PROJECTS\UMS\UMS-1089\OPT-MOD\ARRAY\ARAC-          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\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    ELAPSED TIME      AVERAGE        AVG K-EFF        MATRIX       MATRIX K-EFF
   GENERATION   K-EFFECTIVE      MINUTES       K-EFFECTIVE      DEVIATION      K-EFFECTIVE      DEVIATION
KENO MESSAGE NUMBER K5-132     WARNING....ONLY 916 INDEPENDENT FISSION POINTS WERE GENERATED
         1      8.41911E-01     1.14333E-01     1.00000E+00     0.00000E+00     0.00000E+00     0.00000E+00
KENO MESSAGE NUMBER K5-132     WARNING....ONLY 976 INDEPENDENT FISSION POINTS WERE GENERATED
         2      8.91415E-01     1.59167E-01     1.00000E+00     0.00000E+00     0.00000E+00     0.00000E+00
KENO MESSAGE NUMBER K5-132     WARNING....ONLY 989 INDEPENDENT FISSION POINTS WERE GENERATED
         3      9.04504E-01     2.00500E-01     9.04504E-01     0.00000E+00     0.00000E+00     0.00000E+00
         4      9.06173E-01     2.39833E-01     9.05338E-01     8.34495E-04     0.00000E+00     0.00000E+00
         5      9.10171E-01     2.78167E-01     9.06949E-01     1.68147E-03     0.00000E+00     0.00000E+00
         6      9.50256E-01     3.17667E-01     9.17776E-01     1.08918E-02     0.00000E+00     0.00000E+00
         7      9.04911E-01     3.57000E-01     9.15203E-01     8.82042E-03     0.00000E+00     0.00000E+00
         8      9.29772E-01     3.96333E-01     9.17631E-01     7.60014E-03     0.00000E+00     0.00000E+00
         9      9.16157E-01     4.34833E-01     9.17421E-01     6.42674E-03     0.00000E+00     0.00000E+00
        10      9.84707E-01     4.74167E-01     9.25831E-01     1.00856E-02     0.00000E+00     0.00000E+00
        11      8.95141E-01     5.15333E-01     9.22421E-01     9.52588E-03     0.00000E+00     0.00000E+00
        12      9.25400E-01     5.53833E-01     9.22719E-01     8.52541E-03     0.00000E+00     0.00000E+00
        13      9.19387E-01     5.93167E-01     9.22416E-01     7.71747E-03     0.00000E+00     0.00000E+00
        14      8.94697E-01     6.32500E-01     9.20106E-01     7.41408E-03     0.00000E+00     0.00000E+00
        15      9.36445E-01     6.72833E-01     9.21363E-01     6.93480E-03     0.00000E+00     0.00000E+00
        16      9.48605E-01     7.12167E-01     9.23309E-01     6.70878E-03     0.00000E+00     0.00000E+00
        17      9.35131E-01     7.51500E-01     9.24097E-01     6.29506E-03     0.00000E+00     0.00000E+00
        18      9.22992E-01     7.90000E-01     9.24028E-01     5.88890E-03     0.00000E+00     0.00000E+00
        19      9.29173E-01     8.29333E-01     9.24331E-01     5.53993E-03     0.00000E+00     0.00000E+00
        20      9.35483E-01     8.67833E-01     9.24950E-01     5.25971E-03     0.00000E+00     0.00000E+00
        21      9.34083E-01     9.06167E-01     9.25431E-01     4.99836E-03     0.00000E+00     0.00000E+00
        22      9.30179E-01     9.44667E-01     9.25668E-01     4.74780E-03     0.00000E+00     0.00000E+00
        23      9.11446E-01     9.85000E-01     9.24991E-01     4.56655E-03     0.00000E+00     0.00000E+00
        24      8.80720E-01     1.02333E+00     9.22979E-01     4.79658E-03     0.00000E+00     0.00000E+00
        25      9.52190E-01     1.06183E+00     9.24249E-01     4.75600E-03     0.00000E+00     0.00000E+00
        26      9.21261E-01     1.10117E+00     9.24124E-01     4.55522E-03     0.00000E+00     0.00000E+00
        27      9.33612E-01     1.14050E+00     9.24504E-01     4.38567E-03     0.00000E+00     0.00000E+00
        28      9.13231E-01     1.17817E+00     9.24070E-01     4.23586E-03     0.00000E+00     0.00000E+00
        29      9.27053E-01     1.21750E+00     9.24181E-01     4.07746E-03     0.00000E+00     0.00000E+00
        30      9.66969E-01     1.25583E+00     9.25709E-01     4.21584E-03     0.00000E+00     0.00000E+00
        31      9.47153E-01     1.29533E+00     9.26448E-01     4.13453E-03     0.00000E+00     0.00000E+00
        32      9.63032E-01     1.33367E+00     9.27668E-01     4.17634E-03     0.00000E+00     0.00000E+00
        33      9.64676E-01     1.37217E+00     9.28862E-01     4.21209E-03     0.00000E+00     0.00000E+00
        34      9.50496E-01     1.40967E+00     9.29538E-01     4.13400E-03     0.00000E+00     0.00000E+00
        35      9.33633E-01     1.44900E+00     9.29662E-01     4.00869E-03     0.00000E+00     0.00000E+00
        36      9.20850E-01     1.48850E+00     9.29403E-01     3.89762E-03     0.00000E+00     0.00000E+00
        37      9.30132E-01     1.52867E+00     9.29423E-01     3.78468E-03     0.00000E+00     0.00000E+00
        38      9.28127E-01     1.56617E+00     9.29387E-01     3.67823E-03     0.00000E+00     0.00000E+00
        39      9.08762E-01     1.60650E+00     9.28830E-01     3.62061E-03     0.00000E+00     0.00000E+00
        40      9.28885E-01     1.64583E+00     9.28831E-01     3.52404E-03     0.00000E+00     0.00000E+00
        41      9.33467E-01     1.68333E+00     9.28950E-01     3.43455E-03     0.00000E+00     0.00000E+00
        42      9.12224E-01     1.72100E+00     9.28532E-01     3.37360E-03     0.00000E+00     0.00000E+00
        43      9.09205E-01     1.76033E+00     9.28061E-01     3.32388E-03     0.00000E+00     0.00000E+00
        44      9.35166E-01     1.79883E+00     9.28230E-01     3.24819E-03     0.00000E+00     0.00000E+00
        45      9.14761E-01     1.83633E+00     9.27917E-01     3.18718E-03     0.00000E+00     0.00000E+00
        46      9.44628E-01     1.87283E+00     9.28297E-01     3.13698E-03     0.00000E+00     0.00000E+00
        47      9.10068E-01     1.91233E+00     9.27891E-01     3.09311E-03     0.00000E+00     0.00000E+00
        48      9.01385E-01     1.95067E+00     9.27315E-01     3.07951E-03     0.00000E+00     0.00000E+00
        49      9.02785E-01     1.99100E+00     9.26793E-01     3.05815E-03     0.00000E+00     0.00000E+00
        50      9.24339E-01     2.03033E+00     9.26742E-01     2.99419E-03     0.00000E+00     0.00000E+00
        51      9.38424E-01     2.06967E+00     9.26981E-01     2.94212E-03     0.00000E+00     0.00000E+00
        52      9.32145E-01     2.10633E+00     9.27084E-01     2.88453E-03     0.00000E+00     0.00000E+00
        53      8.98183E-01     2.14483E+00     9.26517E-01     2.88363E-03     0.00000E+00     0.00000E+00
        54      9.37065E-01     2.18317E+00     9.26720E-01     2.83490E-03     0.00000E+00     0.00000E+00
        55      9.45753E-01     2.22267E+00     9.27079E-01     2.80399E-03     0.00000E+00     0.00000E+00
        56      9.40239E-01     2.26017E+00     9.27323E-01     2.76235E-03     0.00000E+00     0.00000E+00
        57      9.21737E-01     2.29767E+00     9.27221E-01     2.71356E-03     0.00000E+00     0.00000E+00
        58      9.39034E-01     2.33617E+00     9.27432E-01     2.67300E-03     0.00000E+00     0.00000E+00
        59      9.17091E-01     2.37550E+00     9.27251E-01     2.63194E-03     0.00000E+00     0.00000E+00
        60      9.37030E-01     2.41400E+00     9.27419E-01     2.59166E-03     0.00000E+00     0.00000E+00
        61      9.21403E-01     2.45333E+00     9.27317E-01     2.54939E-03     0.00000E+00     0.00000E+00
        62      9.05006E-01     2.49350E+00     9.26946E-01     2.53398E-03     0.00000E+00     0.00000E+00
        63      9.55974E-01     2.53300E+00     9.27421E-01     2.53712E-03     0.00000E+00     0.00000E+00
        64      9.06396E-01     2.57133E+00     9.27082E-01     2.51879E-03     0.00000E+00     0.00000E+00
        65      9.29975E-01     2.61067E+00     9.27128E-01     2.47892E-03     0.00000E+00     0.00000E+00
        66      8.89966E-01     2.64917E+00     9.26548E-01     2.50802E-03     0.00000E+00     0.00000E+00
        67      9.14582E-01     2.68767E+00     9.26364E-01     2.47599E-03     0.00000E+00     0.00000E+00
        68      8.74626E-01     2.72700E+00     9.25580E-01     2.56110E-03     0.00000E+00     0.00000E+00
        69      9.04011E-01     2.76550E+00     9.25258E-01     2.54304E-03     0.00000E+00     0.00000E+00
        70      9.21942E-01     2.80383E+00     9.25209E-01     2.50584E-03     0.00000E+00     0.00000E+00
        71      9.31927E-01     2.84233E+00     9.25306E-01     2.47118E-03     0.00000E+00     0.00000E+00
        72      9.06844E-01     2.88083E+00     9.25043E-01     2.44986E-03     0.00000E+00     0.00000E+00
        73      9.36779E-01     2.91917E+00     9.25208E-01     2.42075E-03     0.00000E+00     0.00000E+00
        74      9.25122E-01     2.95683E+00     9.25207E-01     2.38690E-03     0.00000E+00     0.00000E+00
        75      8.87717E-01     2.99617E+00     9.24693E-01     2.40934E-03     0.00000E+00     0.00000E+00
        76      9.34421E-01     3.03467E+00     9.24825E-01     2.38019E-03     0.00000E+00     0.00000E+00
        77      9.24711E-01     3.07300E+00     9.24823E-01     2.34824E-03     0.00000E+00     0.00000E+00
        78      9.85591E-01     3.11050E+00     9.25623E-01     2.45121E-03     0.00000E+00     0.00000E+00
        79      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      AVERAGE                         67 PER CENT           95 PER CENT           99 PER CENT       NUMBER OF
   SKIPPED      K-EFFECTIVE       DEVIATION    CONFIDENCE INTERVAL   CONFIDENCE INTERVAL   CONFIDENCE INTERVAL   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

                                   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     **

                                   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     **
```

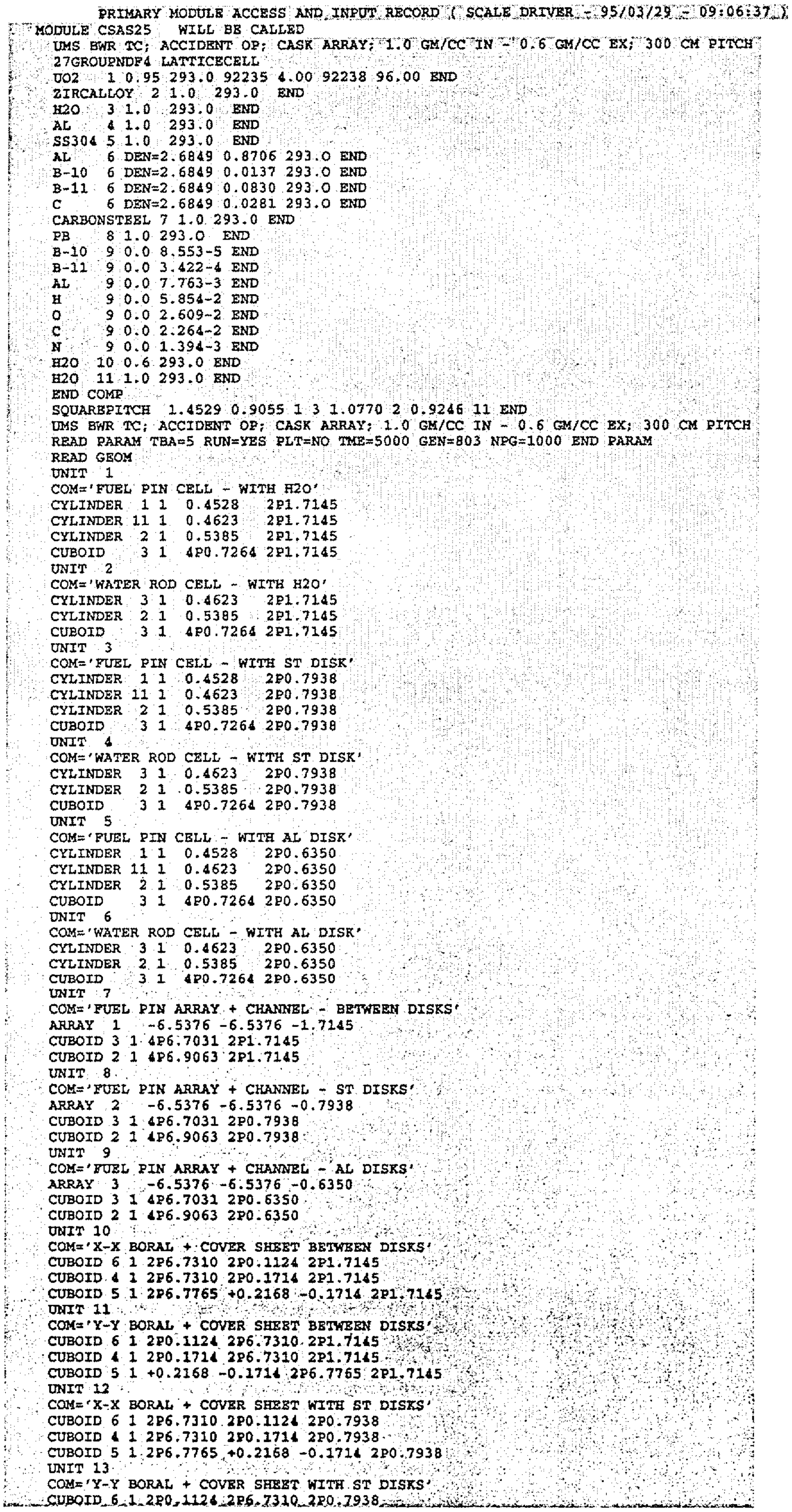
Figure 6.6.2-2 CSAS Input & Output for Accident Conditions Criticality Analysis: PWR Fuel (continued)

```
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

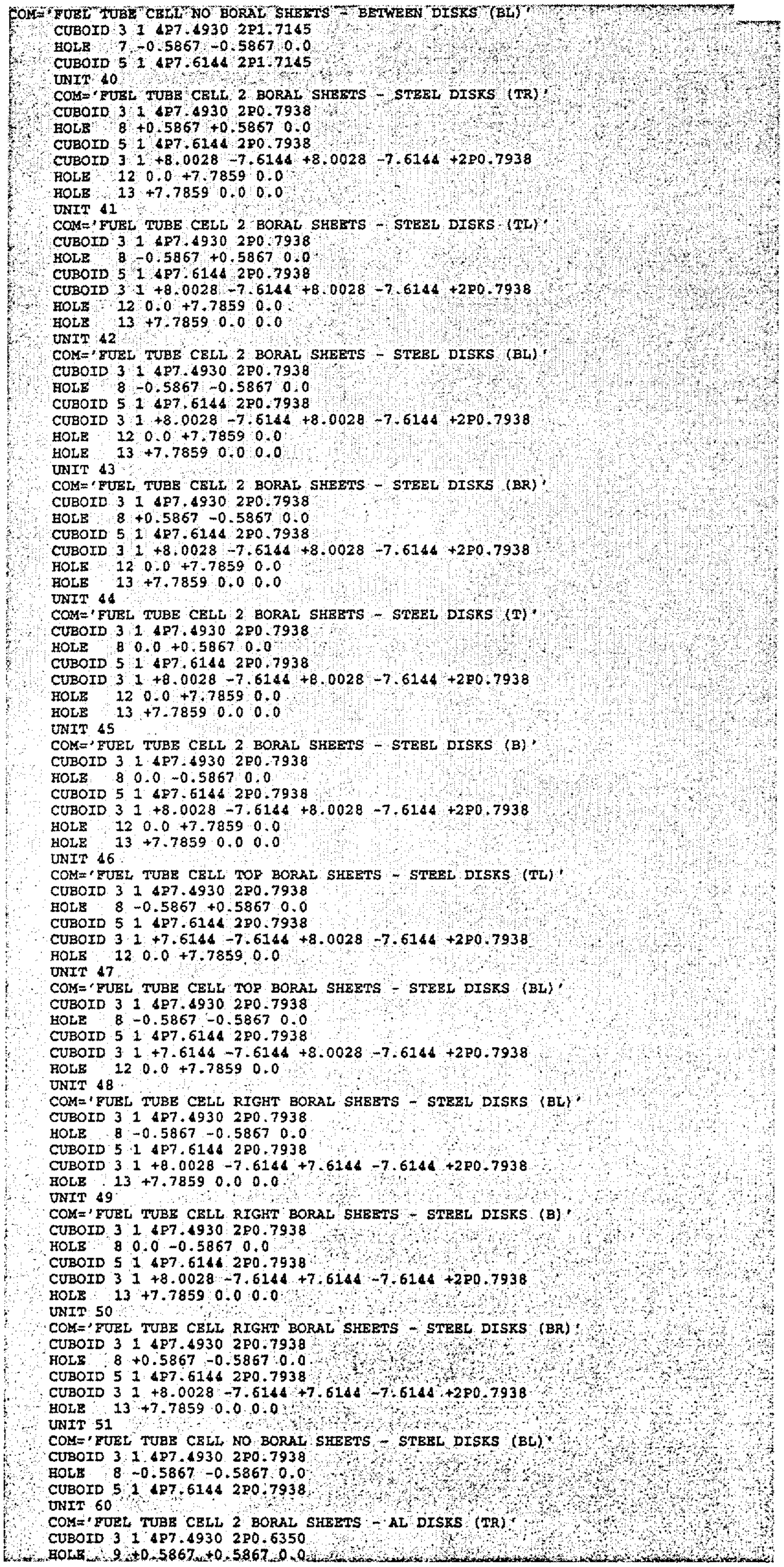


```
     PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
 MODULE CSAS25   WILL BE CALLED
  UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH
  27GROUPNDF4 LATTICECELL
  UO2   1 0.95 293.0 92235 4.00 92238 96.00 END
  ZIRCALLOY  2 1.0  293.0  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 PLT=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
```

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)

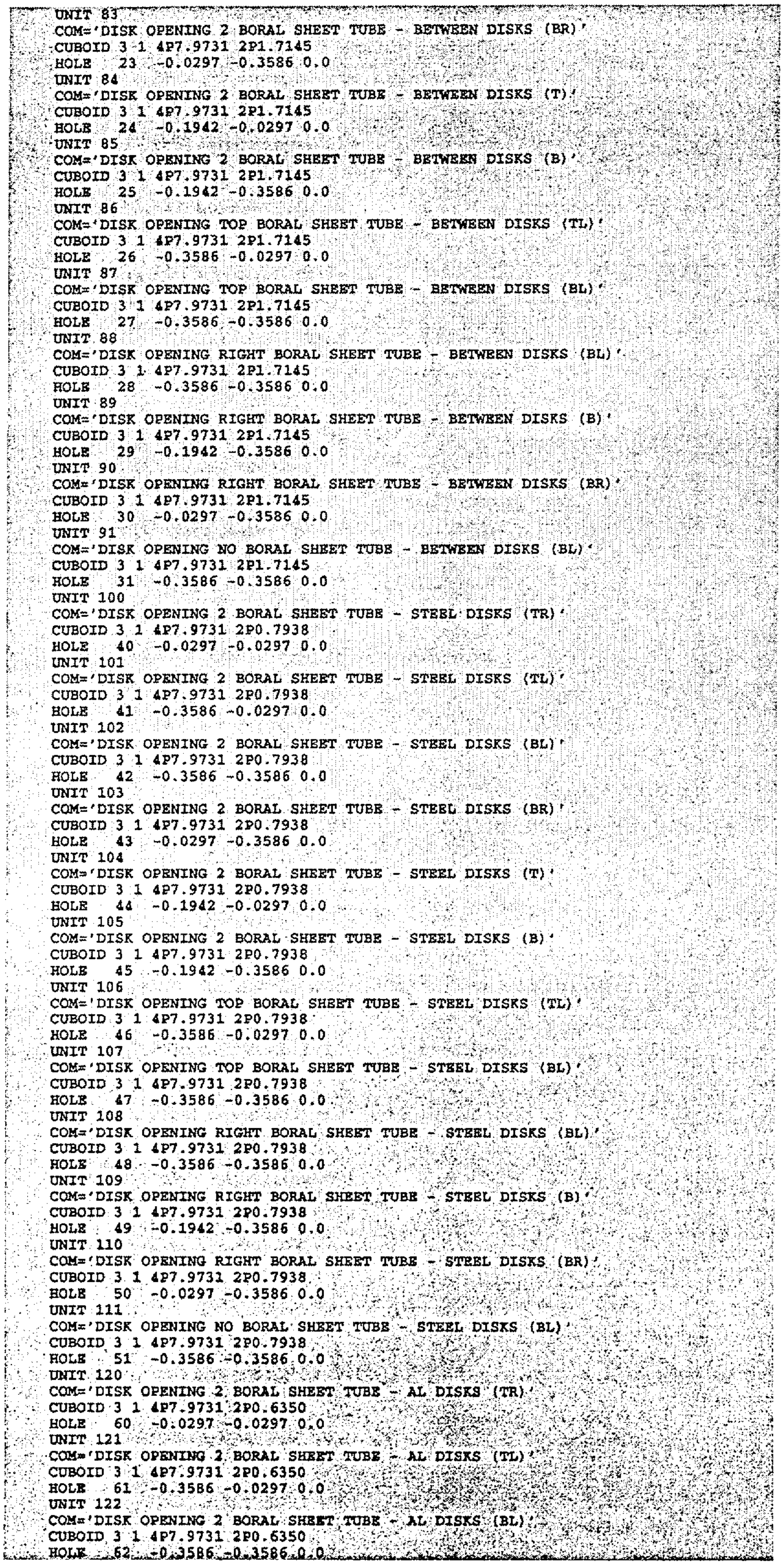


```
COM='FUEL TUBE CELL NO BORAL SHEETS - BETWEEN DISKS (BL)'
     CUBOID 3 1 4P7.4930 2P1.7145
     HOLE   7 -0.5867 -0.5867 0.0
     CUBOID 5 1 4P7.6144 2P1.7145
     UNIT 40
     COM='FUEL TUBE CELL 2 BORAL SHEETS - STEEL DISKS (TR)'
     CUBOID 3 1 4P7.4930 2P0.7938
     HOLE   8 +0.5867 +0.5867 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
```
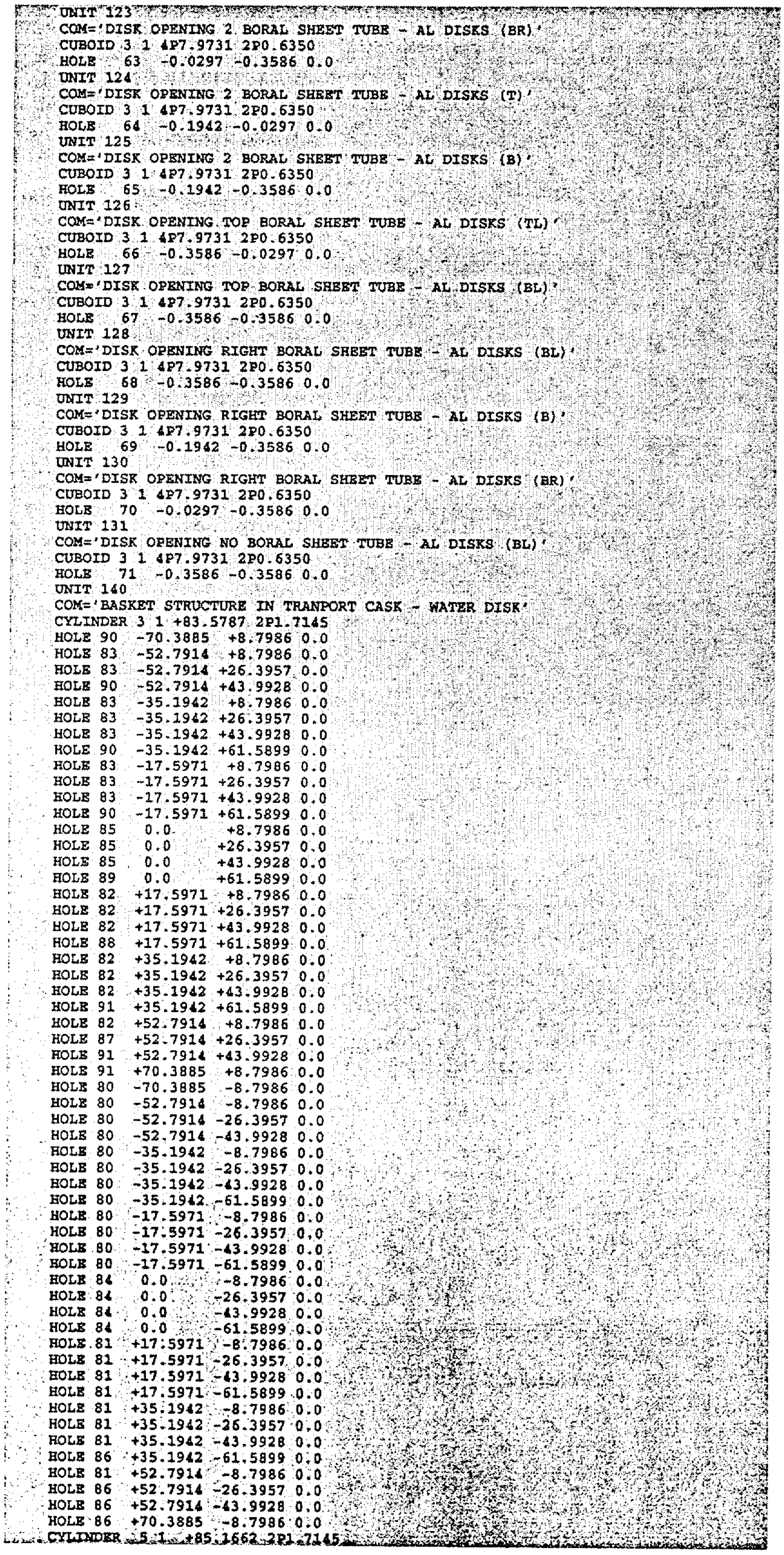

Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)



```
 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 TRANPORT 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 TRANPORT 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 TRANPORT 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
```

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

```
 CCCCCCCCCCC     SSSSSSSSSSS      AAAAAAAAA      SSSSSSSSSSS     22222222222    5555555555555
CCCCCCCCCCCCC   SSSSSSSSSSSSS    AAAAAAAAAAA    SSSSSSSSSSSSS   2222222222222   5555555555555
CC         CC   SS         SS   AA         AA   SS         SS   22         22   55
CC              SS              AA         AA   SS                         22   55
CC              SS              AA         AA   SS                         22   55
CC              SSSSSSSSSSSS    AAAAAAAAAAAAA   SSSSSSSSSSSS             22     555555555555
CC               SSSSSSSSSSSS   AAAAAAAAAAAAA    SSSSSSSSSSSS          22       5555555555555
CC                         SS   AA         AA              SS        22                    55
CC                         SS   AA         AA              SS      22                      55
CC         CC   SS         SS   AA         AA   SS         SS    22             55         55
CCCCCCCCCCCCC   SSSSSSSSSSSSS   AA         AA   SSSSSSSSSSSSS   2222222222222   5555555555555
 CCCCCCCCCCC     SSSSSSSSSSS    AA         AA    SSSSSSSSSSS    2222222222222    55555555555

 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLL    EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLL    EEEEEEEEEEEEE                   PP               CCCCCCCCCCC

   0000000                44               //      0000000       88888888888               //    99999999999     99999999999
  000000000              444              //      000000000     8888888888888             //    9999999999999   9999999999999
 00       00            4444             //      00       00    88         88            //     99         99   99         99
00         00          44 44            //      00         00   88         88           //      99         99   99         99
00         00         44  44           //       00         00   88         88          //       99         99   99         99
00         00        44   44          //        00         00    88888888888          //        9999999999999   9999999999999
00         00       44    44         //         00         00    88888888888         //          999999999999    999999999999
00         00    444444444444       //          00         00   88         88       //                     99              99
00         00    444444444444      //           00         00   88         88      //                      99              99
 00       00              44      //             00       00    88         88     //                       99              99
  000000000               44     //               000000000     8888888888888    //             9999999999999   9999999999999
   0000000                44    //                 0000000       88888888888    //               99999999999     99999999999

    11             0000000                       33333333333     66666666666                    5555555555555   7777777777777
   111            000000000                     3333333333333   6666666666666                   5555555555555   777777777777
  1111           00       00         :::        33         33   66                   :::        55              77         77
    11          00         00        :::                   33   66                   :::        55                        77
    11          00         00        :::                   33   66                   :::        55                       77
    11          00         00                             333   666666666666                    555555555555            77
    11          00         00                             333   6666666666666                   5555555555555           77
    11          00         00        :::                   33   66         66        :::                   55          77
    11          00         00        :::                   33   66         66        :::                   55          77
    11          00         00        :::        33         33   66         66        :::        55         55          77
 11111111         000000000                     3333333333333   6666666666666                   5555555555555          77
 11111111          0000000                       33333333333     66666666666                     55555555555           77
```

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

```
 SSSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC
```

```
**********************************************************************************
**********************************************************************************
**********************************************************************************
*****                                                                        *****
*****                   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 TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH


**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX             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
              5010        1.00 ATOM/MOLECULE
END

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

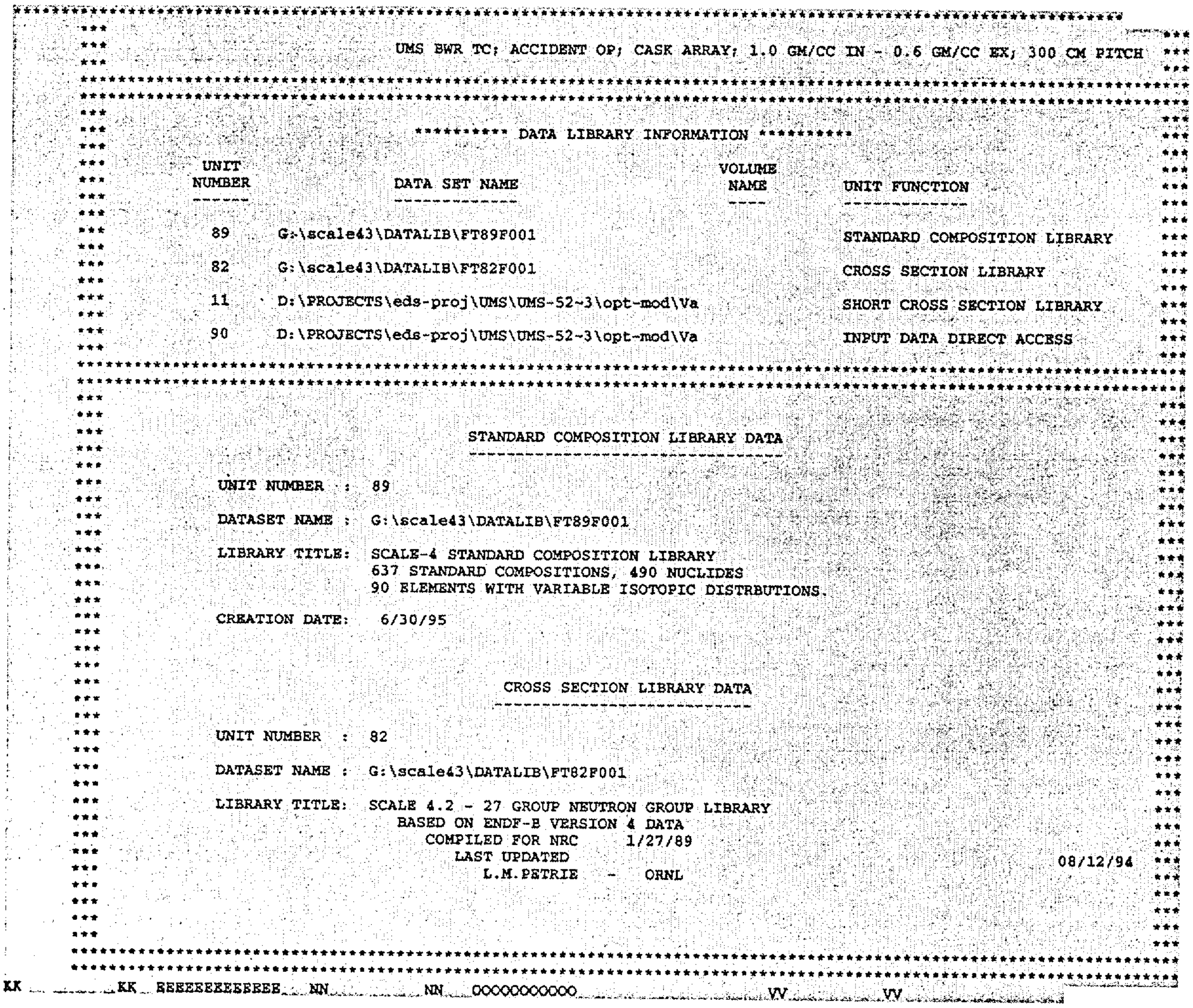
Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
   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
                   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
```

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                                              VOLUME                                         ***
     ***      NUMBER            DATA SET NAME                     NAME       UNIT FUNCTION                      ***
     ***      ------            -------------                     ----       -------------                      ***
     ***                                                                                                        ***
     ***        89     G:\scale43\DATALIB\FT89F001                           STANDARD COMPOSITION LIBRARY       ***
     ***                                                                                                        ***
     ***        82     G:\scale43\DATALIB\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\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                                          08/12/94       ***
     ***                                      L.M.PETRIE    -    ORNL                                           ***
     ***                                                                                                        ***
     ***                                                                                                        ***
     ***                                                                                                        ***
     ***                                                                                                        ***
     ******************************************************************************************************************
     ******************************************************************************************************************
KK          KK  EEEEEEEEEEEEE   NN           NN   OOOOOOOOOOO                    VV             VV
```

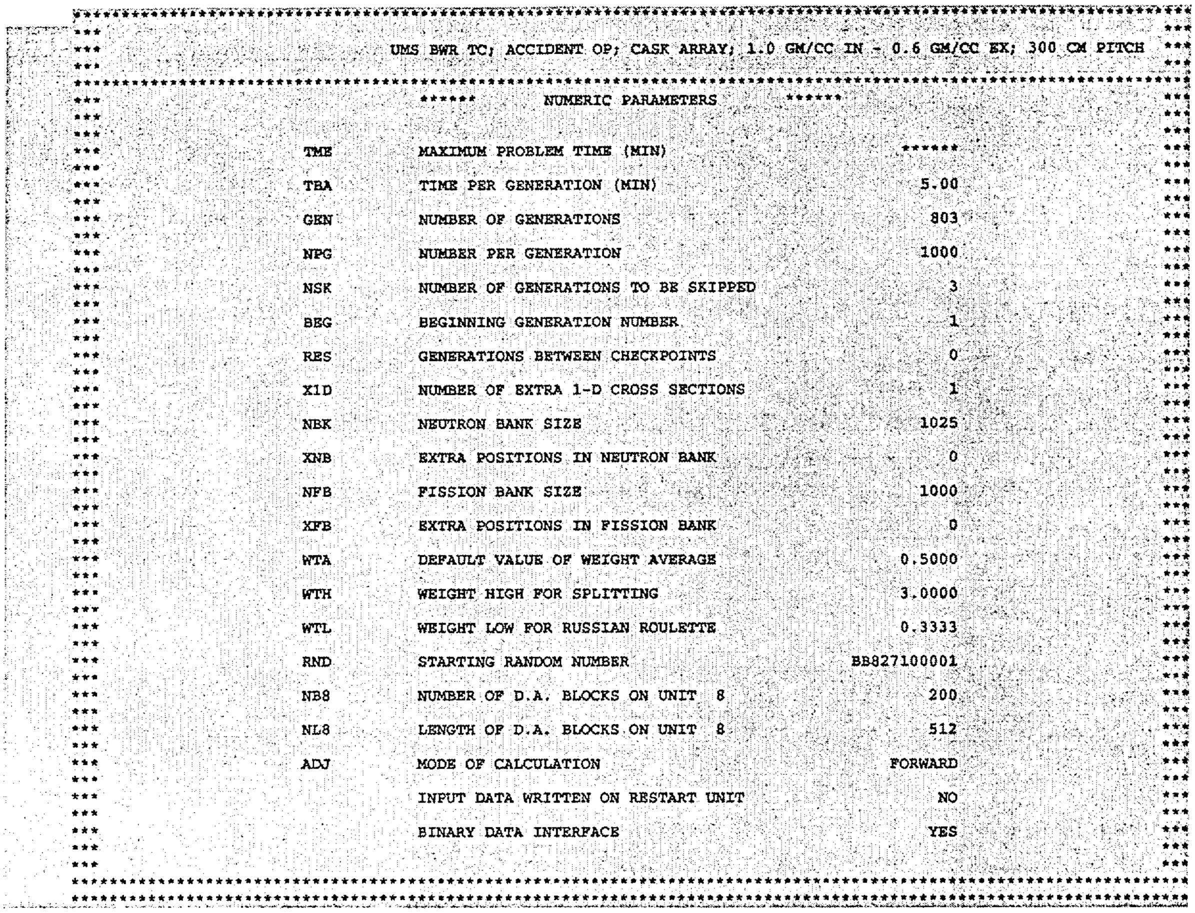
Figure 6.6.2-3 CSAS Input & Output for Normal Conditions Criticality Analysis: BWR Fuel (continued)

```
               KK         KK  EEEEEEEEEEEEE  NNN        NN  OOOOOOOOOOOOO                 VV         VV
               KK       KK    EE             NNNN       NN  OO         OO                 VV         VV
               KK     KK      EE             NN NN      NN  OO         OO                 VV         VV
               KK   KK        EE             NN  NN     NN  OO         OO                 VV         VV
               KKKKKKKK       EEEEEEEEE      NN   NN    NN  OO         OO   ------------  VV         VV
               KKKKKKKK       EEEEEEEEE      NN    NN   NN  OO         OO   ------------   VV       VV
               KK     KK      EE             NN     NN  NN  OO         OO                   VV     VV
               KK      KK     EE             NN      NN NN  OO         OO                    VV   VV
               KK       KK    EE             NN       NNNN  OO         OO                     VV VV
               KK        KK   EEEEEEEEEEEEE  NN        NNN  OOOOOOOOOOOOO                      VVV
               KK         KK  EEEEEEEEEEEEE  NN         NN   OOOOOOOOOOO                        V


 SSSSSSSSSSS    CCCCCCCCCCC     AAAAAAAAA    LL             EEEEEEEEEEEEE                 PPPPPPPPPPPP    CCCCCCCCCCC
SSSSSSSSSSSSS  CCCCCCCCCCCCC   AAAAAAAAAAA   LL             EEEEEEEEEEEEE                 PPPPPPPPPPPPP  CCCCCCCCCCCCC
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
SSSSSSSSSSSS   CC             AAAAAAAAAAAAA  LL             EEEEEEEEE       ------------  PPPPPPPPPPPPP  CC
 SSSSSSSSSSSS  CC             AAAAAAAAAAAAA  LL             EEEEEEEEE       ------------  PPPPPPPPPPPP   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
SSSSSSSSSSSSS  CCCCCCCCCCCCC  AA         AA  LLLLLLLLLLLL   EEEEEEEEEEEEE                 PP             CCCCCCCCCCCCC
 SSSSSSSSSSS    CCCCCCCCCCC   AA         AA  LLLLLLLLLLLL   EEEEEEEEEEEEE                 PP              CCCCCCCCCCC


   0000000              44               //     0000000      88888888888              //   99999999999    99999999999
  000000000            444              //     000000000    8888888888888            //   9999999999999  9999999999999
 00       00          4444             //     00       00   88         88           //    99         99  99         99
00         00        44 44            //     00         00  88         88          //     99         99  99         99
00         00       44  44           //      00         00  88         88         //      99         99  99         99
00         00      44   44          //       00         00   88888888888         //       9999999999999  9999999999999
00         00     44    44         //        00         00   88888888888        //         999999999999   999999999999
00         00  4444444444444      //         00         00  88         88      //                    99             99
00         00  4444444444444     //          00         00  88         88     //                     99             99
 00       00            44      //            00       00   88         88    //                      99             99
  000000000             44     //              000000000    8888888888888   //            9999999999999  9999999999999
   0000000              44    //                0000000      88888888888   //              99999999999    99999999999


     11           0000000                     33333333333   7777777777777                      11         88888888888
    111          000000000                   3333333333333  777777777777                      111        8888888888888
   1111         00       00        :::       33         33  77        77        :::          1111        88         88
     11        00         00       :::                  33         77         :::            11        88         88
     11        00         00       :::                  33        77          :::            11        88         88
     11        00         00                          333       77                          11         88888888888
     11        00         00                          333       77                          11         88888888888
     11        00         00       :::                  33      77            :::            11        88         88
     11        00         00       :::                  33      77            :::            11        88         88
     11         00       00        :::       33         33     77             :::            11        88         88
  11111111       000000000                   3333333333333     77                         11111111     8888888888888
  11111111        0000000                     33333333333      77                         11111111      88888888888
```

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

```
  SSSSSSSSSSS    CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                    PPPPPPPPPPPP    CCCCCCCCCCC
 SSSSSSSSSSSSS  CCCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                    PPPPPPPPPPPPP  CCCCCCCCCCCCC
 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
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------    PPPPPPPPPPPPP  CC
  SSSSSSSSSSSS  CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------    PPPPPPPPPPPP   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
 SSSSSSSSSSSSS  CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                    PP             CCCCCCCCCCCCC
  SSSSSSSSSSS    CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                    PP              CCCCCCCCCCC


                              ******************************************************************************************
                              ******************************************************************************************
                              ******************************************************************************************
                              *****                                                                                *****
                              *****                       PROGRAM VERIFICATION INFORMATION                         *****
                              *****                                                                                *****
                              *****                     CODE SYSTEM:   SCALE-PC VERSION:  4.3                      *****
                              *****                                                                                *****
                              ******************************************************************************************
                              ******************************************************************************************
                              *****                                                                                *****
                              *****                                                                                *****
                              *****              PROGRAM:  000009                                                  *****
                              *****                                                                                *****
                              *****        CREATION DATE:  03/08/96                                                *****
                              *****                                                                                *****
                              *****              VOLUME:  ENG                                                      *****
                              *****                                                                                *****
                              *****              LIBRARY:  G:\SCALE43\WIN_NT\EXE                                   *****
                              *****                                                                                *****
                              *****                                                                                *****
                              *****      PRODUCTION CODE:  KENOVA                                                  *****
                              *****                                                                                *****
                              *****              VERSION:  3.1                                                     *****
                              *****                                                                                *****
                              *****              JOBNAME:  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                    ***
***                                                                                                           ***
***                  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                        BB8271000001                    ***
***                                                                                                           ***
***                  NB8        NUMBER OF D.A. BLOCKS ON UNIT  8                       200                    ***
***                                                                                                           ***
***                  NL8        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 6.6.2-3 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       ***
***                                                                                                                ***
**********************************************************************************************************************
***                               ******    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 ***************

**********************************************************************************************************************
***                                                                                                                ***
***                           UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH       ***
***                                                                                                                ***
**********************************************************************************************************************
**********************************************************************************************************************
***                                                                                                                ***
***        UNIT                                                      VOLUME                                        ***
***       NUMBER                 DATA SET NAME                        NAME        UNIT FUNCTION                    ***
***       ------                 -------------                        ----        -------------                    ***
***                                                                                                                ***
***     XSC  14    D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Va                   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    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        ***
***                                                                                                                ***
**********************************************************************************************************************

                            ........      0 IO'S WERE USED PREPARING INPUT DATA

                          CROSS SECTIONS READ FROM THE AMPX WORKING LIBRARY ON UNIT  4
```

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

                                                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      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) =  0.59890
   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 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

*************************************************************************************************
               ***                                                                                            ***
               ***         UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 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 FISSILE MATERIAL IN THE CORE= 3.16618E-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      ELAPSED TIME      AVERAGE          AVG K-EFF         MATRIX         MATRIX K-EFF
    GENERATION     K-EFFECTIVE       MINUTES        K-EFFECTIVE       DEVIATION       K-EFFECTIVE       DEVIATION
KENO MESSAGE NUMBER K5-132       WARNING....ONLY 989 INDEPENDENT FISSION POINTS WERE GENERATED
         1         8.91976E-01     1.02067E+00     1.00000E+00     0.00000E+00     0.00000E+00     0.00000E+00
KENO MESSAGE NUMBER K5-132       WARNING....ONLY 942 INDEPENDENT FISSION POINTS WERE GENERATED
         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         9.31310E-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     7.94651E-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 TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN & 0.6 GM/CC EX; 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        AVERAGE                              67 PER CENT                95 PER CENT                99 PER CENT        NUMBER OF
   SKIPPED        K-EFFECTIVE        DEVIATION      CONFIDENCE INTERVAL       CONFIDENCE INTERVAL       CONFIDENCE INTERVAL     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)

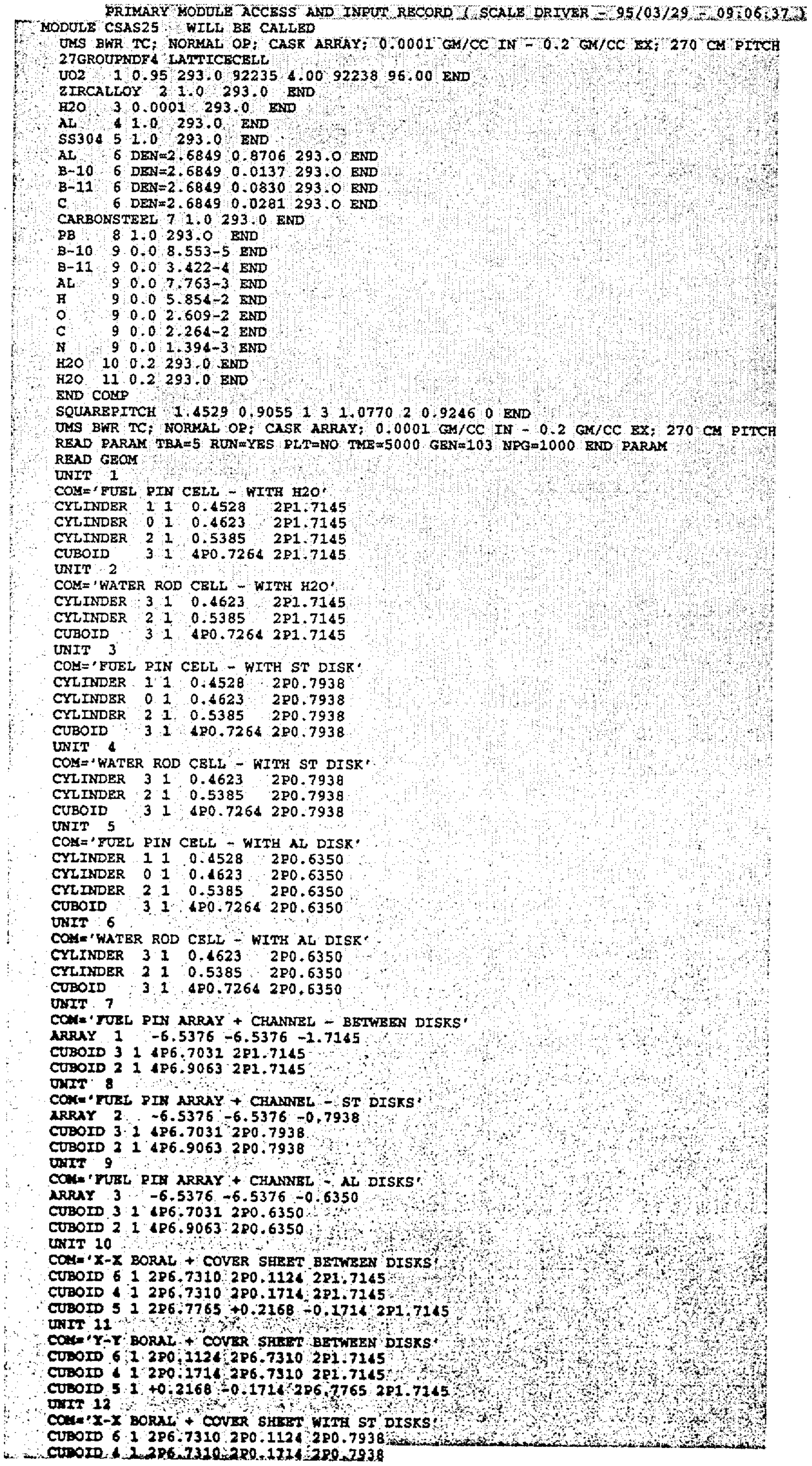
```
UMS_BWR_TC; ACCIDENT_OP; CASK_ARRAY; 1.0 GM/CC IN - 0.6 GM/CC_EX; 300 CM PITCH

                                             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)

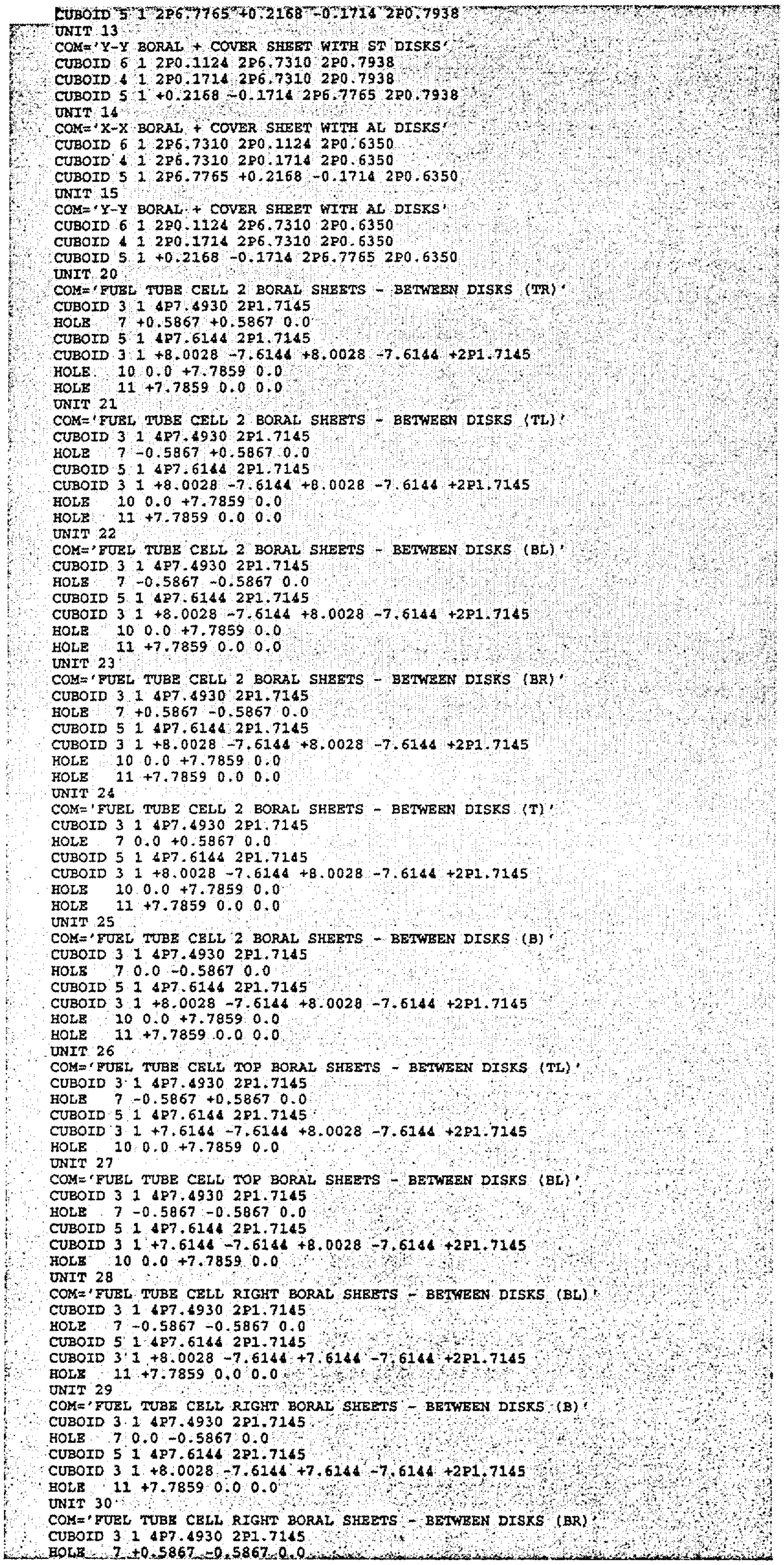
```
UMS BWR TC; ACCIDENT OP; CASK ARRAY; 1.0 GM/CC IN - 0.6 GM/CC EX; 300 CM PITCH

                              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 TC; ACCIDENT OP; 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



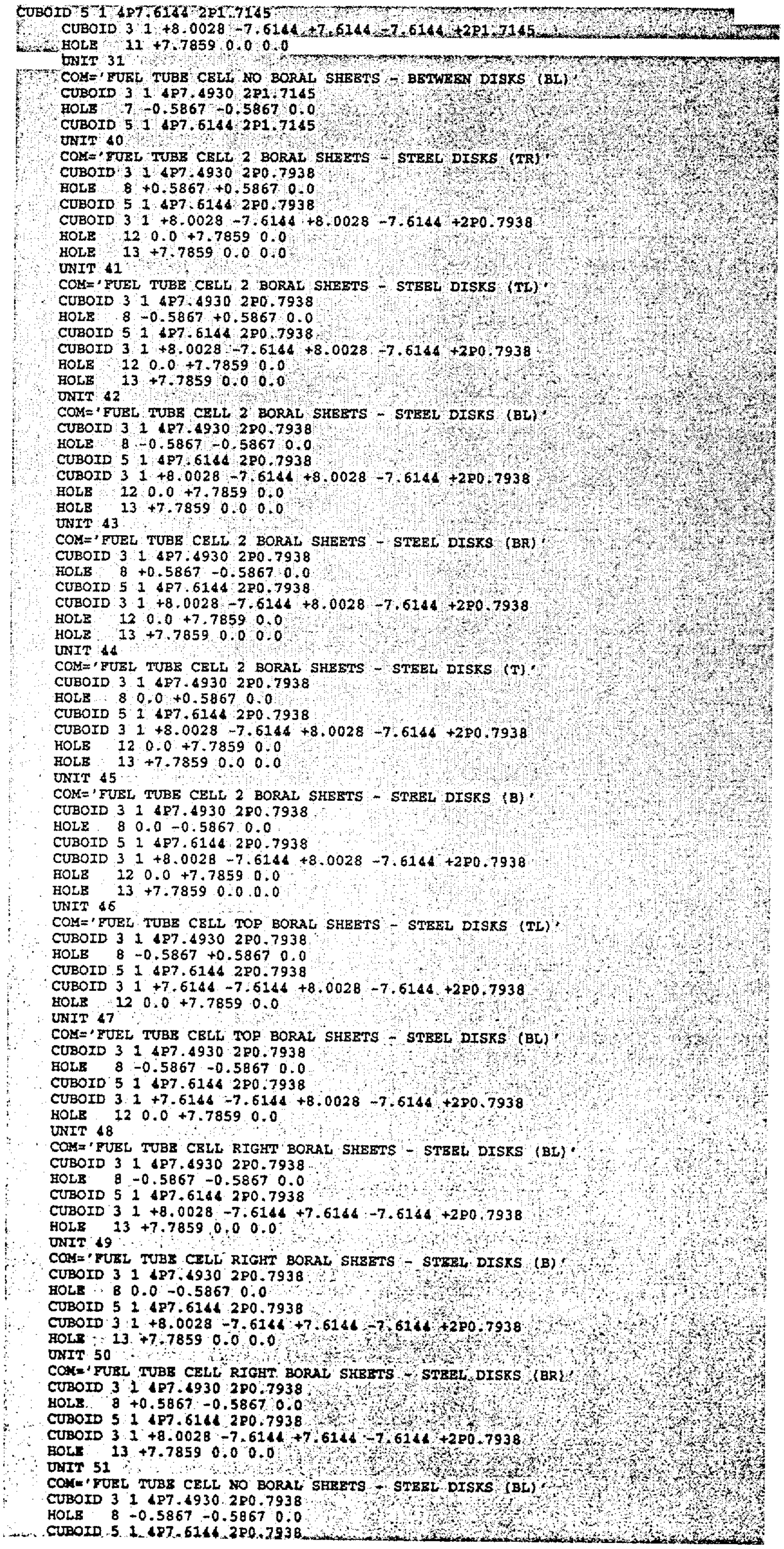
```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
 MODULE CSAS25   WILL BE CALLED
  UMS BWR TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH
  27GROUPNDF4 LATTICECELL
  UO2    1 0.95 293.0 92235 4.00 92238 96.00 END
  ZIRCALLOY  2 1.0  293.0  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.O END
  B-10   6 DEN=2.6849 0.0137 293.O END
  B-11   6 DEN=2.6849 0.0830 293.O END
  C      6 DEN=2.6849 0.0281 293.O END
  CARBONSTEEL 7 1.0 293.0 END
  PB     8 1.0 293.O  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 +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
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
```

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



```
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
```

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

```
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
```

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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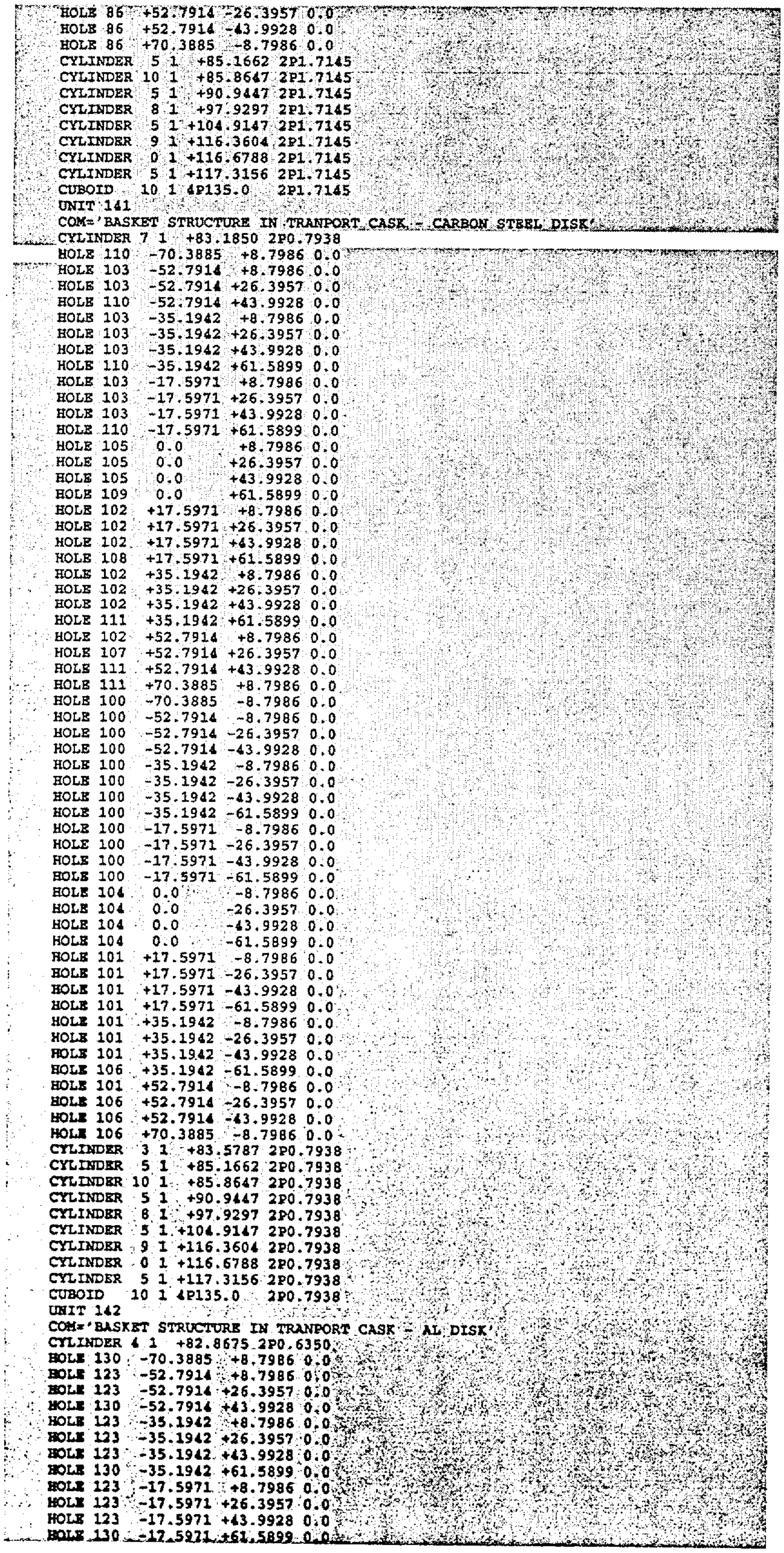
UNIT 122
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BL)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE  62  -0.3586 -0.3586 0.0
UNIT 123
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (BR)'
CUBOID 3 1 4P7.9731 2P0.6350
HOLE  63  -0.0297 -0.3586 0.0
UNIT 124
COM='DISK OPENING 2 BORAL SHEET TUBE - AL DISKS (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 TRANPORT 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 TRANPORT 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 TRANPORT 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 ZFC=PER YXF=MIRROR END BOUNDS
     END DATA
```

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

```
 CCCCCCCCCC    SSSSSSSSSS     AAAAAAAA     SSSSSSSSSS    2222222222   555555555555
CCCCCCCCCCCC  SSSSSSSSSSSS   AAAAAAAAAA   SSSSSSSSSSSS  222222222222  555555555555
CC        CC  SS        SS  AA        AA  SS        SS  22        22  55
CC            SS            AA        AA  SS                      22  55
CC            SS            AA        AA  SS                      22  55
CC            SSSSSSSSSSS   AAAAAAAAAAAA  SSSSSSSSSSS            22   55555555555
CC             SSSSSSSSSSS  AAAAAAAAAAAA   SSSSSSSSSSS         22     555555555555
CC                      SS  AA        AA            SS       22                 55
CC                      SS  AA        AA            SS     22                   55
CC        CC  SS        SS  AA        AA  SS        SS   22           55        55
CCCCCCCCCCCC  SSSSSSSSSSSS  AA        AA  SSSSSSSSSSSS  222222222222  555555555555
 CCCCCCCCCC    SSSSSSSSSS   AA        AA   SSSSSSSSSS   222222222222   5555555555


 SSSSSSSSSS    CCCCCCCCCC     AAAAAAAA    LL            EEEEEEEEEEEE                PPPPPPPPPPP    CCCCCCCCCC
SSSSSSSSSSSS  CCCCCCCCCCCC   AAAAAAAAAA   LL            EEEEEEEEEEEE                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
SSSSSSSSSSS   CC            AAAAAAAAAAAA  LL            EEEEEEEEE     ------------  PPPPPPPPPPPP  CC
 SSSSSSSSSSS  CC            AAAAAAAAAAAA  LL            EEEEEEEEE     ------------  PPPPPPPPPPP   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


   000000             44              //     000000     777777777777            //   9999999999     9999999999
  00000000           444             //     00000000    777777777777           //   999999999999  999999999999
 00      00         4444            //     00      00   77        77          //    99        99  99        99
00        00       44 44           //     00        00           77          //     99        99  99        99
00        00      44  44          //      00        00          77          //      99        99  99        99
00        00     44   44         //       00        00         77          //       999999999999  999999999999
00        00    44    44         //       00        00        77           //        99999999999   99999999999
00        00  444444444444      //        00        00       77           //                  99            99
00        00  444444444444     //         00        00      77           //                   99            99
 00      00           44      //           00      00       77          //                    99            99
  00000000            44     //             00000000        77         //           999999999999  999999999999
   000000             44    //               000000         77        //            99999999999   99999999999


 2222222222       11                              44     3333333333                  3333333333   555555555555
222222222222     111                             444    333333333333                333333333333  555555555555
22        22    1111            :::             4444    33        33      :::       33        33  55
          22      11            :::            44 44              33      :::                 33  55
          22      11            :::           44  44              33      :::                 33  55
         22       11                         44   44             333                         333  55555555555
       22         11                        44    44             333                         333  555555555555
     22           11            :::       444444444444            33      :::                 33            55
   22             11            :::       444444444444            33      :::                 33            55
 22               11            :::               44    33        33      :::       33        33  55        55
222222222222    11111111                          44    333333333333                333333333333  555555555555
222222222222    11111111                          44     3333333333                  3333333333    5555555555
```

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

```
 SSSSSSSSSSS     CCCCCCCCCCC       AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC     AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA    LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA    LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA    LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA    LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC
```

```
********************************************************************************
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                  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 TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH

**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX            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 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
                      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 Criticality Analysis: BWR Fuel (continued)

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

     SC  H2O              STANDARD COMPOSITION
     MX                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
     MX                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

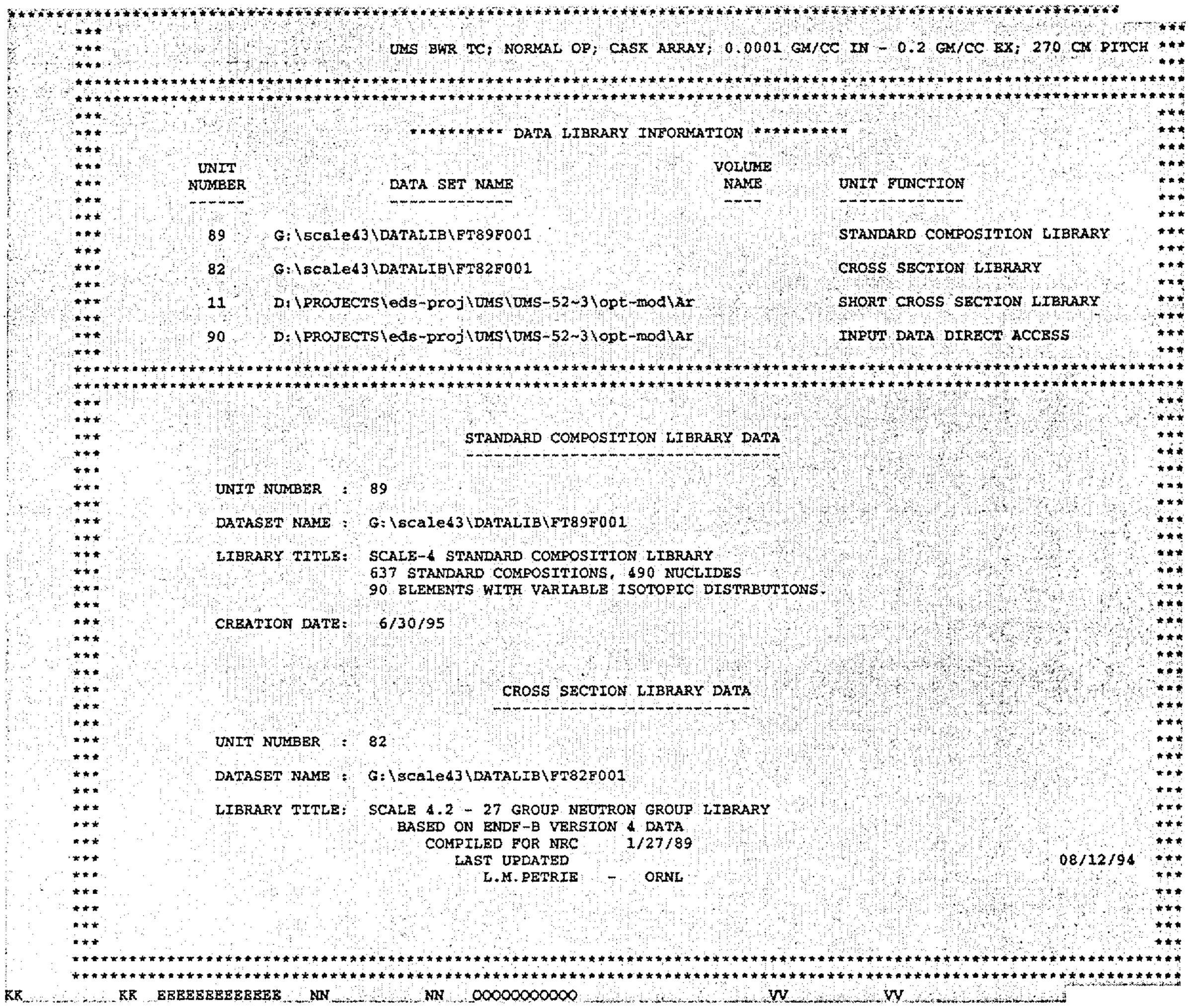
**** PROBLEM GEOMETRY ****

    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            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                                                VOLUME                                          ***
       ***     NUMBER              DATA SET NAME                     NAME         UNIT FUNCTION                     ***
       ***     ------              -------------                     ----         -------------                     ***
       ***                                                                                                          ***
       ***       89      G:\scale43\DATALIB\FT89F001                              STANDARD COMPOSITION LIBRARY      ***
       ***                                                                                                          ***
       ***       82      G:\scale43\DATALIB\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\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                                          08/12/94           ***
       ***                                    L.M.PETRIE   -    ORNL                                                ***
       ***                                                                                                          ***
       ***                                                                                                          ***
       ***                                                                                                          ***
       ***                                                                                                          ***
       ******************************************************************************************************************
       ******************************************************************************************************************
KK         KK  EEEEEEEEEEEEE   NN          NN   OOOOOOOOOOO                    VV              VV
```

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

```
                KK         KK   EEEEEEEEEEEEE   NNN        NN   OOOOOOOOOOOOO                   VV          VV
                KK        KK    EE              NNNN       NN   OO         OO                   VV          VV
                KK       KK     EE              NN NN      NN   OO         OO                   VV          VV
                KK      KK      EE              NN  NN     NN   OO         OO                   VV          VV
                KKKKKKKK        EEEEEEEEE       NN   NN    NN   OO         OO   -------------   VV          VV
                KKKKKKKK        EEEEEEEEE       NN    NN   NN   OO         OO   -------------    VV        VV
                KK      KK      EE              NN     NN  NN   OO         OO                      VV     VV
                KK       KK     EE              NN      NN NN   OO         OO                       VV   VV
                KK        KK    EE              NN       NNNN   OO         OO                        VV VV
                KK         KK   EEEEEEEEEEEEE   NN        NNN   OOOOOOOOOOOOO                         VVV
                KK          KK  EEEEEEEEEEEEE   NN         NN    OOOOOOOOOOO                           V


 SSSSSSSSSSS     CCCCCCCCCCC       AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSSS   CCCCCCCCCCCCC     AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   CCCCCCCCCCCCC
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
SSSSSSSSSSSS    CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS   CC              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    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
SSSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              CCCCCCCCCCCCC
 SSSSSSSSSSS     CCCCCCCCCCC    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               CCCCCCCCCCC


   0000000               44                 //     0000000      7777777777777                // 99999999999     99999999999
  000000000             444                //     000000000     777777777777                //  9999999999999   9999999999999
 00        00          4444               //     00        00   77         77              //   99         99   99         99
00         00         44 44              //     00         00             77              //    99         99   99         99
00         00        44  44             //      00         00            77              //     99         99   99         99
00         00       44   44            //       00         00           77              //      9999999999999   9999999999999
00         00      44    44           //        00         00          77              //        999999999999    999999999999
00         00    444444444444        //         00         00         77              //                   99              99
00         00   4444444444444       //          00         00         77             //                    99              99
 00        00            44        //            00        00        77             //                     99              99
  000000000              44       //              000000000          77            //           9999999999999   9999999999999
   0000000               44      //                0000000           77           //             99999999999     99999999999


 22222222222          11                                 44      33333333333                                  44              44
2222222222222        111                                444     3333333333333                                444             444
22         22       1111             :::               4444     33         33         :::                   4444            4444
           22         11             :::              44 44                33         :::                  44 44           44 44
           22         11             :::             44  44                33         :::                 44  44          44  44
         22           11                            44   44              333                             44   44         44   44
       22             11                           44    44              333                            44    44        44    44
     22               11             :::         444444444444              33         :::             444444444444    444444444444
   22                 11             :::        4444444444444              33         :::            4444444444444   4444444444444
 22                   11             :::                 44     33         33         :::                     44              44
2222222222222      11111111                              44     3333333333333                                 44              44
2222222222222      11111111                              44      33333333333                                  44              44
```

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

```
  SSSSSSSSSSS    CCCCCCCCCCC     AAAAAAAAA    LL              EEEEEEEEEEEEE                    PPPPPPPPPPPP    CCCCCCCCCCC
 SSSSSSSSSSSSS  CCCCCCCCCCCCC   AAAAAAAAAAA   LL              EEEEEEEEEEEEE                    PPPPPPPPPPPPP  CCCCCCCCCCCCC
 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
 SSSSSSSSSSSS   CC             AAAAAAAAAAAAA  LL              EEEEEEEEE     -------------      PPPPPPPPPPPPP  CC
  SSSSSSSSSSSS  CC             AAAAAAAAAAAAA  LL              EEEEEEEEE     -------------      PPPPPPPPPPPP   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
 SSSSSSSSSSSSS  CCCCCCCCCCCCC  AA         AA  LLLLLLLLLLLLL   EEEEEEEEEEEEE                    PP             CCCCCCCCCCCCC
  SSSSSSSSSSS    CCCCCCCCCCC   AA         AA  LLLLLLLLLLLLL   EEEEEEEEEEEEE                    PP              CCCCCCCCCCC
```

```
                         ********************************************************************************
                         ********************************************************************************
                         ********************************************************************************
                         *****                                                                      *****
                         *****                       PROGRAM VERIFICATION INFORMATION               *****
                         *****                                                                      *****
                         *****                    CODE SYSTEM:   SCALE-PC VERSION:  4.3             *****
                         *****                                                                      *****
                         ********************************************************************************
                         ********************************************************************************
                         *****                                                                      *****
                         *****                                                                      *****
                         *****                  PROGRAM:   000009                                   *****
                         *****                                                                      *****
                         *****            CREATION DATE:   03/08/96                                 *****
                         *****                                                                      *****
                         *****                   VOLUME:   ENG                                      *****
                         *****                                                                      *****
                         *****                  LIBRARY:   G:\SCALE43\WIN_NT\EXE                    *****
                         *****                                                                      *****
                         *****                                                                      *****
                         *****          PRODUCTION CODE:   KENOVA                                   *****
                         *****                                                                      *****
                         *****                  VERSION:   3.1                                      *****
                         *****                                                                      *****
                         *****                  JOBNAME:   SCALE-PC                                 *****
                         *****                                                                      *****
                         *****        DATE OF EXECUTION:   04/07/99                                 *****
                         *****                                                                      *****
                         *****        TIME OF EXECUTION:   21:43:44                                 *****
                         *****                                                                      *****
                         *****                                                                      *****
                         ********************************************************************************
                         ********************************************************************************
```

```
         *********************************************************************************************************************
         ***                                                                                                             ***
         ***                         UMS BWR TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH ***
         ***                                                                                                             ***
         *********************************************************************************************************************
         ***                               ******        NUMERIC PARAMETERS         ******                               ***
         ***                                                                                                             ***
         ***                                                                                                             ***
         ***                TME           MAXIMUM PROBLEM TIME (MIN)                           ******                    ***
         ***                                                                                                             ***
         ***                TBA           TIME PER GENERATION (MIN)                              5.00                    ***
         ***                                                                                                             ***
         ***                GEN           NUMBER OF GENERATIONS                                   103                    ***
         ***                                                                                                             ***
         ***                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                     ***
         ***                                                                                                             ***
         ***                NB8           NUMBER OF D.A. BLOCKS ON UNIT  8                        200                    ***
         ***                                                                                                             ***
         ***                NL8           LENGTH OF D.A. BLOCKS ON UNIT  8                        512                    ***
         ***                                                                                                             ***
         ***                ADJ           MODE OF CALCULATION                                 FORWARD                    ***
         ***                                                                                                             ***
         ***                              INPUT DATA WRITTEN ON RESTART UNIT                       NO                    ***
```

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

```
***                                                                                          ***
***                          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        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 ***************

***********************************************************************************************
***                                                                                          ***
***                UMS BWR TC; NORMAL OP; CASK ARRAY; 0.0001 GM/CC IN - 0.2 GM/CC EX; 270 CM PITCH ***
***                                                                                          ***
***********************************************************************************************
***********************************************************************************************
***                                                                                          ***
***         UNIT                                                 VOLUME                      ***
***        NUMBER              DATA SET NAME                      NAME      UNIT FUNCTION     ***
***        ------              -------------                      ----      -------------     ***
***                                                                                          ***
***     XSC  14    D:\PROJECTS\eds-proj\UMS\UMS-52-3\opt-mod\Ar            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    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   ***
***                                                                                          ***
***********************************************************************************************

         ........          0 IO'S WERE USED PREPARING INPUT DATA          ........

               CROSS SECTIONS READ FROM THE AMPX WORKING LIBRARY ON UNIT    4
```

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
  10008016  6.67692E-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

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      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 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    ........
*****************************************************************************************************************
          ***                                                                                                 ***
          ***           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 FISSILE MATERIAL IN THE CORE= 1.90886E-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= 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   ELAPSED TIME    AVERAGE      AVG K-EFF       MATRIX     MATRIX K-EFF
   GENERATION   K-EFFECTIVE     MINUTES     K-EFFECTIVE    DEVIATION    K-EFFECTIVE    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     AVERAGE                          67 PER CENT             95 PER CENT             99 PER CENT        NUMBER OF
   SKIPPED      K-EFFECTIVE      DEVIATION    CONFIDENCE INTERVAL    CONFIDENCE INTERVAL    CONFIDENCE INTERVAL    HISTORIES

      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 0.40338       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 0.40361       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 PWR1.1             *
*                            *

always convert                      ! Always converts intergers to real numbers

********************************************

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

@lfu = 385.1402
@ltcap = 1.7399
@lbcap = 1.7399
@lactfu = 365.76
@lowple = 7.9501
@odclad = 0.9144
@cladth = 0.05715
@odpellet = 0.78435
@lattice = 17
@rpitch = 1.25984
@odgt = 1.08966
@gtth = 0.04064
@odit = 1.22428
@itth = 0.0381
@lassem = 403.352
@wfuel = 21.40204
@lbnozz = 6.858
@ltnozz = 6.7818
@fgapb = 4.5719
@nguidetube = 24
@ninstrument = 1
@nfuelpin = 264
@fuoffz = 11.7093

@fssln = 0.237
@fvoidln = 0.763
@fssun = 0.2801
@fvoidun = 0.7199

@gU235gUO2 = 0.037
@gU238gUO2 = 0.8445
@gOgUO2 = 0.1185

@wft = 22.4282
@ftth = 0.12192
@lfutube = 388.112
@wfto = 23.14448
@ftoffz = 0.0
@asoffx = 0.0
@asoffy = 0.0
@wbrl = 20.9042
@blt = 0.1905
@blct = 0.127
@lboral = 379.9459
@blo = 0.4572
@boffz = 0.0
@bshiftx = 0.0
@bshifty = 0.0
@cvst = 0.04572
@lcvs = 384.302
@cvoffz = 1.6764
@tboffx = 0.2222
@tboffy = 0.2222

@diabw = 166.37
@lbw = 5.0292
@lbwd = 2.54
@lbws = 11.2268
@diatpw = 166.37
@ltpw = 18.6182
@ltpwd = 3.175
@opspd = 23.589
@diassp = 166.5478
@tspd = 1.27
@spx1 = 13.6628
@spx2 = 39.7537
@spx3 = 65.5271
@spxc = 41.0237
@spy1 = 13.6628
@spy2 = 39.7537
@spy3 = 65.5271
@spyc = 41.0237
@diaht = 165.9128
@thtd = 1.27
@gaptubetotop = 1.27
@nhtd = 29
@nspd = 30
@sspcht = 5.6134
@dsspht = 4.9784
@lbasket = 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

@tportcavLT = 488.95
@topnsOFF = 46.8376
@slopeLT = 12.7
@tportcavOD = 171.7294
@lidrcsOD = 199.0344
@tporttopOD = 216.5604
@lidrcsTH = 16.51
@pbID = 181.8894
@pbOD = 195.8594
@outshlTH = 6.985
@tportbotTH = 12.7
@botfrgTH = 10.795
@botnsTH = 2.54
@botringdiskTH = 17.78
@trunOFF = 30.8864
@transportLT = 531.495
@strunOD = 30.6324
@ptrunemTH = 5.08
@ptrunbTH = 8.89
@ptrunOD = 30.48
@ptruntTH = 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 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                     ! Guide tube material

MATERIAL 6 ZIRCALLOY                     ! Instrument Tube Material

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

MATERIAL 8
```

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

```
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 alumnimum 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          !NS-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
*

PART 1 NEST

BOX BH1 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 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
*
```

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

```
PART 3 NEST

BOX BH6 @cvst  0.0  [@blo+@boffz]  @blt            @wbrl  @lboral          ! BORAL Sheet - Axial offset from cover sheet bottom
BOX M3  @cvst  0.0  0.0            @blt            @wbrl  @lcvs            ! Space under cover sheet that allows sheet to shift under
cover
BOX M9  0.0    0.0  0.0            [@blt+@cvst] @wbrl  @lcvs               ! 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*@wfuel/2.0+@asoffx] [-1.0*@wfuel/2.0+@asoffy] @fuoffz
        @wfuel           @wfuel           @lassem               ! fuel assembly
BOX 2 [-1.0*@wft/2.0] [-1.0*@wft/2.0] 0.0
        @wft             @wft             @cavheight            ! space inside tube from can lid to bottom
BOX 3 [-1.0*@wft/2.0-@ftth] [-1.0*@wft/2.0-@ftth] [@baskoff+@lbw+@ftoffz]
       [@wft+2*@ftth]  [@wft+2*@ftth]  @lfutube                ! fuel tube
BOX 4 [-1.0*@wft/2.0-@ftth] [-1.0*@wft/2.0-@ftth] 0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight              ! 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*@wfuel/2.0+@asoffx] [-1.0*@wfuel/2.0+@asoffy] @fuoffz
        @wfuel           @wfuel           @lassem               ! fuel assembly
BOX 2 [-1.0*@wft/2.0] [-1.0*@wft/2.0] 0.0
        @wft             @wft             @cavheight            ! space inside tube from can lid to bottom
BOX 3 [-1.0*@wft/2.0-@ftth] [-1.0*@wft/2.0-@ftth] [@baskoff+@lbw+@ftoffz]
       [@wft+2*@ftth]  [@wft+2*@ftth]  @lfutube                ! fuel tube
BOX 4 [-1.0*@wft/2.0-@ftth] [-1.0*@wft/2.0-@ftth] 0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight              ! 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*@wft/2.0-@ftth] [-1.0*@wft/2.0-@ftth]  0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight             ! Fuel element with fuel tube
* BORAL Sheet -X
BOX P3 [(-1.0*@wfto/2.0)]                                     ! x
       [(-1.0*@wfto/2.0)+(@wfto-@wbrl)/2.0+@bshifty]          ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs                              ! delta x, delta y, delta z
* BORAL Sheet +X - prior to rotation shift fuel assmbly width right, and half sheet up
BOX P3 [(-1.0*@wfto/2.0)+@wfto]
       [(-1.0*@wfto/2.0)+(@wfto+@wbrl)/2.0+@bshifty]
       [@baskoff+@lbw+@ftoffz+@cvoffz]
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180
* BORAL Sheet +Y
BOX P3 [(-1.0*@wfto/2.0)+(@wfto-@wbrl)/2.0+@bshiftx]          ! x
       [(-1.0*@wfto/2.0)+@wfto]                               ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 90                  ! delta x, delta y, delta z
* BORAL Sheet -Y
BOX P3 [(-1.0*@wfto/2.0)+(@wfto+@wbrl)/2.0+@bshiftx]          ! x
       [(-1.0*@wfto/2.0)]                                     ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 270                 ! delta x, delta y, delta z
BOX M3 [-1.0*@opspd/2.0-@tboffx] [-1.0*@opspd/2.0-@tboffy] 0.0
       @opspd  @opspd    @cavheight                           ! Support disk opening width
```

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*@wft/2.0-@ftth] [-1.0*@wft/2.0-@ftth] 0.0
       [@wft+2*@ftth] [@wft+2*@ftth] @cavheight              ! Fuel element with fuel tube
* BORAL Sheet -X
BOX P3 [(-1.0*@wfto/2.0)]                                    ! x
       [(-1.0*@wfto/2.0)+(@wfto-@wbrl)/2.0+@bshifty]         ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                       ! z
       [@blt+@cvst] @wbrl  @lcvs                             ! delta x, delta y, delta z
* BORAL Sheet +X - prior to rotation shift fuel assmbly width right, and half sheet up
BOX P3 [(-1.0*@wfto/2.0)+@wfto]
       [(-1.0*@wfto/2.0)+(@wfto+@wbrl)/2.0+@bshifty]
       [@baskoff+@lbw+@ftoffz+@cvoffz]
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180
* BORAL Sheet +Y
BOX P3 [(-1.0*@wfto/2.0)+(@wfto-@wbrl)/2.0+@bshiftx]         ! x
       [(-1.0*@wfto/2.0)+@wfto]                              ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                       ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 90                 ! delta x, delta y, delta x
* BORAL Sheet -Y
BOX P3 [(-1.0*@wfto/2.0)+(@wfto+@wbrl)/2.0+@bshiftx]         ! x
       [(-1.0*@wfto/2.0)]                                    ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                       ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 270                  ! delta x, delta y, delta z
BOX M3 [-1.0*@opspd/2.0-@tboffx] [-1.0*@opspd/2.0-@tboffy] 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  [@spx1-@opspd/2.0] [@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 2

BOX  P10  [@spx1-@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 5
BOX  P13  [@spxc-@opspd/2.0] [@spyc-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 6

BOX  P10  [@spx1-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd  @cavheight                        ! Basket Opening 10
BOX  P10  [@spx2-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd  @cavheight                        ! Basket Opening 11
BOX  P10  [@spx3-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 12

*Quadrant 2 Openings (1, 3, 4, 7, 8, 9)

BOX  P9   [-1*@spx1-@opspd/2.0] [@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 1

BOX  P9   [-1*@spx1-@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 4
BOX  P12  [-1*@spxc-@opspd/2.0] [@spyc-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 3

BOX  P9   [-1*@spx1-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd  @cavheight                        ! Basket Opening 9
BOX  P9   [-1*@spx2-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd  @cavheight                        ! Basket Opening 8
BOX  P9   [-1*@spx3-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 7

*Quadrant 3 Openings (23, 19, 20, 13, 14, 15)

BOX  P6   [-1*@spx1-@opspd/2.0] [-1*@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 23

BOX  P6   [-1*@spx1-@opspd/2.0] [-1*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 20
BOX  P7   [-1*@spxc-@opspd/2.0] [-1*@spyc-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 19

BOX  P6   [-1*@spx1-@opspd/2.0] [-1*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd  @cavheight                        ! Basket Opening 15
BOX  P6   [-1*@spx2-@opspd/2.0] [-1*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd  @cavheight                        ! Basket Opening 14
BOX  P6   [-1*@spx3-@opspd/2.0] [-1*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 13

*Quadrant 4 Openings (24, 21, 22, 16, 17, 18)

BOX  P11  [@spx1-@opspd/2.0] [-1*@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
          @opspd @opspd @cavheight                            ! Basket Opening 24
```

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

```
BOX  P11  [@spx1-@opspd/2.0] [-1*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
           @opspd @opspd @cavheight                                 ! Basket Opening 21
BOX  P14  [@spxc-@opspd/2.0] [-1*@spyc-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
           @opspd @opspd @cavheight                                 ! Basket Opening 22

BOX  P11  [@spx1-@opspd/2.0] [-1*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
           @opspd @opspd  @cavheight                            ! Basket Opening 16
BOX  P11  [@spx2-@opspd/2.0] [-1*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
           @opspd @opspd  @cavheight                            ! Basket Opening 17
BOX  P11  [@spx3-@opspd/2.0] [-1*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lbws)]
           @opspd @opspd @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       @opspd   0.0
        @opspd  @opspd   @cavheight  ZROT 90    ! Rotated Opening
BOX M3  0.0       0.0        0.0
        @opspd  @opspd   @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  @opspd  @opspd   0.0
        @opspd  @opspd   @cavheight  ZROT 180   ! Rotated Opening
BOX M3  0.0       0.0        0.0
        @opspd  @opspd   @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  @opspd  0.0      0.0
        @opspd  @opspd   @cavheight  ZROT 270   ! Rotated Opening
BOX M3  0.0       0.0        0.0
        @opspd  @opspd   @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       @opspd   0.0
        @opspd   @opspd   @cavheight  ZROT 90   ! Rotated Opening
BOX M3  0.0       0.0        0.0
        @opspd   @opspd   @cavheight            ! container

*
* Corner Opening Rotated 180 degrees
* Maximum shift implies shift to lower left corner (-x,-y) of opening
*

PART 13 NEST

BOX P7  @opspd  @opspd   0.0
        @opspd  @opspd   @cavheight  ZROT 180   ! Rotated Opening
BOX M3  0.0       0.0        0.0
        @opspd   @opspd   @cavheight            ! container

*
* Corner Opening Rotated 270 degrees
* Maximum shift implies shift to upper left corner (-x,+y) of opening
*

PART 14 NEST

BOX P7  @opspd  0.0      0.0
        @opspd  @opspd  @cavheight  ZROT 270    ! Rotated Opening
BOX M3  0.0      0.0       0.0
        @opspd  @opspd  @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  [@diaht/2.0]          @cavheight          ! Basket Inserted - Includes Gap to Lid
ZROD M3  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
*       This may have to be modified for use of a temprary 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                     [@canod/2.0-@canth]  @cavheight        ! Canister cavity contents
ZROD  2 0.0 0.0 [-1*@canbot]            [@canod/2.0]         @canbot           ! Canister Bottom Plate
ZROD  3 0.0 0.0 @cavheight              [@canod/2.0-@canth]  @shieldl          ! Shield Lid
ZROD  4 0.0 0.0 [@cavheight+@shieldl]   [@canod/2.0-@canth]  @structl          ! Structural Lid
ZROD  5 0.0 0.0 0.0                   [@canod/2.0-@canth] [@canl-@canbot]     ! Canister Shell Inner
ZROD  6 0.0 0.0 0.0                   [@canod/2.0]        [@canl-@canbot]     ! Canister Shell Outer
ZROD  7 0.0 0.0 [-1.*@canbot]           [@canod/2.0]  @canl                    ! Inner Detetor Surface

ZONES
/Cavity/       P15  +1
/BottomPlate/  M15  +2
/ShieldLid/    M15  +3
/StructLid/    M15  +4
/Shell/        M15  +6 -5
/Canister/     M0   +7 -6 -4 -2

***********************************
12345678901234567890123456789012345678901234567890123456789012

PART [@tscNUM + 1]
ZROD 1     0.0  0.0  0.0  [@tporttopOD/2]          @transportLT             ! Container
ZROD 2     0.0  0.0  0.0  [@pbOD/2+@outshlTH] @tportbotTH                   ! Bottom
ZROD 3     0.0  0.0  [@tportbotTH+@botfrgTH+@botnsTH]
           [@tportcavOD/2.]     [@tportcavLT]                               ! Cavity
ZROD 4     0.0  0.0  [@tportbotTH+@botfrgTH+@botnsTH+(@tportcavLT-@canl)]
           [@canod/2.0]   @canl                                             ! Canister
ZROD 5     0.0  0.0  [@transportLT-@lidrcsTH]
           [@lidrcsOD/2]  @lidrcsTH                                 ! Lid
ZROD 6     0.0  0.0  @tportbotTH     [ @pbID/2.0 ]  @botnsTH                      ! Bottom neutron shield
XROD 7     [-1*(@tporttopOD/2)-(@ptrunbTH-@ptrunemTH)-@ptruntTH]  0.0
           [@transportLT-@trunOFF]
           [@ptrunOD/2.]  [-2*(-1*(@tporttopOD/2)-(@ptrunbTH-@ptrunemTH)-@ptruntTH)]          ! Primary
trunnion
YROD 8     0.0  [-1*(@tporttopOD/2)]        [@transportLT-@trunOFF]
           [@strunOD/2 ]  @tporttopOD                                       ! Secondary trunnion
ZROD 9     0.0  0.0  [@transportLT-@topnsOFF]
           [@tporttopOD/2]      @topnsOFF                                   ! Top shell
ZROD 10    0.0  0.0  0.0  [  @pbID/2.0  ]       @transportLT                          ! Inner shell
ZROD 11    0.0  0.0  [@tportbotTH+@botringdiskTH]
           [ @pbOD/2.0 ]  [@transportLT-@topnsOFF-@tportbotTH-@botringdiskTH]    ! Lead shield
ZROD 12    0.0  0.0  @tportbotTH     [   @pbOD/2  ] @botringdiskTH               ! Bottom ring/disk
ZCONE      13   0.0  0.0  [@transportLT-@topnsOFF-@slopeLT]  [@pbOD/2+@outshlTH]
           [@tporttopOD/2.]     @slopeLT                                    ! Outer shell OD change
ZROD 14    0.0  0.0  @tportbotTH
           [@pbOD/2.+@outshlTH]      [@transportLT-@tportbotTH-@topnsOFF-@slopeLT]    ! Outer shell
ZONES

/Transport/             M[@tscMAT + @matCE] +1    -2    -14   -13   -9
/Lid/                   M[@tscMAT + @matSS304]    +5
/TSC/                   P@tscNUM             +4
/Cavity/          M[@tscMAT + @matCI] +3    -4
/Bottom/          M[@tscMAT + @matSS304]    +2
/BottomNS/              M[@tscMAT + @matNS4FR]    +6
/PrimaryTrunnion/       M[@tscMAT + @matSS304]    +7    +1    -3    -5
/SecondTrunnion/        M[@tscMAT + @matSS304]    +8    +1    -3    -5
/TopShell/              M[@tscMAT + @matSS304]    +9    -5    -3    -7    -8
/InnerShell/      M[@tscMAT + @matSS304]    +10   -2    -6    -3    -9
/LeadShield/      M[@tscMAT + @matLead]     +11   -10
/Bottomringdisk/        M[@tscMAT + @matSS304]    +12   -10
/OuterShellCone/        M[@tscMAT + @matSS304]    +13   -11
/OuterShell/      M[@tscMAT + @matSS304]    +14   -11   -12

**********************************************

ALBEDO 1 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 z direction
2                           ! number of planes in the z direction
[@lassem-@ltnozz]    8      ! top nozzle
[@lbnozz]           -2      ! space between nozzles (HOLE#2) - shifted up by @lbnozz
7                           ! bottom nozzle

* Hole 2 - 17x17 OFA 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.]                              ! 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   -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   -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
@lbnozz                                   ! bottom nozzle elevation - correlates to HOLE 1 geometry
[@lbnozz+@fgapb]                          ! gap to bottom of fuel rod
[@lbnozz+@fgapb+@lbcap]                   ! top of bottom end cap region
[@lbnozz+@fgapb+@lbcap+@lowple]           ! bottom plenum region ends
[@lbnozz+@fgapb+@lbcap+@lowple+@lactfu]   ! top of active fuel region
[@lbnozz+@fgapb+@lfu-@ltcap]              ! bottom of top plug
[@lbnozz+@fgapb+@lfu]                     ! 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
@lbnozz [@lassem - @ltnozz]  ! guide and instrument tubes go all through to t. nozz.
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
@lbnozz [@lassem - @ltnozz]  ! guide and instrument tubes go all through to t. nozz.
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
* Stuctured 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
[@lbasket-@lbws-@lbw]                3       ! Top of Basket
@diskstack                          -8       ! Top of Highest Support Disk
0.0                                -10       ! Bottom of Lowest Support Disk
[-1.0*(@lbw+@lbws)]                 -9       ! Bottom of Basket
[-1.0*(@baskoff+@lbw+@lbws)]         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    ! number of radial points
[@diatpw/2.0]
1   ! number of axial intervals
[@lbasket-@lbws-@lbw-@ltpw]
[@lbasket-@lbws-@lbw-@ltpw+@ltpwd]          ! 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    ! number of radial points
[@diabw/2.0]
1   ! number of axial intervals
[-1.0*(@lbws+@lbwd)]
[-1.0*@lbws]                                ! Coordinates inherited from PLATE Hole
13                                          ! Plate Material
3

* Hole 10 Support disk and heat transfer disk stack

PLATE
0 0 1
4
CELL [@tspd+@dsspht+@thtd+@dsspht]           ! Sets up a repeating lattice of cells
[@tspd+@dsspht+@thtd+@dsspht]      3         ! water
[@tspd+@dsspht+@thtd]              3         ! water gap
[@tspd+@dsspht]                   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
*SEEK MULTIPLE DEFINITIONS

SEEDS 12345 12345
STAGES -10 810 5000 STDV 0.0005

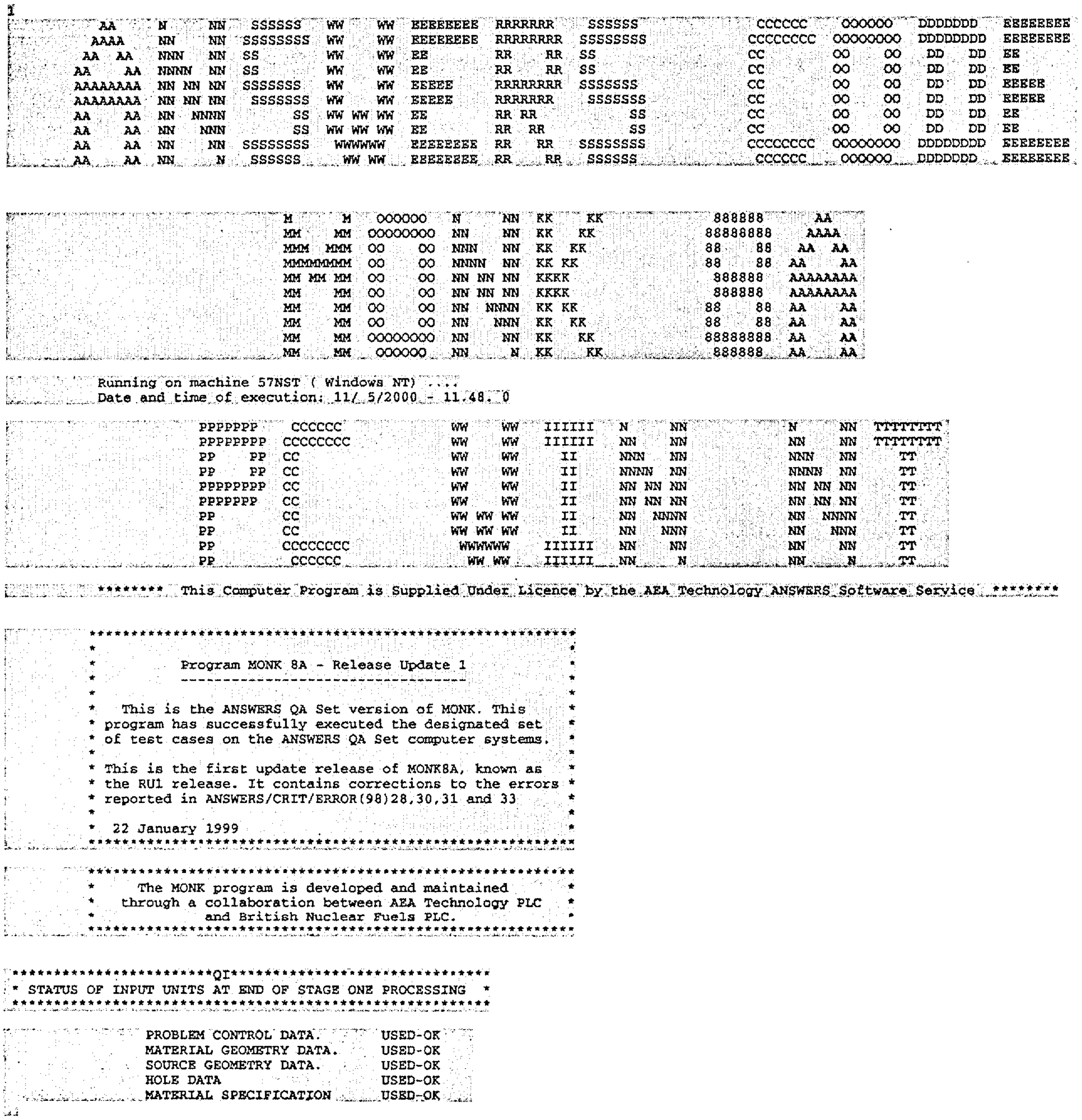
END

**************************************************
BEGIN SOURCE GEOMETRY
**************************************************

ZONEMAT
ALL / MATERIAL @fuelMAT

END
```

Figure 6.6.3-2 MONK8a Output Summary -UMS Transport Cask PWR Top End Impact



```
1
           AA     N     NN   SSSSSS   WW    WW  EEEEEEEE  RRRRRRR    SSSSSS               CCCCCC    OOOOOO   DDDDDDD   EEEEEEEE
          AAAA    NN    NN  SSSSSSSS  WW    WW  EEEEEEEE  RRRRRRRR  SSSSSSSS            CCCCCCCC  OOOOOOOO  DDDDDDDD  EEEEEEEE
         AA  AA   NNN   NN  SS        WW    WW  EE        RR    RR  SS                  CC        OO    OO  DD    DD  EE
        AA    AA  NNNN  NN  SS        WW    WW  EE        RR    RR  SS                  CC        OO    OO  DD    DD  EE
        AAAAAAAA  NN NN NN  SSSSSSS   WW    WW  EEEEE     RRRRRRRR  SSSSSSS             CC        OO    OO  DD    DD  EEEEE
        AAAAAAAA  NN NN NN   SSSSSSS  WW    WW  EEEEE     RRRRRRR    SSSSSSS            CC        OO    OO  DD    DD  EEEEE
        AA    AA  NN  NNNN        SS  WW WW WW  EE        RR RR            SS            CC        OO    OO  DD    DD  EE
        AA    AA  NN   NNN        SS  WW WW WW  EE        RR  RR           SS            CC        OO    OO  DD    DD  EE
        AA    AA  NN    NN  SSSSSSSS   WWWWWW   EEEEEEEE  RR   RR   SSSSSSSS            CCCCCCCC  OOOOOOOO  DDDDDDDD  EEEEEEEE
        AA    AA  NN     N   SSSSSS     WW WW   EEEEEEEE  RR    RR   SSSSSS              CCCCCC    OOOOOO   DDDDDDD   EEEEEEEE


                                M      M   OOOOOO   N     NN  KK    KK             888888      AA
                                MM    MM  OOOOOOOO  NN    NN  KK   KK             88888888    AAAA
                                MMM  MMM  OO    OO  NNN   NN  KK  KK              88    88   AA  AA
                                MMMMMMMM  OO    OO  NNNN  NN  KK KK               88    88  AA    AA
                                MM MM MM  OO    OO  NN NN NN  KKKK                 888888   AAAAAAAA
                                MM    MM  OO    OO  NN NN NN  KKKK                 888888   AAAAAAAA
                                MM    MM  OO    OO  NN  NNNN  KK KK               88    88  AA    AA
                                MM    MM  OO    OO  NN   NNN  KK  KK              88    88  AA    AA
                                MM    MM  OOOOOOOO  NN    NN  KK   KK             88888888  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  TTTTTTTT
                      PPPPPPPP  CCCCCCCC            WW    WW   IIIIII   NN    NN            NN    NN  TTTTTTTT
                      PP    PP  CC                  WW    WW     II     NNN   NN            NNN   NN     TT
                      PP    PP  CC                  WW    WW     II     NNNN  NN            NNNN  NN     TT
                      PPPPPPPP  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  NNNN            NN  NNNN     TT
                      PP        CC                  WW WW WW     II     NN   NNN            NN   NNN     TT
                      PP        CCCCCCCC             WWWWWW    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 RU1 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    30.000 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   148.88 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
=====================================================

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      12345
TRAJECTORIES TRACKED THIS RUN            =  148082462
NUMBER OF COLLISIONS THIS RUN            =  194833026
ZONE SEARCH LOCATIONS USED(PAIRS)        =        297
1**********************************************************************************************************
 ***********************************   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)

```
1PLOT OF CUMULATIVE K(THREE) ESTIMATOR AGAINST STAGE NUMBER
 ==========================================================

  0.905     0.910     0.915     0.920     0.925     0.930     0.935     0.940     0.945     0.950     0.955     0.960     0.965
     I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
   1                                   I-------X-------I
   2                                         I-----X-----I
   3                                              I----X----I
   4                                                 I---X---I
   5                                                  I---X---I
   6                                                    I--X--I
   7                                                     I--X--I
   8                                                    I--X--I
   9                                                   I--X--I
  10                                                    I--X--I
  11                                                     I--X--I
  12                                                       I-X-I
  13                                                      I-X-I
  14                                                      I-X-I
  15                                                     I-X-I
  16                                                      I-X-I
  17                                                      I-X-I
  18                                                      I-X-I
  19                                                      I-X-I
  20                                                       I-X-I
  21                                                       I-X-I
  22                                                        I-X-I
  23                                                        I-X-I
  24                                                         I-X-I
  25                                                         I-X-I
  26                                                         I-X-I
  27                                                         I-X-I
  28                                                        I-X-I
  29                                                        I-X-I
  30                                                        I-X-I
  31                                                         IXI
  32                                                         IXI
  33                                                         IXI
  34                                                         IXI
  35                                                          IXI
  36                                                          IXI
  37                                                          IXI
  38                                                          IXI
  39                                                          IXI
  40                                                          IXI
  41                                                          IXI
  42                                                          IXI
  43                                                          IXI
  44                                                          IXI
  45                                                          IXI
  46                                                          IXI
  47                                                          IXI
  48                                                          IXI
  49                                                          IXI
  50                                                          IXI
  51                                                          IXI
  52                                                          IXI
  53                                                           IXI
  54                                                           IXI
  55                                                           IXI
  56                                                           IXI
  57                                                           IXI
  58                                                          IXI
  59                                                          IXI
  60                                                          IXI
  61                                                          IXI
  62                                                          IXI
  63                                                         IXI
  64                                                         IXI
  65                                                         IXI
  66                                                         IXI
  67                                                         IXI
  68                                                         IXI
  69                                                         IXI
     I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
  0.905     0.910     0.915     0.920     0.925     0.930     0.935     0.940     0.945     0.950     0.955     0.960     0.965
```

Figure 6.6.3-2 MONK8a Output Summary -UMS Transport Cask PWR 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 = 0.5835

 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)

1SAMPLING 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   -4   -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   12   13   14

         NO PARTICLE TRACKS IN ZONE   83 FOR STAGES:
               54

         NO PARTICLE TRACKS IN ZONE   88 FOR STAGES:
               53   54   67

         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   -4   -3    1    3    5    7   21   25   26   28   32   34   37   39   44   45   47

         NO PARTICLE TRACKS IN ZONE   93 FOR   42 STAGES

              The first  20 stages that this occurred are:

               -9   -8   -7   -5   -4   -2    2    3   10   11   14   16   17   18   19   21   22   23   25

         NO PARTICLE TRACKS IN ZONE   94 FOR   29 STAGES

              The first  20 stages that this occurred are:

               -9   -3   -2    5   10   14   16   18   19   24   26   27   28   30   32   34   37   38   44

         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   -7   -6   -5   -4   -3   -2   -1    0    1    2    3    4    5    6    7    8    9

         NO PARTICLE TRACKS IN ZONE   99 FOR STAGES:
               53

     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
         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            Chi squared per          Probability
                     Settling stages   degree of freedom
         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   ( 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 *
*                               *

@lfu = 410.464
@ltcap = 4.2342
@lbcap = 0.9017
@lactfu = 381
@lowple = 12.164
@odclad = 1.077
@cladth = 0.0762
@odpellet = 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
@fuoffz = 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
@lfutube = 409.448
@wfto = 15.61846
@wftonb = 15.22984
@ftoffz = 0.0
@asoffx = 0.5867
@asoffy = 0.5867
@wbrl = 13.5636
@blt = 0.3429
@blct = 0.127
@lboral = 396.21714
@blo = 0.4572
@boffz = 0.0
@bshiftx = 0.0
@bshifty = 0.0
@cvst = 0.04572
@lcvs = 398.526
@cvoffz = 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
@spx1 = 17.5839
@spx2 = 35.1942
@spx3 = 52.7914
```

Figure 6.6.3-3 MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```
@spx4 = 70.3885
@spy1 = 8.7986
@spy2 = 26.3957
@spy3 = 43.9928
@spy4 = 61.5899
@diaht = 165.735
@thtd = 1.27
@gaptubetotop = 1.27
@nhtd = 17
@nspd = 41
@sspcht = 4.064
@dsspht = 3.429
@lbasket = 452.1454
@diskstack = 390.4869
@baskoff = 0.0
@ovopspd = 16.3271

@canod = 170.3324
@canth = 1.5875
@canl = 483.489
@canbot = 4.4196
@shieldl = 17.526
@structl = 7.62
@cavheight = 453.9234

*********************************

* 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   = 27                ! Last part number of TSC going into cask
@fuelMAT  = 1                 ! Material number of fuel from TSC model
********************************************

* Cask Parameters

@tportcavLT = 488.95
@topnsOFF = 46.8376
@slopeLT = 12.7
@tportcavOD = 171.7294
@lidrcsOD = 199.0344
@tporttopOD = 216.5604
@lidrcsTH = 16.51
@pbID = 181.8894
@pbOD = 195.8594
@outshlTH = 6.985
@tportbotTH = 12.7
@botfrgTH = 10.795
@botnsTH = 2.54
@botringdiskTH = 17.78
@trunOFF = 30.8864
@transportLT = 531.495
@strunOD = 30.6324
@ptrunemTH = 5.08
@ptrunbTH = 8.89
@ptrunOD = 30.48
@ptruntTH = 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       ! 1.95% 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 alumnimum 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          !NS-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 1 NEST

BOX BH1 [-(@rpitch*@lattice)/2.0] [-(@rpitch*@lattice)/2.0] @lbnozz
  [(@rpitch*@lattice)] [(@rpitch*@lattice)] [@lassem-@ltnozz-@lbnozz] ! fuel lattice
BOX M3 [-(@chwidth/2.0)+@chth] [-(@chwidth/2.0)+@chth] @lbnozz
  [@chwidth-2.0*@chth] [@chwidth-2.0*@chth][@lassem-@ltnozz-@lbnozz]   ! channel inner
BOX M6 [-(@chwidth/2.0)] [-(@chwidth/2.0)] @lbnozz
  @chwidth @chwidth [@lassem-@ltnozz-@lbnozz]                          ! channel outer
BOX M7 [-(@wfuel/2.0)] [-(@wfuel/2.0)] 0.0
  @wfuel @wfuel [@lassem-@ltnozz]                                   ! bottom nozzle
BOX M8 [-(@wfuel/2.0)] [-(@wfuel/2.0)] 0.0
  @wfuel @wfuel @lassem                                             ! bottom nozzle

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

BOX BH4 @cvst  0.0  [@blo+@boffz]  @blt         @wbrl  @lboral       ! BORAL Sheet - Axial offset from cover sheet bottom
BOX M3  @cvst  0.0  0.0            @blt         @wbrl  @lcvs         ! Space under cover sheet that allows sheet to shift under
cover
BOX M9  0.0    0.0  0.0            [@blt+@cvst] @wbrl  @lcvs         ! 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*@wfuel/2.0+@asoffx] [-1.0*@wfuel/2.0+@asoffy] @fuoffz
        @wfuel          @wfuel          @lassem                ! fuel assembly
BOX 2 [-1.0*@wft/2.0] [-1.0*@wft/2.0] 0.0
        @wft            @wft            @cavheight             ! space inside tube from can lid to bottom
BOX 3 [-1.0*@wft/2.0-@ftth] [-1.0*@wft/2.0-@ftth] [@baskoff+@lbw+@ftoffz]
      [@wft+2*@ftth]  [@wft+2*@ftth]  @lfutube                 ! fuel tube
BOX 4 [-1.0*@wft/2.0-@ftth] [-1.0*@wft/2.0-@ftth] 0.0
      [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight               ! 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 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

BOX 1 [-1.0*@wfuel/2.0+@ovasoffx] [-1.0*@wfuel/2.0+@ovasoffy] @fuoffz
        @wfuel            @wfuel            @lassem                ! fuel assembly
BOX 2 [-1.0*@ovwft/2.0] [-1.0*@ovwft/2.0] 0.0
        @ovwft            @ovwft            @cavheight             ! space inside tube from can lid to bottom
BOX 3 [-1.0*@ovwft/2.0-@ftth] [-1.0*@ovwft/2.0-@ftth] [@baskoff+@lbw+@ftoffz]
      [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @lfutube                 ! fuel tube
BOX 4 [-1.0*@ovwft/2.0-@ftth] [-1.0*@ovwft/2.0-@ftth] 0.0
      [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @cavheight               ! 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
*

* 2 BORAL SHEET - QIII
```

Figure 6.6.3-3 MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```
PART 6 CLUSTER

BOX P4 [-1.0*@wfto/2.0] [-1.0*@wfto/2.0]  0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight              ! Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*@wfto/2.0)+@wfto]                           ! x
       [(-1.0*@wfto/2.0)+(@wfto+@wbrl)/2.0+@bshifty]          ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180                     ! delta x, delta y, delta z
* BORAL Sheet +Y
BOX P3 [(-1.0*@wfto/2.0)+(@wfto-@wbrl)/2.0+@bshiftx]          ! x
       [(-1.0*@wfto/2.0)+@wfto]                           ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 90                  ! delta x, delta y, delta z
BOX M3 [-1.0*@opspd/2.0-@tboffx] [-1.0*@opspd/2.0-@tboffy] 0.0
       @opspd  @opspd     @cavheight                          ! Support disk opening width

* RIGHT BORAL SHEET - QII Shift

PART 7 CLUSTER

BOX P17 [-1.0*@wfto/2.0] [-1.0*@wftonb/2.0]  0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight             ! Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*@wfto/2.0)+@wfto]                           ! x
       [(-1.0*@wftonb/2.0)+(@wftonb+@wbrl)/2.0+@bshifty]          ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180                     ! delta x, delta y, delta z
BOX M3 [-1.0*@opspd/2.0-@tboffx] [-1.0*@opspd/2.0+@tboffynb] 0.0
       @opspd  @opspd     @cavheight                          ! Support disk opening width

* TOP BORAL SHEET - Could also be generated by rotating right BORAL - Q1 Shift

PART 8 CLUSTER

BOX P18 [-1.0*@wftonb/2.0] [-1.0*@wfto/2.0]  0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight             ! Fuel element with fuel tube
* BORAL Sheet +Y
BOX P3 [(-1.0*@wftonb/2.0)+(@wftonb-@wbrl)/2.0+@bshiftx]      ! x
       [(-1.0*@wfto/2.0)+@wfto]                           ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 90                  ! delta x, delta y, delta z
BOX M3 [-1.0*@opspd/2.0+@tboffxnb] [-1.0*@opspd/2.0+@tboffy] 0.0
       @opspd  @opspd     @cavheight                          ! Support disk opening width

* NO BORAL SHEET - Q1 Shift

PART 9 CLUSTER

BOX P18 [-1.0*@wftonb/2.0] [-1.0*@wftonb/2.0]  0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight             ! Fuel element with fuel tube
BOX M3 [-1.0*@opspd/2.0+@tboffxnb] [-1.0*@opspd/2.0+@tboffynb] 0.0
       @opspd  @opspd     @cavheight                          ! Support disk opening width


*
* Base PART B - 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*@ovwfto/2.0] [-1.0*@ovwfto/2.0]  0.0
       [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @cavheight             ! Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*@ovwfto/2.0)+@ovwfto]                           ! x
       [(-1.0*@ovwfto/2.0)+(@ovwfto+@wbrl)/2.0+@bshifty]          ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180                     ! delta x, delta y, delta z
* BORAL Sheet +Y
BOX P3 [(-1.0*@ovwfto/2.0)+(@ovwfto-@wbrl)/2.0+@bshiftx]          ! x
       [(-1.0*@ovwfto/2.0)+@ovwfto]                               ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 90                  ! delta x, delta y, delta z
BOX M3 [-1.0*@ovopspd/2.0-@ovtboffx] [-1.0*@ovopspd/2.0-@ovtboffy] 0.0
       @ovopspd  @ovopspd     @cavheight                          ! Support disk opening width

* Right BORAL Sheet - QII

PART 11 CLUSTER

BOX P20 [-1.0*@ovwfto/2.0] [-1.0*@ovwftonb/2.0]  0.0
       [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @cavheight             ! Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*@ovwfto/2.0)+@ovwfto]                           ! x
       [(-1.0*@ovwftonb/2.0)+(@ovwftonb+@wbrl)/2.0+@bshifty]          ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180                     ! delta x, delta y, delta z
BOX M3 [-1.0*@ovopspd/2.0-@ovtboffx] [-1.0*@ovopspd/2.0+@ovtboffynb] 0.0
       @ovopspd  @ovopspd     @cavheight                          ! 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

BOX P22 [-1.0*@ovwftonb/2.0] [-1.0*@ovwfto/2.0] 0.0
        [@ovwft+2*@ftth] [@ovwft+2*@ftth] @cavheight         ! Fuel element with fuel tube
* BORAL Sheet +Y
BOX P3 [(-1.0*@ovwftonb/2.0)+(@ovwftonb-@wbrl)/2.0+@bshiftx]      ! x
        [(-1.0*@ovwfto/2.0)+@ovwfto]                              ! y
        [@baskoff+@lbw+@ftoffz+@cvoffz]                          ! z
        [@blt+@cvst] @wbrl  @lcvs     ZROT 90                    ! delta x, delta y, delta z
BOX M3 [-1.0*@ovopspd/2.0+@ovtboffxnb] [-1.0*@ovopspd/2.0-@ovtboffy] 0.0
        @ovopspd  @ovopspd    @cavheight                         ! Support disk opening width

* No BORAL Sheet - QI

PART 13 CLUSTER

BOX P21 [-1.0*@ovwftonb/2.0] [-1.0*@ovwftonb/2.0]  0.0
        [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @cavheight           ! Fuel element with fuel tube
BOX M3 [-1.0*@ovopspd/2.0+@ovtboffxnb] [-1.0*@ovopspd/2.0+@ovtboffynb] 0.0
        @ovopspd  @ovopspd    @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*@spx2-@opspd/2.0] [@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 1
BOX  P7  [-1.0*@spx1-@opspd/2.0] [@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 2
BOX  P7  [-1.0*@opspd/2.0] [@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 3
BOX  P26 [@spx1-@opspd/2.0] [@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 4
BOX  P9  [@spx2-@opspd/2.0] [@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 5

* Openings (6, 7, 8, 9, 10, 11, 12)
BOX  P11  [-1.0*@spx3-@ovopspd/2.0] [@spy3-@ovopspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @ovopspd @ovopspd @cavheight                           ! Basket Opening 6 - Oversize
BOX  P23  [-1.0*@spx2-@opspd/2.0] [@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 7
BOX  P23  [-1.0*@spx1-@opspd/2.0] [@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 8
BOX  P23  [-1.0*@opspd/2.0] [@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 9
BOX  P24  [@spx1-@opspd/2.0] [@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 10
BOX  P24  [@spx2-@opspd/2.0] [@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 11
BOX  P13  [@spx3-@ovopspd/2.0] [@spy3-@ovopspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @ovopspd @ovopspd @cavheight                           ! Basket Opening 12 - Oversize

* Openings (13, 14, 15, 16, 17, 18, 19)
BOX  P23 [-1.0*@spx3-@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 13
BOX  P23  [-1.0*@spx2-@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 14
BOX  P23  [-1.0*@spx1-@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 15
BOX  P23  [-1.0*@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 16
BOX  P24  [@spx1-@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 17
BOX  P24  [@spx2-@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 18
BOX  P8  [@spx3-@opspd/2.0] [@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 19

* Openings (20, 21, 22, 23, 24, 25, 26, 27, 28)
BOX  P7  [-1.0*@spx4-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 20
BOX  P23  [-1.0*@spx3-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 21
BOX  P23  [-1.0*@spx2-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 22
BOX  P23  [-1.0*@spx1-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 23
BOX  P23  [-1.0*@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 24
BOX  P24  [@spx1-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 25
BOX  P24  [@spx2-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 26
BOX  P24  [@spx3-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 27
BOX  P9  [@spx4-@opspd/2.0] [@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
          @opspd @opspd @cavheight                               ! Basket Opening 28

* Openings (29, 30, 31, 32, 33, 34, 35, 36, 37)
```

Figure 6.6.3-3 MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```
BOX  P6  [-1.0*@spx4-@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 29
BOX  P6  [-1.0*@spx3-@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 30
BOX  P6  [-1.0*@spx2-@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 31
BOX  P6  [-1.0*@spx1-@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 32
BOX  P6  [-1.0*@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 33
BOX  P25 [@spx1-@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 34
BOX  P25 [@spx2-@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 35
BOX  P25 [@spx3-@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 36
BOX  P27 [@spx4-@opspd/2.0] [-1.0*@spy1-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 37

* Openings (38, 39, 40, 41, 42, 43, 44)
BOX  P6  [-1.0*@spx3-@opspd/2.0] [-1.0*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 38
BOX  P6  [-1.0*@spx2-@opspd/2.0] [-1.0*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 39
BOX  P6  [-1.0*@spx1-@opspd/2.0] [-1.0*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 40
BOX  P6  [-1.0*@opspd/2.0] [-1.0*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 41
BOX  P25 [@spx1-@opspd/2.0] [-1.0*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 42
BOX  P25 [@spx2-@opspd/2.0] [-1.0*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 43
BOX  P27 [@spx3-@opspd/2.0] [-1.0*@spy2-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 44

* Openings (45, 46, 47, 48, 49, 50, 51)
BOX  P10 [-1.0*@spx3-@ovopspd/2.0] [-1.0*@spy3-@ovopspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @ovopspd @ovopspd @cavheight                       ! Basket Opening 45 - Oversize
BOX  P6  [-1.0*@spx2-@opspd/2.0] [-1.0*@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 46
BOX  P6  [-1.0*@spx1-@opspd/2.0] [-1.0*@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 47
BOX  P6  [-1.0*@opspd/2.0] [-1.0*@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 48
BOX  P25 [@spx1-@opspd/2.0] [-1.0*@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 49
BOX  P25 [@spx2-@opspd/2.0] [-1.0*@spy3-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 50
BOX  P12 [@spx3-@ovopspd/2.0] [-1.0*@spy3-@ovopspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @ovopspd @ovopspd @cavheight                       ! Basket Opening 51 - Oversize

*Bottom Openings (52, 53, 54, 55, 56)
BOX  P6  [-1.0*@spx2-@opspd/2.0] [-1.0*@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 52
BOX  P6  [-1.0*@spx1-@opspd/2.0] [-1.0*@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 53
BOX  P6  [-1.0*@opspd/2.0] [-1.0*@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 54
BOX  P25 [@spx1-@opspd/2.0] [-1.0*@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 55
BOX  P27 [@spx2-@opspd/2.0] [-1.0*@spy4-@opspd/2.0] [-1.0*(@baskoff+@lbw+@lfs)]
         @opspd @opspd @cavheight                           ! Basket Opening 56

ZROD H5   0.0 0.0 [-1.0*(@baskoff+@lbw+@lfs)]
         [ @diaht/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)
*

PART 15 NEST

ZROD P14  0.0 0.0 0.0  [@diaht/2.0]          @cavheight        ! Basket Inserted - Includes Gap to Lid
ZROD M3   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
*       This may have to be modified for use of a temprary 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                      [@canod/2.0-@canth]  @cavheight      ! Canister cavity contents
ZROD  2 0.0 0.0 [-1*@canbot]             [@canod/2.0]         @canbot         ! Canister Bottom Plate
ZROD  3 0.0 0.0 @cavheight               [@canod/2.0-@canth]  @shieldl        ! Shield Lid
ZROD  4 0.0 0.0 [@cavheight+@shieldl]    [@canod/2.0-@canth]  @structl        ! Structural Lid
ZROD  5 0.0 0.0 0.0                    [@canod/2.0-@canth] [@canl-@canbot]    ! Canister Shell Inner
ZROD  6 0.0 0.0 0.0                    [@canod/2.0]        [@canl-@canbot]    ! Canister Shell Outer
ZROD  7 0.0 0.0 [-1.*@canbot]            [@canod/2.0]  @canl                  ! Inner Detetor Surface
```

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 -2

* 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           [@wft+2*@ftth]  0.0
        [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight  ZROT 90     ! Rotated fuel tube
BOX M3  0.0           0.0           0.0
        [@wft+2*@ftth]  [@wft+2*@ftth]  @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  [@wft+2*@ftth]  [@wft+2*@ftth]  0.0
        [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight  ZROT 180    ! Rotated fuel tube
BOX M3  0.0           0.0           0.0
        [@wft+2*@ftth]  [@wft+2*@ftth]  @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  [@wft+2*@ftth]  0.0           0.0
        [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight  ZROT 270    ! Rotated fuel tube
BOX M3  0.0           0.0           0.0
        [@wft+2*@ftth]  [@wft+2*@ftth]  @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           [@ovwft+2*@ftth]  0.0
        [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @cavheight  ZROT 90     ! Rotated fuel tube
BOX M3  0.0           0.0           0.0
        [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @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  [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  0.0
        [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @cavheight  ZROT 180    ! Rotated fuel tube
BOX M3  0.0           0.0           0.0
        [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @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 NEST

BOX P5  [@ovwft+2*@ftth]  0.0     0.0
        [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @cavheight  ZROT 270   ! Rotated fuel tube
BOX M3  0.0       0.0       0.0
        [@ovwft+2*@ftth]  [@ovwft+2*@ftth]  @cavheight               ! container

* 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 QII
* Direction changed for tboff variables
*

PART 23 CLUSTER

BOX P17 [-1.0*@wfto/2.0] [-1.0*@wfto/2.0]  0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight           ! Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*@wfto/2.0)+@wfto]                           ! x
       [(-1.0*@wfto/2.0)+(@wfto+@wbrl)/2.0+@bshifty]          ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180                  ! delta x, delta y, delta z
* BORAL Sheet +Y
BOX P3 [(-1.0*@wfto/2.0)+(@wfto-@wbrl)/2.0+@bshiftx]          ! x
       [(-1.0*@wfto/2.0)+@wfto]                           ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 90                  ! delta x, delta y, delta z
BOX M3 [-1.0*@opspd/2.0-@tboffx] [-1.0*@opspd/2.0+@tboffy] 0.0
       @opspd  @opspd    @cavheight                           ! Support disk opening width

*
* Disk Opening 2 BORAL Sheet Tube QI
* Direction changed for tboff variables
*

PART 24 CLUSTER

BOX P18 [-1.0*@wfto/2.0] [-1.0*@wfto/2.0]  0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight           ! Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*@wfto/2.0)+@wfto]                           ! x
       [(-1.0*@wfto/2.0)+(@wfto+@wbrl)/2.0+@bshifty]          ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180                  ! delta x, delta y, delta z
* BORAL Sheet +Y
BOX P3 [(-1.0*@wfto/2.0)+(@wfto-@wbrl)/2.0+@bshiftx]          ! x
       [(-1.0*@wfto/2.0)+@wfto]                           ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 90                  ! delta x, delta y, delta z
BOX M3 [-1.0*@opspd/2.0+@tboffx] [-1.0*@opspd/2.0+@tboffy] 0.0
       @opspd  @opspd    @cavheight                           ! Support disk opening width

*
* Disk Opening 2 BORAL Sheet Tube QIV
* Direction changed for tboff variables
*

PART 25 CLUSTER

BOX P19 [-1.0*@wfto/2.0] [-1.0*@wfto/2.0]  0.0
       [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight           ! Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3 [(-1.0*@wfto/2.0)+@wfto]                           ! x
       [(-1.0*@wfto/2.0)+(@wfto+@wbrl)/2.0+@bshifty]          ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 180                  ! delta x, delta y, delta z
* BORAL Sheet +Y
BOX P3 [(-1.0*@wfto/2.0)+(@wfto-@wbrl)/2.0+@bshiftx]          ! x
       [(-1.0*@wfto/2.0)+@wfto]                           ! y
       [@baskoff+@lbw+@ftoffz+@cvoffz]                        ! z
       [@blt+@cvst] @wbrl  @lcvs     ZROT 90                  ! delta x, delta y, delta z
BOX M3 [-1.0*@opspd/2.0+@tboffx] [-1.0*@opspd/2.0-@tboffy] 0.0
       @opspd  @opspd    @cavheight                           ! Support disk opening width

*
* Disk Opening Right BORAL Sheet Tube QI
* Direction changed for tboff variables
*
PART 26 CLUSTER

BOX P18 [-1.0*@wfto/2.0] [-1.0*@wftonb/2.0] 0.0
```

Figure 6.6.3-3   MONK8a Input File - UMS Transport Cask BWR Top End Impact (Continued)

```
         [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight               ! Fuel element with fuel tube
* BORAL Sheet +X - prior to rotation shift fuel assembly width right, and half sheet up
BOX P3  [(-1.0*@wfto/2.0)+@wfto]                                ! x
         [(-1.0*@wftonb/2.0)+(@wftonb+@wbrl)/2.0+@bshifty]           ! y
         [@baskoff+@lbw+@ftoffz+@cvoffz]                              ! z
         [@blt+@cvst] @wbrl  @lcvs     ZROT 180                       ! delta x, delta y, delta z
BOX M3  [-1.0*@opspd/2.0+@tboffx] [-1.0*@opspd/2.0+@tboffynb] 0.0
         @opspd  @opspd    @cavheight                            ! Support disk opening width

* TOP BORAL SHEET - QIV Shift

PART 27 CLUSTER

BOX P19 [-1.0*@wftonb/2.0] [-1.0*@wfto/2.0]  0.0
         [@wft+2*@ftth]  [@wft+2*@ftth]  @cavheight               ! Fuel element with fuel tube
* BORAL Sheet +Y
BOX P3  [(-1.0*@wftonb/2.0)+(@wftonb-@wbrl)/2.0+@bshiftx]            ! x
         [(-1.0*@wfto/2.0)+@wfto]                                ! y
         [@baskoff+@lbw+@ftoffz+@cvoffz]                              ! z
         [@blt+@cvst] @wbrl  @lcvs     ZROT 90                        ! delta x, delta y, delta z
BOX M3  [-1.0*@opspd/2.0+@tboffxnb] [-1.0*@opspd/2.0-@tboffy] 0.0
         @opspd  @opspd    @cavheight                            ! Support disk opening width


***********************************
1234567890123456789012345678901234567890123456789012345678901234567890123456789012

PART [@tscNUM + 1]
ZROD 1     0.0  0.0  0.0  [@tporttopOD/2]           @transportLT          ! Container
ZROD 2     0.0  0.0  0.0  [@pbOD/2+@outshlTH] @tportbotTH               ! Bottom
ZROD 3     0.0  0.0  [@tportbotTH+@botfrgTH+@botnsTH]
           [@tportcavOD/2.]    [@tportcavLT]                          ! Cavity
ZROD 4     0.0  0.0  [@tportbotTH+@botfrgTH+@botnsTH+(@tportcavLT-@canl)]
           [@canod/2.0]   @canl                                       ! Canister
ZROD 5     0.0  0.0  [@transportLT-@lidrcsTH]
           [@lidrcsOD/2]  @lidrcsTH                              ! Lid
ZROD 6     0.0  0.0  @tportbotTH     [ @pbID/2.0 ]  @botnsTH                 ! Bottom neutron shield
XROD 7     [-1*(@tporttopOD/2)-(@ptrunbTH-@ptrunemTH)-@ptruntTH]  0.0
           [@transportLT-@trunOFF]
           [@ptrunOD/2 ]  [-2*(-1*(@tporttopOD/2)-(@ptrunbTH-@ptrunemTH)-@ptruntTH)]               ! Primary
trunnion
YROD 8     0.0  [-1*(@tporttopOD/2)]     [@transportLT-@trunOFF]
           [@strunOD/2 ]  @tporttopOD                                   ! Secondary trunnion
ZROD 9     0.0  0.0  [@transportLT-@topnsOFF]
           [@tporttopOD/2]    @topnsOFF                                ! Top shell
ZROD 10    0.0  0.0  0.0  [  @pbID/2.0  ]      @transportLT                        ! Inner shell
ZROD 11    0.0  0.0  [@tportbotTH+@botringdiskTH]
           [ @pbOD/2.0 ]  [@transportLT-@topnsOFF-@tportbotTH-@botringdiskTH]     ! Lead shield
ZROD 12    0.0  0.0  @tportbotTH    [   @pbOD/2  ] @botringdiskTH          ! Bottom ring/disk
ZCONE      13   0.0  0.0  [@transportLT-@topnsOFF-@slopeLT]  [@pbOD/2+@outshlTH]
           [@tporttopOD/2.]    @slopeLT                                ! Outer shell OD change
ZROD 14    0.0  0.0  @tportbotTH
           [@pbOD/2.+@outshlTH]     [@transportLT-@tportbotTH-@topnsOFF-@slopeLT]    ! Outer shell
ZONES

/Transport/           M[@tscMAT + @matCB] +1   -2   -14  -13  -9
/Lid/                 M[@tscMAT + @matSS304]  +5
/TSC/                 P16           +4
/Cavity/         M[@tscMAT + @matCI] +3   -4
/Bottom/         M[@tscMAT + @matSS304]   +2
/BottomNS/            M[@tscMAT + @matNS4FR]   +6
/PrimaryTrunnion/     M[@tscMAT + @matSS304]   +7   +1   -3   -5
/SecondTrunnion/      M[@tscMAT + @matSS304]   +8   +1   -3   -5
/TopShell/            M[@tscMAT + @matSS304]   +9   -5   -3   -7   -8
/InnerShell/     M[@tscMAT + @matSS304]   +10  -2   -6   -3   -9
/LeadShield/     M[@tscMAT + @matLead]    +11  -10
/Bottomringdisk/      M[@tscMAT + @matSS304]   +12  -10
/OuterShellCone/      M[@tscMAT + @matSS304]   +13  -11
/OuterShell/     M[@tscMAT + @matSS304]   +14  -11  -12

**************************************************

ALBEDO 1 1 1
PERIODIC

END

**************************************************
BEGIN HOLE DATA
**************************************************

*******************************
* Inserting TSC Hole Data Here  *
*                               *

* Hole 1 - 9x9 79 Fuel Rod
*  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)] [-(@rpitch/2.0)]
PINS
[@odwr/2.0]  [@odwr/2.]                                 ! radius of rod, radius of can (largest rod)
-2 -2 -2 -2 -2 -2 -2 -2 -2
```

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 -2 -2 -3 -2 -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
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
[@odpellet/2.0] [(@odclad/2.0)-@cladth] [@odclad/2.0]
5! 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-@ltcap]              ! 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
[(@blt+@blct)/2.0]  11
[(@blt-@blct)/2.0]  10
11

* Hole 5 - General Basket Structure
* Stuctured 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+@dsspht+@thtd+@dsspht)]          -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]
[@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)]
[-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 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+@dsspht+@thtd+@dsspht]            ! Sets up a repeating lattice of cells
[@tspd+@dsspht+@thtd+@dsspht]    3            ! water
[@tspd+@dsspht+@thtd]            3            ! water gap
[@tspd+@dsspht]                 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
*SEEK 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

```
1
           AA     N     NN   SSSSSS   WW    WW  EEEEEEEE  RRRRRRR    SSSSSS              CCCCCC    OOOOOO   DDDDDDD   EEEEEEEE
          AAAA    NN    NN  SSSSSSSS  WW    WW  EEEEEEEE  RRRRRRRR  SSSSSSSS            CCCCCCCC  OOOOOOOO  DDDDDDDD  EEEEEEEE
         AA  AA   NNN   NN  SS        WW    WW  EE        RR    RR  SS                  CC        OO    OO   DD   DD  EE
        AA    AA  NNNN  NN  SS        WW    WW  EE        RR    RR  SS                  CC        OO    OO   DD   DD  EE
        AAAAAAAA  NN NN NN  SSSSSSS   WW    WW  EEEEE     RRRRRRRR  SSSSSSS             CC        OO    OO   DD   DD  EEEEE
        AAAAAAAA  NN NN NN   SSSSSSS  WW    WW  EEEEE     RRRRRRR    SSSSSSS            CC        OO    OO   DD   DD  EEEEE
        AA    AA  NN  NNNN        SS  WW WW WW  EE        RR RR           SS            CC        OO    OO   DD   DD  EE
        AA    AA  NN   NNN        SS  WW WW WW  EE        RR  RR          SS            CC        OO    OO   DD   DD  EE
        AA    AA  NN    NN  SSSSSSSS   WWWWWW   EEEEEEEE  RR   RR   SSSSSSSS            CCCCCCCC  OOOOOOOO  DDDDDDDD  EEEEEEEE
        AA    AA  NN     N   SSSSSS     WW WW   EEEEEEEE  RR    RR   SSSSSS              CCCCCC    OOOOOO   DDDDDDD   EEEEEEEE

                                M      M   OOOOOO   N     NN  KK    KK             888888      AA
                                MM    MM  OOOOOOOO  NN    NN  KK   KK             88888888    AAAA
                                MMM  MMM  OO    OO  NNN   NN  KK  KK              88    88   AA  AA
                                MMMMMMMM  OO    OO  NNNN  NN  KK KK               88    88  AA    AA
                                MM MM MM  OO    OO  NN NN NN  KKKK                 888888   AAAAAAAA
                                MM    MM  OO    OO  NN NN NN  KKKK                 888888   AAAAAAAA
                                MM    MM  OO    OO  NN  NNNN  KK KK               88    88  AA    AA
                                MM    MM  OO    OO  NN   NNN  KK  KK              88    88  AA    AA
                                MM    MM  OOOOOOOO  NN    NN  KK   KK             88888888  AA    AA
                                MM    MM   OOOOOO   NN     N  KK    KK             888888   AA    AA

          Running on machine 57NST ( Windows NT) ....
          Date and time of execution: 10/ 5/2000 - 18.41.58

                      PPPPPPP    CCCCCC             WW    WW   IIIIII   N     NN            N     NN  TTTTTTTT
                      PPPPPPPP  CCCCCCCC            WW    WW   IIIIII   NN    NN            NN    NN  TTTTTTTT
                      PP    PP  CC                  WW    WW     II     NNN   NN            NNN   NN     TT
                      PP    PP  CC                  WW    WW     II     NNNN  NN            NNNN  NN     TT
                      PPPPPPPP  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  NNNN            NN  NNNN     TT
                      PP        CC                  WW WW WW     II     NN   NNN            NN   NNN     TT
                      PP        CCCCCCCC             WWWWWW    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 RU1 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 6.6.3-4 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)= 0.8886 ( 0.0046)
STAGE  -9 COMPLETED AFTER      8.24 MIN - K(THREE)= 0.8971 ( 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    115.58 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    236.54 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   -956.31 MIN - K(THREE)= 0.9361 ( 0.0005)
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
======================QO=================================
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      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)

```
1PLOT OF CUMULATIVE K(THREE) ESTIMATOR AGAINST STAGE NUMBER
 -----------------------------------------------------------

  0.905     0.910     0.915     0.920     0.925     0.930     0.935     0.940     0.945     0.950     0.955     0.960     0.965
      I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
    1                                                I-------X-------I
    2                                                    I-----X-----I
    3                                                      I----X----I
    4                                                       I---X---I
    5                                                      I---X---I
    6                                                       I--X--I
    7                                                        I--X--I
    8                                                        I--X--I
    9                                                        I--X--I
   10                                                          I--X--I
   11                                                           I-X-I
   12                                                           I-X-I
   13                                                           I-X-I
   14                                                           I-X-I
   15                                                           I-X-I
   16                                                           I-X-I
   17                                                           I-X-I
   18                                                           I-X-I
   19                                                           I-X-I
   20                                                            I-X-I
   21                                                             I-X-I
   22                                                            I-X-I
   23                                                            I-X-I
   24                                                             I-X-I
   25                                                             I-X-I
   26                                                             I-X-I
   27                                                              I-X-I
   28                                                              I-X-I
   29                                                              I-X-I
   30                                                               IXI
   31                                                                IXI
   32                                                                IXI
   33                                                                IXI
   34                                                                IXI
   35                                                               IXI
   36                                                               IXI
   37                                                                IXI
   38                                                               IXI
   39                                                               IXI
   40                                                               IXI
   41                                                               IXI
   42                                                               IXI
   43                                                               IXI
   44                                                               IXI
   45                                                              IXI
   46                                                               IXI
   47                                                               IXI
   48                                                               IXI
   49                                                               IXI
   50                                                              IXI
   51                                                               IXI
   52                                                               IXI
   53                                                               IXI
   54                                                              IXI
   55                                                              IXI
   56                                                               IXI
   57                                                              IXI
   58                                                              IXI
   59                                                              IXI
   60                                                              IXI
   61                                                               IXI
   62                                                               IXI
   63                                                               IXI
   64                                                               IXI
   65                                                               IXI
   66                                                               IXI
   67                                                               IXI
   68                                                               IXI
      I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
  0.905     0.910     0.915     0.920     0.925     0.930     0.935     0.940     0.945     0.950     0.955     0.960     0.965
```

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
 =================

     1.   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    1    2    3    4    5    6    7    8    9   10   11   12

          NO PARTICLE TRACKS IN ZONE    11 FOR STAGES:
                  -10

          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            Chi squared per       Probability
                      Settling stages   degree of freedom
            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    ( STDV    =  0.0005 )

            K(THREE) + (3 x STDV)     =   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[3]	**Loaded Transport (O-Ring Replacement)**[2,3]	**Loaded Transport (No O-Ring Replacement)**[2]	**Empty Transport**
Allowable Reference Leak Rate[1]	2.4×10^{-5} cm^3/sec	2.4×10^{-5} cm^3/sec	1×10^{-3} cm^3/sec	1×10^{-3} cm^3/sec
Allowable Helium Leak Rate[1]	3.3×10^{-5} cm^3/sec	3.3×10^{-5} cm^3/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 1.6×10^{-5} cm^3/sec, establish a vacuum in the o-ring annulus and test for helium leakage. The leak rate must be less than 3.3×10^{-5} cm^3/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 1.6×10^{-5} cm^3/sec, establish a vacuum in the o-ring annulus and test for helium leakage. The leak rate must be less than 3.3×10^{-5} cm^3/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 1.6×10^{-5} cm^3/sec, establish a vacuum in the o-ring annulus and test for helium leakage. The leak rate must be less than 3.3×10^{-5} cm^3/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^2 β, γ, and 220 dpm/100 cm^2 α) 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.

- 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 ± 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 5×10^{-5} cm^3/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 x 10^{-7} cm^3/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 ± 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}C, ^{59}Ni, and ^{94}Nb, and/or short-lived radionuclides, i.e., ^{3}H, ^{60}Co, and ^{63}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.

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 2×10^{-7} std cm^3/sec (helium), or less, using a minimum detector sensitivity of 1×10^{-7} std cm^3/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 3.3×10^{-5} std cm^3/sec (helium), or less. The helium leak detector sensitivity shall be 1.6×10^{-5} std cm ^{3}/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^{60} 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 ^{10}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}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}B areal density.

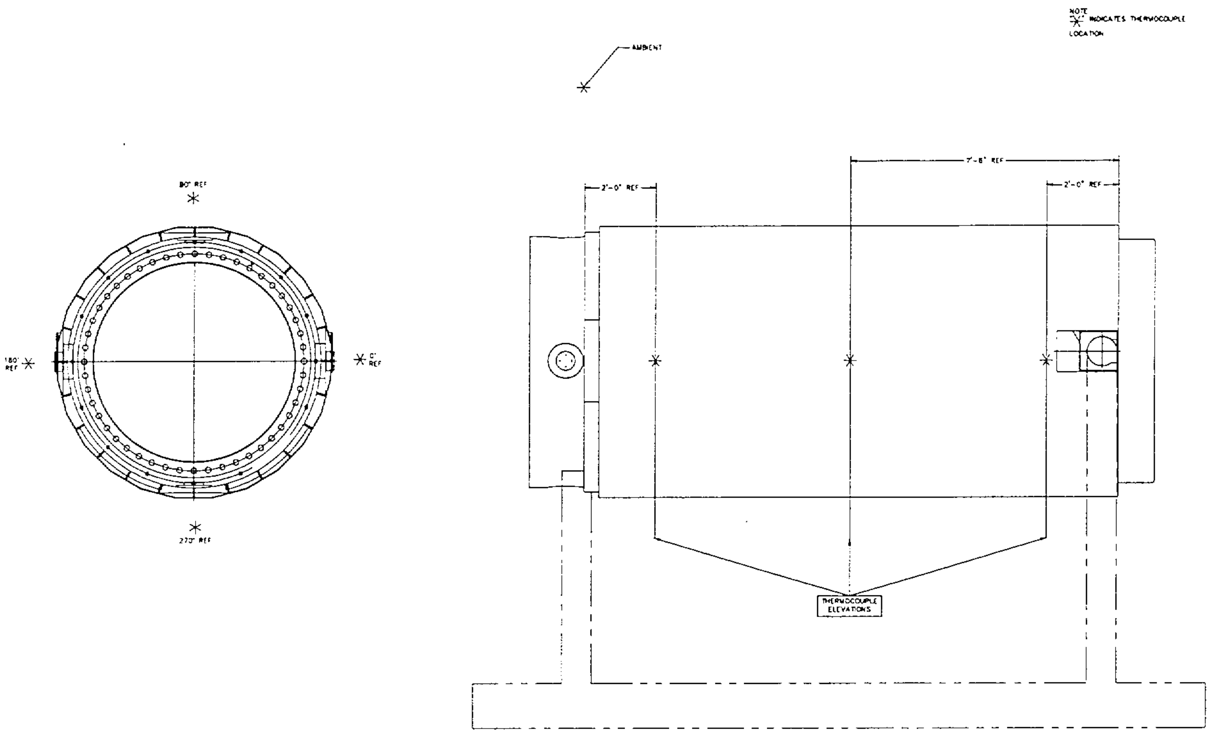
The most common method of verifying the acceptability of neutron absorber material is the wet chemistry method—a chemical analysis where the aluminum is separated from a sample with known thickness and volume. The remaining boron-carbide material is weighed and the areal density of ^{10}B is computed. 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}B areal density is determined to be equal to, or greater than, 0.011 g/cm^2 for the BORAL sheets used in BWR fuel tubes and 0.025 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 componsition (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:

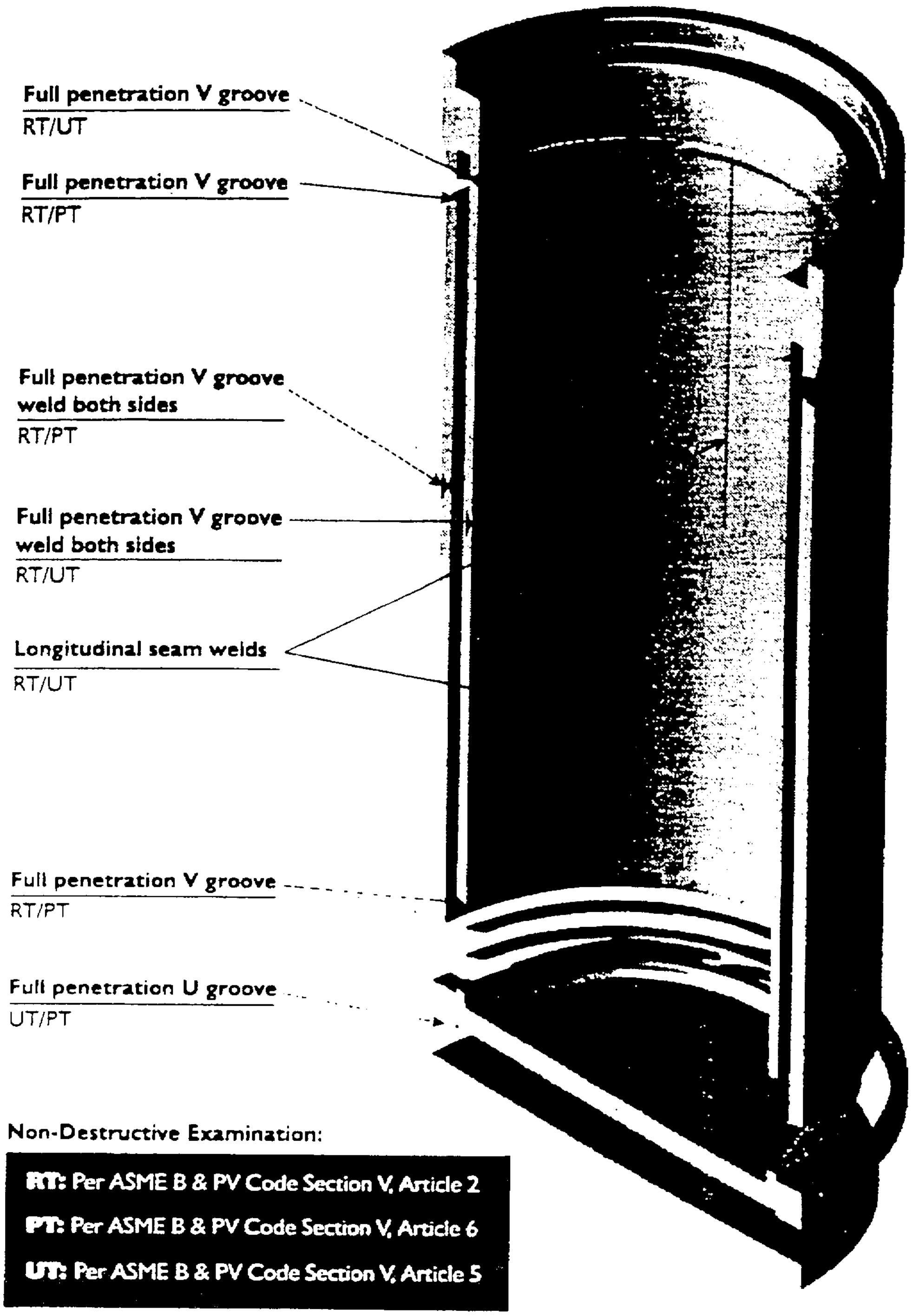
1. Certificate of chemical analysis of the lead.

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



Non-Destructive Examination:

RT: Per ASME B & PV Code Section V, Article 2
PT: Per ASME B & PV Code Section V, Article 6
UT: Per ASME B & PV Code Section V, Article 5

Figure 8.3-2 Arrangement of Lead Pour Equipment